NATIONAL TRANSPORTATION SAFETY BOARD

PIPELINE ACCIDENT REPORT

LOW-PRESSURE NATURAL GAS DISTRIBUTION SYSTEM GARY, INDIANA JUNE 3, 1969

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Bureau of Surface Transportation Safety
Washington, D. C. 20591

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ADOPTED: DECEMBER 4, 1969

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FOREWORD

The National Transportation Safety Board held a public hearing in Gary, Indiana, on June 25 to 27, 1969, inclusive, to inquire into the facts and circumstances surrounding the natural gas pipeline accident in the distribution system of the Gary suburb of Glen Park on June 3, 1969. At the public hearing, which was chaired by a Board Member, 19 persons testified and 48 exhibits were introduced into the public record.

The Safety Board's investigation began on the date of the accident and was conducted with the assistance of representatives from the Office of Pipeline Safety of the Department of Transportation, the State of Indiana Fire Marshal's office, the Mayor of Gary and his staff, the Gary Fire Department, and the Northern Indiana Public Service Company, the public utility involved.

After determining the basic facts of this case, the Safety Board decided to hold a public hearing because of its concern with the safety of natural gas pipelines in close proximity to populated areas of the United States. The Safety Board has received information about nine natural gas pipeline accidents in 1968, and three in 1969, including the instant accident. Details of these accidents are given in Appendix II of this report. Most of these accidents caused a number of deaths, serious injuries, and extensive property damage.

In 1967, there were over 800,000 miles of gas pipeline in the United States, including approximately 63,000 miles of gathering lines, 224,000 miles of transmission lines, and 536,000 miles of distribution lines. These lines range in diameter from less than 1 inch to 42 inches, with 48-inch lines under consideration, and vary in condition from old, unprotected lines to new, well-protected lines. They differ in function from low-pressure distribution lines operated at 1/4 pound per square inch gauge to high-pressure transmission lines operated at 1,300 pounds per square inch. Thus, any failure of a pipe may cause large amounts of gas to be released to the atmosphere in a relatively short period of time. When mixed with air, the gas is subject to exploding and burning when ignited. Burning gas may reach temperatures of 2,500° F.

There is no readily available information concerning past accidents in distribution systems as there is with respect to interstate transmission lines which have been under the jurisdiction of the Federal Power Commission. In 1967, when testifying on behalf of the present Pipeline Safety Act of 1968, the Secretary of Transportation pointed out that the safety of distribution lines is a vast unknown. Prior to passage of the above Act, a survey undertaken jointly by the Department of Transportation and the National Association of State Regulatory Utilities Commissioners, an organization of Federal and State Commissions, revealed substantial gaps in the regulation of distribution systems. These systems distribute gas to 38 million customers, located in virtually every city and town throughout the Nation.

TABLE OF CONTENTS

LIST OF FIGURES

I. SYNOPSIS AND CAUSE

On June 3, 1969, a series of explosions and fires occurred in the natural gas distribution system in the western half of the Glen Park residential subdivision of Gary, Indiana. There were no fatalities, but nine residents and five firemen were injured. Seven houses were destroyed, and 45 others incurred damage extending from minor to virtual destruction. Total property damage was about $350,000.

Northern Indiana Public Service Company (NIPSCO), a public utility, decided early in 1969 to upgrade its gas services to customers in the eastern half of Glen Park by increasing the gas pressure of 1/4 pound per square inch gauge (p.s.i.g.) to 20 p.s.i.g. The decision was based on the impending increased demand for gas at a new school then under construction, and on NIPSCO's continuing program over the years in Gary to upgrade all gas services to the medium pressure of 20 p.s.i.g. The western half of Glen Park, where the accident happened, was to remain at the low pressure of 1/4 p.s.i.g. for a period of months until NIPSCO was ready to increase pressure in that area also. By June 1969, approximately 95 percent of the Gary area was operating at 20 p.s.i.g. gas pressure.

In preparation for the conversion, gas service lines from the mains to houses and other buildings in the eastern half of Glen Park were equipped with individual gas pressure regulators to reduce the planned 20 p.s.i.g. gas pressure to 1/4 p.s.i.g. pressure for which gas furnaces and appliances are designed and operated. Inspections were made of individual service lines at connections to gas mains and, where bare gas pipe was found, those service lines were replaced with coated and wrapped pipe. Approximately 45 percent of the service lines were so replaced. A further preliminary move was to conduct a leak survey over a small percentage of the eastern half of Glen Park, with the survey limited to portions of the gas mains and not over individual service lines.

On May 29, 1969, a separation valve was installed between the western half of Glen Park, which was to remain at 1/4 p.s.i.g., and the eastern half, where pressure was to be increased to 20 p.s.i.g. This valve was to be closed when east-side pressure was increased and thus was left open after installation, awaiting the pressure increase operation.

Already in use on the western edge of the Glen Park subdivision (46th Avenue and Grant Street) was a primary pressure regulator which reduced the pressure of gas flowing in from the western side of Gary from its inlet pressure of 20 p.s.i.g. to 1/4 p.s.i.g. A similar regulator was in use at the eastern edge of Glen Park (47th Avenue and Broadway Street) to control pressure for the eastern sector of Glen Park. There were no other pressure-reducing or overpressure protection devices installed in either area of Glen Park prior to the installation of individual service regulators on all individual service lines in the eastern half of Glen Park preparatory to increase of pressure. Individual service line regulators were not installed in the western half of Glen Park.

On June 3, 1969, NIPSCO crews were stationed at the separation valve and at the regulator on the eastern edge of Glen Park. No one was stationed at the regulator at 46th Avenue and Grant Street in the western sector. Pressure was slowly increased in the eastern sector by routing gas through a bypass line around the eastern edge regulator at 47th Avenue and Broadway Street. When the increase was noted on gas pressure gauges installed at the separation valve, this valve was closed slowly to isolate the western sector and maintain its pressure at 1/4 pound. The valve then was covered with about 2 feet of earth. Pressure was held at 6 p.s.i.g. in the eastern sector, while crews checked the regulator and meter at each of the premises for leaks. Pressure was then increased slowly to 20 pounds, and additional checks were made about 10:30 a.m. on the same day, including patrolling over the mains.

NIPSCO crews, after being satisfied that apparently there were no leaks, opened a valve on the south side of 47th Avenue and Harrison Streets for additional supply of gas at 20 pounds in the eastern section of Glen Park.

The Assistant Foreman for NIPSCO received notice at about 12:20 p.m. of a leak in an 8-inch main near the eastern edge of Glen Park. Action was taken to close the 4-inch valve at 47th Avenue and Harrison Street, shutting off one source of 20 p.s.i.g. gas, and to reduce the incoming pressure to 3 p.s.i.g. at the original source of higher pressure -- 47th Avenue and Broadway Street -- to facilitate repairing the leak.

The NIPSCO Assistant Foreman then ordered a crew to remove the dirt from above the stem of the separation valve and to stand by until further instructions were given. His explanation was that he had felt it might be necessary to supply the eastern sector of Glen Park with gas at 1/4 p.s.i.g. from the western sector should the leak be severe enough to require a further reduction to a pressure of 1/4 p.s.i.g.

Testimony of the four persons in the crew at the separation valve established that one crewmember, without any instructions, opened the separation valve while under the impression that he was closing it. This action, at about 1:20 p.m., permitted eastern sector gas at about 20 p.s.i.g. to flow in the low-pressure western sector of Glen Park. As a result, the flexible diaphragm in the regulator at the western edge of Glen Park was ruptured by the back pressure. This in turn permitted gas at the 20 p.s.i.g. pressure to flow into the western low-pressure sector of Glen Park.

When the field crew foreman discovered that the separation valve had been opened, he ordered it closed immediately. It was estimated that the valve was open between 1 and 2 minutes. However, the gas pressure at 20 p.s.i.g. was continuing to pour into the western section through the damaged regulator at the section's west edge.

It took from one-half to three-quarters of an hour to get a crew to shut off the flow of gas at the western sector regulator at 46th Avenue and Grant Street. The crew at that time was attempting to control the emergency at individual houses. The western or low-pressure (1/4 p.s.i.g.) area of Glen Park was subjected to the pressure of gas at 20 p.s.i.g. for 30 to 45 minutes. This was a pressure overload 80 times greater than the western area of Glen Park was designed to handle.

The entire western sector depended upon the one regulator at 46th Avenue and Grant Street for reduction of pressure to the normal 1/4 p.s.i.g. for which furnaces, hot water heaters, washers, dryers, and stoves in the area were designed. With that one regulator ineffective, and gas flowing at 20 p.s.i.g., pilot light and burner flames from many appliances became torches, igniting ceilings, cabinets, and other combustibles. In other buildings, the sudden surge of gas blew out pilot lights and burners and filled the homes with gas. This gas exploded violently, ignited by any one of the many possible sources that were present. Many meters at houses already on fire could not

be shut off because the meters and valves were located inside the homes. In other cases, women at home did not know how to close shutoff valves or did not have appropriate wrenches. Fire Department personnel also did not have wrenches of the correct size.

The Gary Fire Department used 12 engines, three ladder trucks, one rescue unit, and three vehicles with inhalators from Gary, aided by 15 out-of-town fire engines, to extinguish the fires. For some time, the Fire Department had no information on the possible geographical area involved in the disaster. The first contact between the Fire Department and the Assistant Foreman of NIPSCO, who knew the geographical extent of the disaster, came one-half to three-quarters of an hour after the pressure first had been increased. The Fire Department, through normal telephone contact, had been unable to reach anyone at the gas company office who knew this fact.

Under Section 5(a) of the Natural Gas Pipeline Safety Act of 1968, the State of Indiana certified on December 13, 1968, that it was establishing and enforcing safety standards for gas transmission and distribution lines within the State. On May 28, 1969, the Department of Transportation accepted the certification from Indiana. In accordance with the provisions of the Natural Gas Pipeline Safety Act of 1968, the existing Indiana regulations were required to be adopted as interim minimum Federal safety standards in Indiana. The State's regulations required that NIPSCO construct, operate, and maintain its plant in accordance with the provisions of the 1968 version of the United States of America Standards Institute Code B31.8. This Code is entitled "Gas Transmission and Distribution Piping Systems." This Code does not require "fail-safe" installations in existing low-pressure systems adjacent to higher pressure areas and does not prescribe methods to be used to ascertain clearly the condition of existing distribution piping prior to increase of pressure. The Code also does not contain detailed prescriptions for corrosion prevention in existing systems or new installations.

NIPSCO operates under its own "Gas Standards" which in many instances are more stringent than the provisions of Code B31.8.

CAUSE

The Board finds that the probable cause of this accident was a combination of personnel error and system inadequacy. Involved were the inadvertent opening of a separation valve by a gas company employee allowing gas at 20 p.s.i.g. to flow into a 1/4 p.s.i.g. system and a system which could not control adequately such an increase in pressure owing to the lack of overpressure protection devices. Thereafter, the increase in pressure caused the failure of a regulator diaphragm which allowed an 80-fold overpressure in the low-pressure system to become continuous for 30 to 45 minutes.

Significant contributing causal factors were:

1. The inaccessibility of the shutoff valve for the regulator which failed.

2. The lack of a systematic review of the hazards in the conversion operation which could have revealed the hazardous condition in which one human error could produce catastrophe, coupled with the lack of a written plan for the conversion.

3. The absence in Code B31.8 of any specification of safeguards to be employed at separation (isolation) valves during pressure conversions.

4. The lack of complete leakage surveys, before and during the pressure increase in the eastern area, which would have probably disclosed the leaking condition of the pipe and avoided the major leaks which occurred on June 3, 1969.

The relationship of the detailed causal factors involved in this accident is diagrammed in Appendix I. The above statement of cause is derived from the relationships of the diagram.

II. FACTS AND ANALYSIS

A. Location and Method of Operation

The Northern Indiana Public Service Company (NIPSCO), a public utility, furnishes gas service to approximately 390,000 customers in the northern part of Indiana, including about 57,000 in the city of Gary, Indiana. Natural gas is received from interstate transmission lines and is piped into local distribution systems for use by commercial, municipal, industrial, and residential consumers. Approximately 95 percent of the local distribution system in Gary, Indiana, was being operated under medium pressure of 20 pounds per square inch gauge (p.s.i.g.), with individual regulators installed on each service to reduce the incoming 20 p.s.i.g. pressure to low pressure (1/4 p.s.i.g.) for use with residential appliances such as furnaces, stoves, and other home appliances which are designed to operate at that low pressure.

The balance of about 5 percent of the local distribution system was still operating at low pressure of 6 to 8 inches of water as measured by manometers or approximately 1/4 p.s.i.g. The distribution system in Gary was originally largely a low-pressure system and was converted gradually to a medium (20 p.s.i.g.) system over the years.

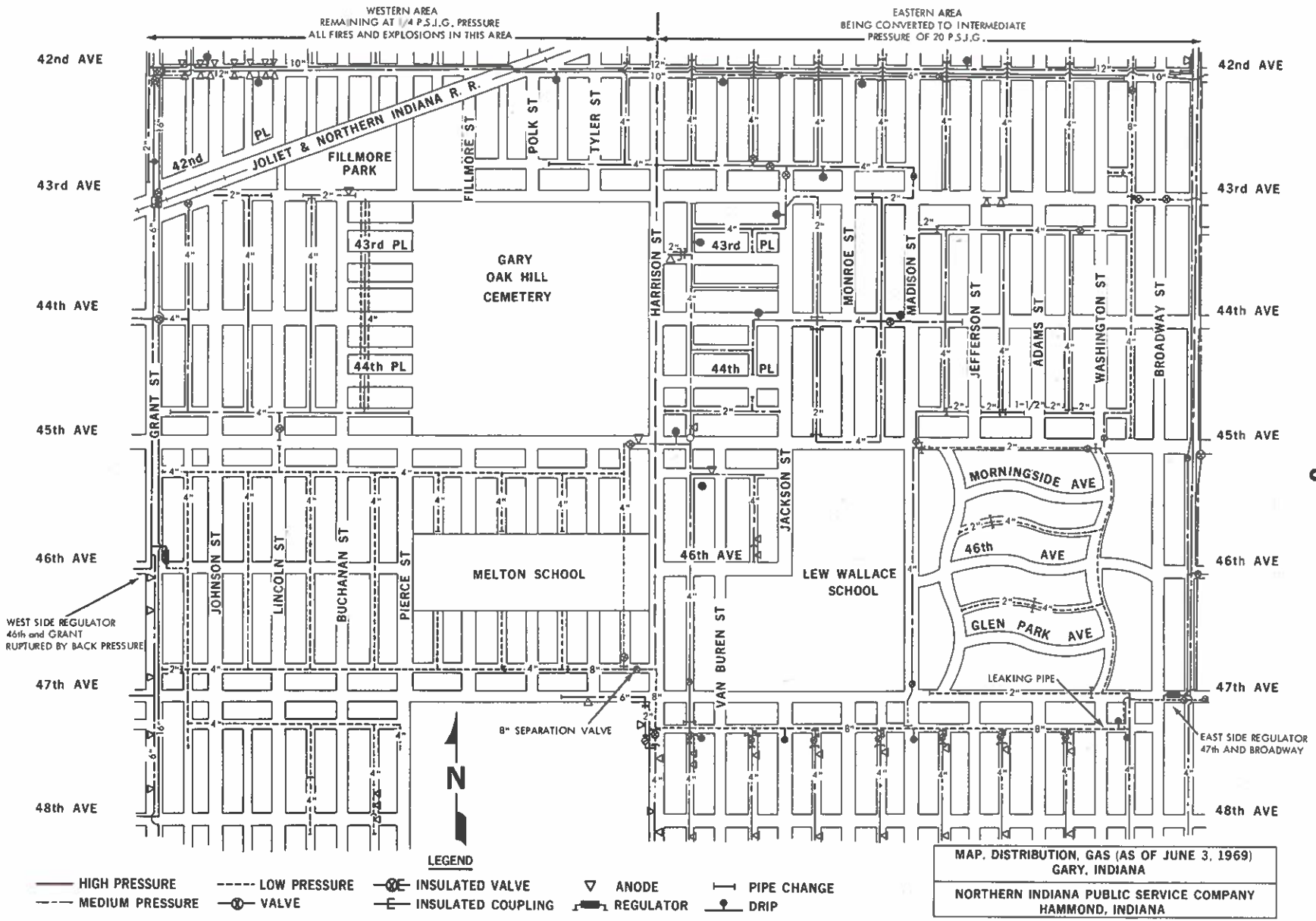
Included in the approximately 5 percent of the local distribution system still operating under low pressure (1/4 p.s.i.g.) within Gary was the south part of the residential community of Glen Park. NIPSCO decided early in 1969 to convert the eastern half of the Glen Park area to a medium-pressure (20 p.s.i.g.) system, with further plans to convert the western half of the Glen Park area soon thereafter. The work in the eastern half of the Glen Park area was scheduled for the summer of 1969 when customer demand was lowest, and prior to opening of a new school which was under construction and which would use gas for heating purposes.

The eastern half of the Glen Park area involved consists of approximately 16 square blocks, bounded on the north by 45th Avenue, on the south by 47th Avenue, on the east by Broadway Street, and on the west by Harrison Street. In addition, there was a small area extending north to 42nd Avenue just west of Broadway Street. The western half of the area involved is of similar size, bounded on the north by 45th Avenue,

on the south by 47th Avenue, on the east by Harrison Street, and on the west by Grant Street. In addition, there are eight blocks of residences adjacent to and south of 47th Street which are in the western area, but in Ross Township rather than Glen Park. For purposes of this report, those eight blocks are described as part of the western area of Glen Park. (See map on page 8.)

Prior to beginning the conversion, the entire southern half of Glen Park, including the eastern and western parts described above, was operating under 1/4 p. s. i. g. gas pressure supplied through two regulators. The first was located at the eastern limit at 47th Avenue and Broadway Street, and the second was located at the western limit at 46th Avenue and Grant Street. The regulators were both Model 014 made by Rockwell Manufacturing Company (see sketch on page 23) and were designed to reduce pressure up to 125 p. s. i. g. to low pressure, and adjusted by NIPSCO to maintain a pressure of approximately 1/4 p. s. i. g. in the low-pressure system when connected to an inlet pressure of 20 p. s. i. g. The regulators operated with the flow of gas from the 20 p. s. i. g. inlet end being restricted by a set of valves in the regulators. These valves were actuated through push rods and levers which in turn were controlled by a leather diaphragm or membrane which was sensitive to gas pressure on the outlet or 1/4 p. s. i. g. end. Weights were installed above the diaphragm and supported by the 1/4 p. s. i. g. pressure under the diaphragm. As pressure under the diaphragm would decrease due to customer use, the diaphragm would move down, and through the linkage, the valves were opened to increase the incoming flow of gas to satisfy the demand. Conversely, a decrease in demand would cause the pressure under the diaphragm to increase slightly, the diaphragm would move up, and thereby through the linkage would reduce the incoming flow of gas. In operation, the regulators would constantly adjust incoming gas flow at 20 p. s. i. g. to maintain a normal outlet pressure of about 1/4 p. s. i. g. The regulators were installed in pits below ground level, with the tops of the pits being covered with heavy steel-hinged doors which were normally secured with chains or locking devices and locks.

Prior to beginning the conversion of the eastern area of Glen Park, there were no individual pressure regulators installed at any residence or service, and protection of the entire low-pressure area of Glen Park depended solely upon the two main regulators at 47th Avenue and Broadway Street and 46th Avenue and Grant Street. The northern half of the entire Glen Park subdivision and residential areas adjacent to the portions of Glen Park still on low gas pressure had been previously


WESTERN AREA
REMAINING AT 1/4 P.S.I.G. PRESSURE
ALL FIRES AND EXPLOSIONS IN THIS AREA
EASTERN AREA
BEING CONVERTED TO INTERMEDIATE
PRESSURE OF 20 P.S.I.G.
42nd AVE
43rd AVE
44th AVE
45th AVE
46th AVE
47th AVE
48th AVE
JOLIET & NORTHERN INDIANA R. R.
42nd PL
FILLMORE PARK
FILLMORE ST
POLK ST
TYLER ST
43rd PL
44th PL
GARY OAK HILL CEMETERY
HARRISON ST
43rd PL
44th PL
MONROE ST
MADISON ST
JEFFERSON ST
ADAMS ST
WASHINGTON ST
BROADWAY ST
GRANT ST
JOHNSON ST
LINCOLN ST
BUCHANAN ST
PIERCE ST
MELTON SCHOOL
46th AVE
JACKSON ST
LEW WALLACE SCHOOL
VAN BUREN ST
MORNINGSIDE AVE
46th AVE
GLEN PARK AVE
LEAKING PIPE
WEST SIDE REGULATOR
46th and GRANT
RUPTURED BY BACK PRESSURE
8" SEPARATION VALVE
EAST SIDE REGULATOR
47th AND BROADWAY
N
LEGEND
HIGH PRESSURE
MEDIUM PRESSURE
LOW PRESSURE
VALVE
INSULATED VALVE
INSULATED COUPLING
ANODE
REGULATOR
PIPE CHANGE
DRIP
MAP, DISTRIBUTION, GAS (AS OF JUNE 3, 1969)
GARY, INDIANA
NORTHERN INDIANA PUBLIC SERVICE COMPANY
HAMMOND, INDIANA

converted to medium pressure of 20 p.s.i.g. The boundaries between the medium- and low-pressure installations contained a series of plug valves which were shut off and buried in the ground to isolate the low-pressure area. There were no overpressure limiting controls installed in the low-pressure area other than the two regulators mentioned above. Individual shutoff valves were located at the meters for each gas service, with some meters being located in basements in homes. Individual homeowners and business operators were not furnished wrenches for shutting off meters and, as developed later in this report, in many cases did not know how to shut off meters. No instructions in this regard were routinely furnished by NIPSCO to its customers. Shutoff valves on the 8-inch and 4-inch low-pressure gas mains, generally located along streets and alleys in the area, were buried beneath the surface in widely separated locations.

A pressure recording device, which continuously registered the pressure in the low-pressure area of Glen Park, was located in a control station at 45th Avenue and Harrison Street. This device recorded pressure versus time and date.

Gas main in the Glen Park low-pressure area is welded steel pipe which was installed in stages as the area developed, between 1916 and 1969. Prior to March 1969, the majority of the pipe in the eastern portion of Glen Park, which was to be converted to medium pressure, was installed between 1924 and 1941. In the western sector of Glen Park, which was to remain at low pressure, the majority of the pipe was installed between 1947 and 1956, with a small portion of 1927-28 vintage pipe. All of the gas pipe in the 8-inch and 4-inch size was installed in the bare, unwrapped condition and was designed when new to withstand about 800 pounds of pressure. Over the years, some cathodic protection against corrosion has been added by installation of magnesium anodes to the piping after 1960. Most of the anodes were added to medium-pressure gas main piping surrounding the low-pressure area, with only a few installations in the low-pressure area. The gas mains are 8-inch and 4-inch, with 1 3/4- and 1 1/4-inch service lines to individual customers.

NIPSCO conducts a continuing surveillance of its distribution system from a leakage standpoint. As part of that program, Century Geophysical Corporation of Tulsa, Oklahoma, was employed to make year-round leakage surveys, using the flame ionization technique. This process utilizes a vehicle which has a system of air-gathering funnels which take samples of the air closest to the ground. This air

is automatically analyzed for combustibles in the interior of the vehicle, with the results recorded continuously on a strip chart. The strip chart is geared to vehicle movement so that combustible gases can be identified as to location where found. By this method, the location of a gas leak which comes to the surface can be found and repaired. Tests of this type were made in the area to be converted in Glen Park in 1967, 1968, and February 1969. The tests were conducted over small percentages of the area to be converted and were generally limited to passages over the gas mains along alleys. The gas leak surveys were conducted with a pressure of 1/4 p.s.i.g. in the mains.

NIPSCO was operating under the requirements of "Rules and Standards for the Gas Public Utilities of Indiana," issued by the Indiana Public Service Commission. Indiana rules specified that the 1968 edition of United States of America Standards Institute Code B31. (USAS B31.8) was the standard to be complied with. In addition, NIPS was operating under the requirements of its own "Gas Standards" when not in conflict with USAS B31.8. In many instances, NIPSCO's "Gas Standards" were more stringent than USAS B31.8.

The relationships between the Federal and State Governments, the City of Gary, and NIPSCO are treated in detail later in this report, along with discussions of USAS B31.8 and NIPSCO's "Gas Standards."

B. Description of the Accident

1. Prior Events

After the decision to increase pressure in the eastern sector of the low-pressure area of Glen Park, conferences were held and plans were made to convert in the early summer. Individual service regulators were installed at each house and business outlet. NIPSCO crews dug up the connections of each service line to the main to determine conditions of the pipe. The service lines which were bare steel pipe were replaced with coated and wrapped new pipe from the main line to the meter at the building, and anodes were installed for corrosion protection. It was necessary to replace about 45 percent of the service lines with coated and wrapped pipe. The balance, or 55 percent, was found to be already coated and wrapped and was left in place. Service lines which were replaced were abandoned and new lines were installed adjacent to them.

To isolate the western area of Glen Park, which was to remain at low pressure, an 8-inch plug valve was installed on May 29, 1969, in the 8-inch main on the north side of the intersection of 47th Avenue and Harrison Street. This valve was an ON-OFF valve operated by an independent hand wrench. The valve stem rotated 90° in a clockwise motion from the ON to the OFF position. The ON and OFF positions were not marked on the valve body, but there were beads of metal on top of two of the four corners of the valve stem. These beads were in line with the gas piping when the valve was in the open position and at right angles to the line of piping when the valve was closed. After installation of this separation valve, it was left in the open position and covered with about 2 feet of earth.

Other than the examinations of the service lines where they connected to the mains, no pipe was exposed to determine its condition. There were no tests conducted at that time using pressures higher than the service pressure of 1/4 p.s.i.g. to determine adequacy of the piping for the planned increased pressure of 20 p.s.i.g.

NIPSCO supervisory personnel, who had conducted many similar increases in pressure in their distribution systems, did not employ a written plan for the operation, but rather relied upon their knowledge and experience from previous conversions.

On June 2, 1969, NIPSCO service crews made a final check of each service regulator and meter in the eastern sector of Glen Park to assure that all services were protected against the planned pressure increase. A small number of services using large amounts of gas had not had regulators installed while the system was on low pressure, and those regulators were installed on June 3, just prior to the increase of pressure. The Assistant Foreman, who was in charge of the conversion, ordered crews to expose the top of the 8-inch separation valve on June 2, in preparation for activities the next day. In addition, a 4-inch plug valve located on the south side of 47th Avenue and Harrison Street was uncovered and left

in the closed position. The valve was to be opened after the conversion for an additional source of 20 p.s.i.g. gas to the area. The valves were exposed, and the holes were barricaded. The station regulators at 47th Avenue and Broadway Street and at 46th Avenue and Grant Street were checked to assure correct pressure and that they were operating properly.

On June 3, about 8:30 a.m., the Assistant Foreman stationed a field crew of four men at the 8-inch separation valve at 47th Avenue and Harrison Street, with instructions to install manometers (pressure gauges) on either side of the valve and to stand by until further instructions, which would be received on the radio in the crew's truck. The Assistant Foreman had advised the supervisor of the crew of the intended operations and, in turn, the crew supervisor had advised his three assistants that pressure was to be increased, and that when the manometers showed the first increase, the separation valve was to be closed. Further, they were told that the Assistant Foreman would advise when pressure was to be increased.

Another field crew was stationed at the regulator pit at 47th Avenue and Broadway Street to make preparations to bypass the regulator through the existing bypass line and valves so that pressure could be slowly increased in the eastern section of Glen Park. This crew was also on location about 8:30 a.m., on June 3.

Between 9:30 a.m. and 10 a.m., final checks of individual service regulators were made by service crews.

At about 9:30 a.m., with all preparations completed, the Assistant Foreman, who was at the regulator station at 47th Avenue and Broadway Street, advised the crew supervisor at the separation valve at 47th Avenue and Harrison Street that the pressure increase would begin and to watch the manometers. Several minutes after 10 a.m., the regulator at 47th Avenue and Broadway Street was isolated and pressure was slowly increased by opening the valve in the bypass line. The increase was noted at the separation valve which was closed slowly. The manometer on the east or higher pressure side of

the valve was then removed and replaced with a spring gauge of 100 p.s.i.g. capacity. The crew supervisor called the Assistant Foreman by radio and advised that the separation valve was closed, pressure on the western side of the separation valve was about 1/4 p.s.i.g., and that a gauge had been installed on the eastern side. This was necessary because the manometer could record a maximum pressure of 24 inches of water or about 8/10 of a pound per square inch. The crew remained at the separation valve, watching the gauge and the manometer to insure that the east and west sections were in fact isolated from each other.

About 10:15 a.m., on June 3, the pressure in the eastern sector had been raised to 6 pounds and was held at that level while crews checked for gas leaks at the individual regulators and meters. At about 10:25 a.m., after not having received reports of leaks, the Assistant Foreman directed that pressure be increased slowly. At about 10:35, pressure had reached 20 p.s.i.g. Crews were then directed to check for leaks by walking through the alleys. Only two leaks were found in pipe unions at meters; these were immediately stopped by tightening the fittings.

About 11 a.m., the Assistant Foreman instructed the crew supervisor at the separation valve at 47th Avenue and Harrison Street to remove the manometer and gauge and to cover the valve with earth. This was done. The same crew was ordered to open the 4-inch plug valve located on the south side of 47th Avenue and Harrison Street for additional 20 p.s.i.g. gas feed and then to cover that valve with earth. The crew complied at about 11:05 a.m. After having instructed several crews, including the one at the 8-inch separation valve, to patrol the eastern sector that afternoon in case of leaks, the Assistant Foreman departed the area about 11:15 a.m. He proceeded to his office where a report was made to the Foreman for the Gary, Indiana, area, advising that the conversion appeared to be successful.

Section 845.44 of USAS B31.8 "Conversion of Low-Pressure Distribution Systems to High-Pressure Distribution Systems," states as follows:

(a) Before converting a low-pressure distribution system to a high-pressure distribution system, it is recommended that the following factors be taken into consideration:

(1) The design of the system including kinds of material and equipment used.

(2) Past maintenance records including results of any previous leakage surveys.

(b) Before increasing the pressure, the following steps (not necessarily in sequence shown) should be taken:

(1) Make a leakage survey, if past maintenance records indicate that such a survey is advisable, and repair leaks found.

(2) Reinforce or replace parts of the system found to be inadequate for the higher operating pressures.

(3) Install a service regulator on each service line, and test each regulator to determine that it is functioning. In some cases, it may be necessary to raise the pressure slightly to permit proper operation of the service regulator.

(4) Isolate the system from adjacent low-pressure systems.

(5) At bends or offsets in coupled or bell and spigot pipe, reinforce or replace anchorages determined to be inadequate for the higher pressures.

(c) The pressure in the system being converted should be increased by steps, with a period to check the effect of the previous increase before making the next increase. The desirable magnitude of each increase and the length of the check period will vary depending upon conditions. The objective of this procedure is to afford an opportunity to discover before excessive pressures are reached any unknown open and unregulated connections to adjacent low-pressure systems or to individual customers.

It is apparent, from review of the testimony and exhibits, that a leakage survey of the area to be converted (eastern area) was not made in conjunction with the conversion plan. Various sections of the conversion area were checked by Century Geophysical Corporation using the leakmobile in 1967, 1968, and early 1969, as part of routine surveillance. However, the entire area to be converted was not surveyed. In addition, the testimony brought out that no specific tests were conducted to determine the condition of the mains after the pressure was raised to approximately 6 p.s.i.g. Checks, however, were made of the meters and individual regulators at the premises of each customer. After the pressure was raised to 20 p.s.i.g., company employees were directed to walk over the mains in an attempt to locate any gas leakage. A more reliable type of survey, such as a leakmobile or bar test survey, was not conducted.

About 12:20 p.m., on June 3, a customer called and reported smelling gas in the vicinity of 47th Avenue and Washington Street, about 3 blocks from the regulator station at 47th Avenue and Broadway Street. The dispatcher sent a crew to the area immediately. The crew called the Assistant Foreman by radio and requested that he return immediately because the leak appeared to

be extensive. The Assistant Foreman proceeded to the area, arriving about 12:40 p.m., with intentions to reduce gas pressure to make repairs to the leaks.

The crew, which had been at the separation valve during the morning, returned from lunch about 12:25 p.m. and began a patrol of that vicinity, looking for leaks. At about 12:40 p.m., the Assistant Foreman called by radio and instructed the crew supervisor to proceed to the 4-inch plug valve on the south side of 47th Avenue and Harrison Street and to remove the earth and close the valve. The crew proceeded to comply and, about 12:45, as the crew was closing the 4-inch valve, the Assistant Foreman arrived and directed the crew to uncover the 8-inch separation valve and wait for further instructions.

During the Safety Board's hearing, the Assistant Foreman stated that his reason for having the separation valve uncovered was to have a ready source of low-pressure gas available to feed the east sector should it be necessary during repairs to the leak at 47th Avenue and Washington Street. He further stated that if it were necessary to reduce gas pressure in the eastern area to 1/4 p.s.i.g. to effect repairs to the leak, he was concerned that the leakage of gas at the repair location, which was upstream from most services, might cause a loss of service to many of the 138 customers in the eastern area. Should that contingency appear imminent, he planned to open the separation valve for additional low-pressure gas to the eastern area.

The crew proceeded to the separation valve, and at about 1:20 p.m., completed uncovering the valve. Pressure gauges were not installed. The Assistant Foreman proceeded to the leak at 47th Avenue and Washington Street, arriving about 1:15 p.m. The Assistant Foreman testified that in his opinion, the leak was so large that he could not reduce pressure in the eastern area to 1/4 p.s.i.g. without interrupting service to many of the consumers, even if the separation valve were opened to provide for additional 1/4 p.s.i.g. gas pressure to the eastern area. The Assistant Foreman stated that from that moment on, he had no

intention to open the separation valve. He then directed the crew at the regulator pit at 47th Avenue and Broadway Street by radio to reduce pressure from 20 to 3 p.s.i.g. These directions were given at about 1:20 p.m. In further conversation with the crew at this regulator, a decision was made to further reduce gas pressure to 1 1/2 to 2 p.s.i.g. for the repairs. This was accomplished about 1:25 p.m.

2. Events During Accident

At approximately 1:15 p.m., on June 3, the supervisor of the three-man crew, which was uncovering the 8-inch separation valve, heard a call on the radio of his truck parked about 75 feet away. He proceeded to the truck, assuming that the call was for him, and upon arrival, ascertained that it was not, but remained at the radio for about 5 minutes. During the crew supervisor's absence, one of the crewmembers, who was in the hole surrounding the separation valve, asked another crewmember to obtain a valve wrench from the truck. This was done and, about 1:20 p.m., when the wrench was given to the crewmember at the valve, he put the wrench on the valve stem and opened the separation valve.

A few moments later, the crew supervisor returned, and upon seeing the wrench on the ground alongside the valve, asked the same crewmember who had turned the valve, whether the valve had been touched. The crewmember said, "Yes, I closed it." The supervisor replied, "No, you didn't close it, you opened it, and close it right away." The valve was immediately closed, having been open about 1 minute. The crew supervisor did not see one of his crew obtain the wrench from the truck because he was at the cab of the truck while the crewmember went to another part of the truck. The crew supervisor did not know the wrench was being obtained.

Testimony from five witnesses, including the person who opened the separation valve about 1:20 p.m., clearly established that no instructions or suggestions were given

by anyone to open the valve and further that the decision to open the valve was made solely by the crewmember who opened it. That crewmember had been with NIPSCO for about 10 years as of June 3, and was classified as a welder on that date. He had been with the same crew supervisor for about 4 months. This crewmember was the person who had closed the separation valve on the morning of June 3, and was in the crew that both opened and closed the 4-inch valve south of 47th Avenue and Harrison Street that day.

At the Safety Board's hearing, the crewmember who opened the separation valve about 1:20 p.m. on June 3, gave conflicting testimony. He first testified that he told another crewmember, who had been in the crew for only 2 weeks and who was a probationary mechanic welder, to get a pipe wrench so the valve could be closed. The latter crewmember normally received welding instructions from qualified welders when on the job and did not question the instruction. In addition, he had been absent for a doctor's appointment most of the morning and was not familiar with the purpose of the separation valve.

In later testimony, the person who opened the separation valve stated that he "thought they wanted it opened because the pressure had dropped and they were afraid they were going to lose the area because the pressure was dropping through the leak." He further stated that his action was of his own volition without instructions from anyone. He acknowledged being familiar with a provision in NIPSCO's Safety Manual, which is issued to all employees, stating that no employee will take any action without proper instructions from proper authority. He also stated that he took his action because he felt one had to accept a little responsibility and therefore he opened the valve when he thought it should be done.

The pressure recorder chart from the station at 45th Avenue and Harrison Street shows that the recorder needle went off the scale at about 1:20 p.m. on June 3, indicating a sudden rise in pressure in the western area. The recorder could only measure up to 15 inches of water, or about 1/2 p.s.i.g. pressure. There was no other pressure recording device for the western area in use that day.

When the separation valve was opened about 1:20 p.m. on June 3, there was approximately 20 p.s.i.g. of pressure in the east sector and 1/4 p.s.i.g. pressure in the west sector of Glen Park. The 80-fold increase in pressure rapidly flowed into the west sector and ruptured the diaphragm in the pressure regulator at 46th Avenue and Grant Street. The back pressure, which entered the low-pressure end of the regulator, existed in the western sector only for about a minute until the separation valve was closed, but the rupture of the diaphragm permitted the weights above the diaphragm to fall, and through the regulator linkage, the regulator valves on the medium-pressure (20 p.s.i.g.) inlet end were placed in a wide-open position. This permitted gas under pressure of 20 p.s.i.g. from the west side main to flow unobstructed into the western area, since there were no relief or other overpressure devices installed at the regulator or in the western area. A crew was not stationed at the regulator at 46th Avenue and Grant Street on June 3.

While the regulator station at Grant Street and 46th Avenue did conform to the requirements of USAS B31.8, it would not be permitted if it were to be constructed today, or had it been constructed any time since 1964. The interim regulations in effect on June 3, 1969, did not require existing regulator stations to be upgraded to the standard required for new construction under Section 845.4 "Control and Limiting of Gas Pressure in Low-Pressure Distribution Systems" of USAS B31.8. Section 845.42 states in part:

> ... a suitable device shall be provided to prevent accidental overpressuring. Suitable types of protective devices to prevent overpressuring of low-pressure distribution systems include:
>
> (a) A liquid seal relief device that can be set to open accurately and consistently at the desired pressure.
>
> (b) Weight loaded relief valves.

(c) An automatic shutoff device as described in 845.32(e)

> (845.32(e): An automatic shutoff device installed in series with the primary pressure regulator and set to shut off when the pressure on the distribution system reaches the maximum allowable operating pressure, or less. This device must remain closed until manually reset. It should not be used where it might cause an interruption in service to a large number of customers.)

(d) A pilot-loaded back-pressure regulator as described in 845.21(b).

> (845.21(b): Pilot-loaded back-pressure regulators used as relief valves, so designed that failure of the pilot system or control lines will cause the regulator to open.)

(e) A monitoring regulator as described in 845.32(c).

> (845.32(c): A monitoring regulator installed in series with the primary pressure regulator.)

(f) A series regulator as described in 845.32(d).

> (845.32(d): A series regulator installed upstream from the primary regulator, and set to continuously limit the pressure on the inlet of the primary regulator to the maximum allowable operating pressure of the distribution system or less.)

In addition, NIPSCO's Standard No. Reg-721-2, page 2 of "Gas Standards," states in part:

> Regulators which fail open on diaphragm failure can be installed where failure of the regulator will not create an unsafe outlet pressure, such as regulation from high-pressure to medium-pressure systems where service regulators will provide service protection, or where auxiliary safety devices or downstream regulators will prevent outlet pressure increases above a safe limit.

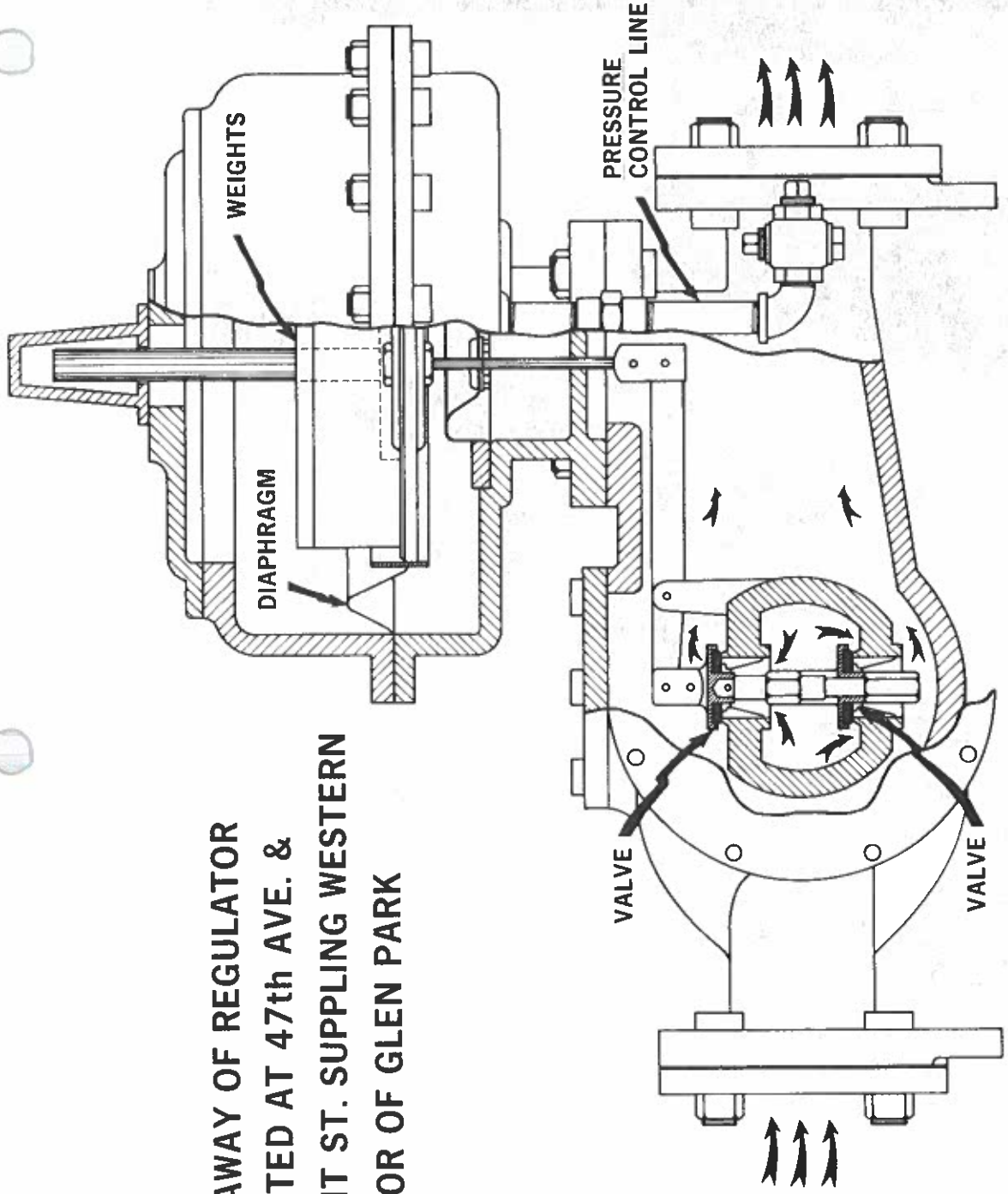
This clearly indicates that the two regulator stations (one at Grant Street and 46th Avenue and one at Broadway Street and 47th Avenue) serving the Glen Park area were not in conformance with NIPSCO's own standards.

The Assistant Foreman was advised about 1:30 p.m. that he was wanted on the radio. Upon answering the call, he was informed that the Fire Department was proceeding to 45th Avenue and Johnson Street, but that the reason was not known. The Assistant Foreman immediately proceeded to the 8-inch separation valve and was advised of what had occurred. Instructions were then given to remove meters at all buildings in the western area to relieve the pressure, and at the same time stop the flow of gas into the buildings. The crew supervisor at the 8-inch separation valve had opened gauge fittings at the valve to relieve pressure immediately after it was discovered that the valve had been opened.

The Assistant Foreman then proceeded to the regulator at 46th Avenue and Grant Street to ascertain if anything was not working properly at that location. Upon arrival at about 1:40 p.m., the odor of gas was detected at the regulator pit. The Assistant Foreman was unable to lift the heavy steel covers over the regulator pit by himself and immediately called for assistance. A crew which was nearby arrived about 1:45 p.m., proceeded to open the regulator pit, obtained wrenches from their truck,

FIGURE 2

REGULATOR REMOVED FROM PIT AT 47th AVENUE AND BROADWAY STREET IN EASTERN SECTOR OF GLEN PARK. IT IS SIMILAR TO REGULATOR WHICH FAILED AT 46th AVENUE AND GRANT STREET IN WESTERN SECTOR



CUT AWAY OF REGULATOR LOCATED AT 47th AVE. & GRANT ST. SUPPLING WESTERN SECTOR OF GLEN PARK

FIGURE 3

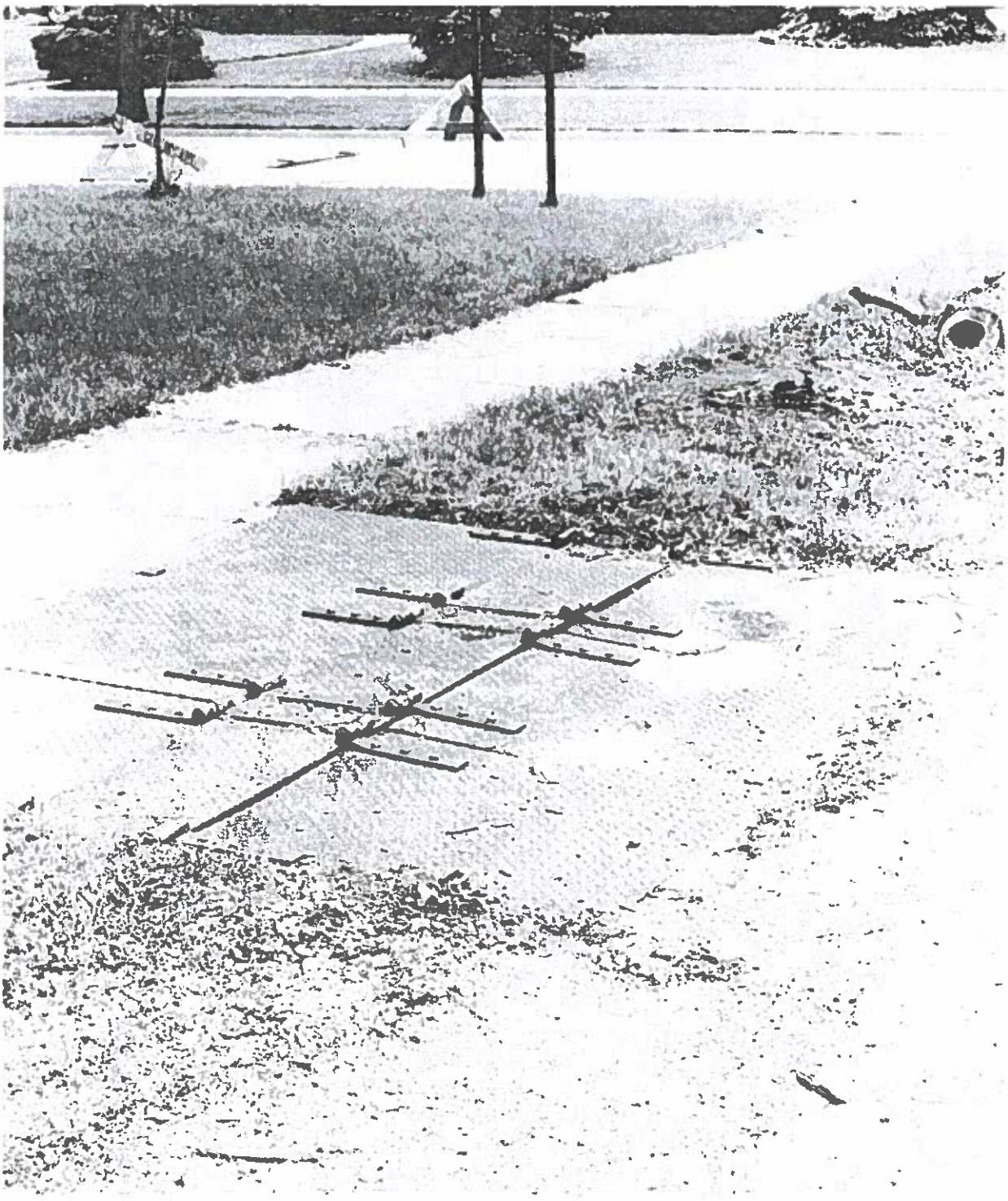


FIGURE 4

STEEL COVER ON REGULATOR PIT
AT 46TH AVENUE AND GRANT STREET
COVER WAS CHAINED AND LOCKED AT TIME OF ACCIDENT

and closed the inlet gas valve to stop the flow of all gas into the western area. The gas was finally shut off between 1:50 p.m. and 2:05 p.m. No witness could state exact times, but estimates were that the western area of Glen Park was subjected to overpressure (up to 20 p.s.i.g. from the norm of 1/4 p.s.i.g.) for a period of 30 to 45 minutes.

During the period of overpressure, pilot lights and burner flames in appliances in buildings in the western area became high-pressure torches -- igniting ceilings, cabinets, and other combustibles. Flames from appliances in basements ignited rafters, clothes on lines, and household items, with the result that in a brief period, many houses were set afire. In other buildings, the sudden surge of gas pressure blew out pilot lights; the buildings filled with gas, and, with many sources of ignition available, violent explosions resulted.

As the result, seven houses were destroyed by internal explosions and fires; 45 additional houses received damage ranging from minor to virtual destruction. Damage was estimated at $350,000.

From the testimony of witnesses, it was evident that much greater damage probably would have resulted had it not been for the actions of many persons. Residents, NIPSCO personnel, and Gary firemen and policemen shut off gas at individual meters in or outside of houses, broke windows and opened doors to allow gas to escape, and assisted in the evacuation of residences. Many meters located inside houses already on fire could not be shut off due to flames at the meter locations. In other cases, women at home did not know how to close shutoff valves at the meters or did not have appropriate wrenches. Fire Department personnel also did not have wrenches of the correct size.

At approximately 1:30 p.m. on June 3, the Gary Fire Chief heard a report of an explosion at 46th Avenue and Pierce Street in the western area of Glen Park. A few moments later, a report was received of a fire at 45th Avenue and Lincoln Street. Soon after, a report was received of a fire in an area outside of Glen Park, unrelated to events in Glen Park. The Chief of the local district covering Glen Park called in to the Gary Fire Chief and advised that gas explosions had damaged several houses in the western area of Glen Park. This call at about 1:40 p.m. was the first knowledge received that gas was involved.

The Gary Fire Chief, who was then close to Glen Park, proceeded to the area and directed firemen throughout the western area of Glen Park in ventilating houses, shutting off gas, and fighting fires. In all, there were 12 engines, three ladder trucks, one rescue unit, and three vehicles with inhalators from Gary, aided by 15 out-of-town fire engines. Until about 2:00 p.m., when the Gary Fire Chief met the NIPSCO Assistant Foreman in the area, the Gary Fire Department did not know the geographical extent of the area which might be involved in potential explosions and fires. In addition, the first calls to the Fire Department were from citizens who did not have certain knowledge of the causes of the explosions and fires. Fire Department attempts to reach NIPSCO through an emergency telephone number were unsuccessful insofar as ascertaining potential area of involvement was concerned.

Section 850.6 of USAS B31.8 "Emergency Plan" states as follows:

Each operating company shall:

(a) Set up an emergency plan to be implemented in the event of facility failures or other emergencies.

(b) Acquaint appropriate maintenance and operating employees with the operation of the applicable portion of the plan.

(c) Establish liaison with appropriate public officials with respect to this plan.

Even though the Fire Department had a special telephone number to call to obtain information or request assistance from NIPSCO, it could not reach the company during the early stages of the accident. In addition, there is no indication that NIPSCO contacted the Fire Department to inform it of the extent of the disaster.

The NIPSCO Assistant Foreman told the Gary Fire Chief about 2:00 p.m. that all gas supply to the western area of Glen Park had been shut off and it was now a case of gas in the pipelines blowing itself out. Several additional explosions and numerous fires continued until about 3:30 p.m. when no more explosions occurred and the situation came under control. Hospitals had been notified and, under direction of the Mayor of Gary, an emergency civil defense center was set up in the area. Searches were made of the western area to check all damaged properties, care for the injured, and to make estimates of losses and damages. All persons in the area, including firemen, policemen, and defense personnel and private citizens, cooperated and assisted in maintaining reasonable calm and avoiding panic.

Of particular note was the activation of a "rumor line" telephone. It was widely described by radio and television stations that private citizens could call for accurate information. This telephone number, with additional circuits to ensure its availability, was activated by the Mayor's office and helped immeasurably in keeping the emergency in proper public perspective, and in offsetting garbled accounts of events that could cause irrational fear and overreaction during emergencies.

Although there were no fatalities, nine persons were injured, mostly by burns. Total property damage

FIGURE 5
RESIDENCE AT 4586 LINCOLN STREET
SHOWING DAMAGE CAUSED BY EXPLOSION

FIGURE 6

RESIDENCE AT 4666 LINCOLN STREET DURING HEIGHT OF FIRE

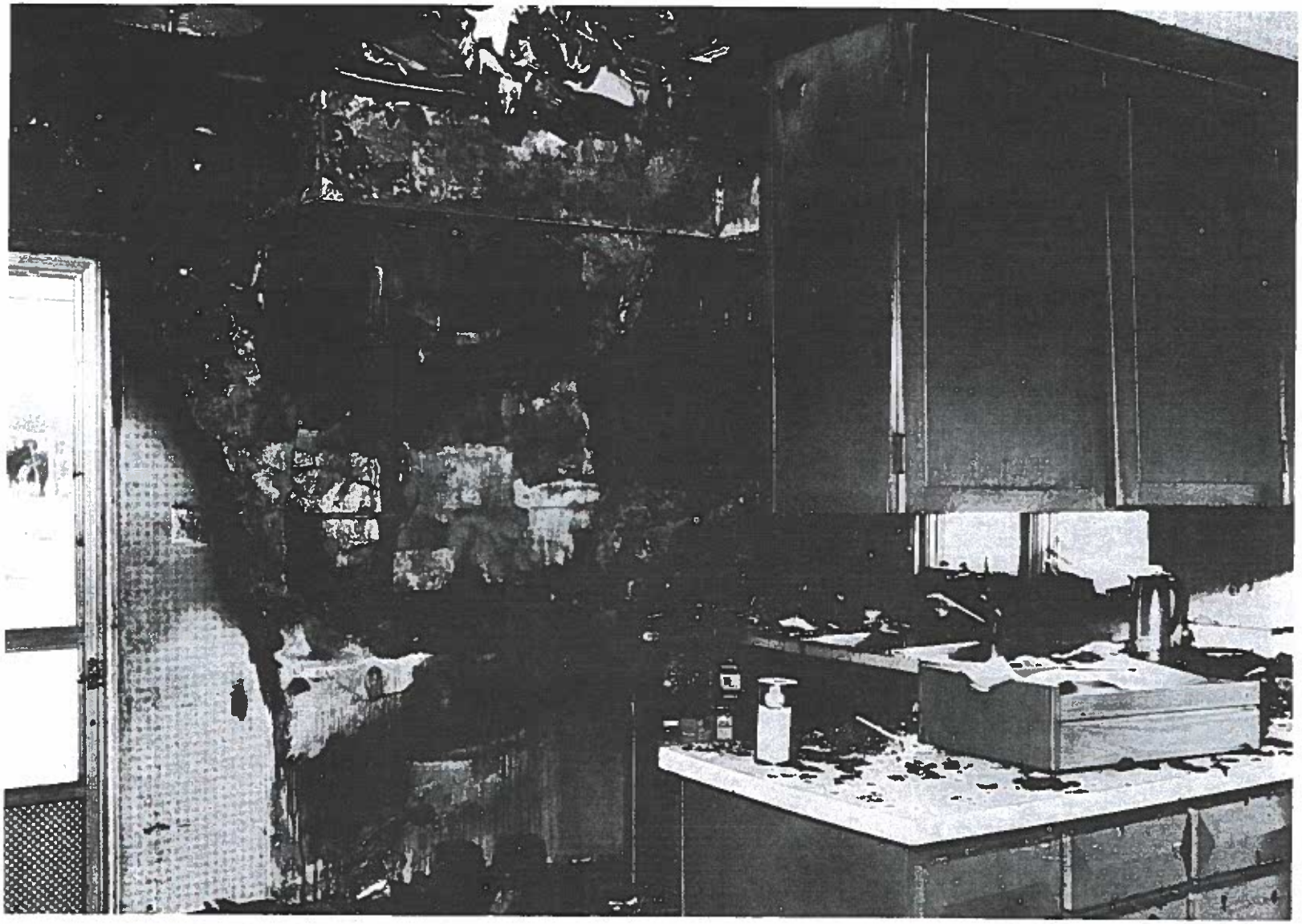


FIGURE 7

TYPICAL FIRE DAMAGE TO KITCHEN

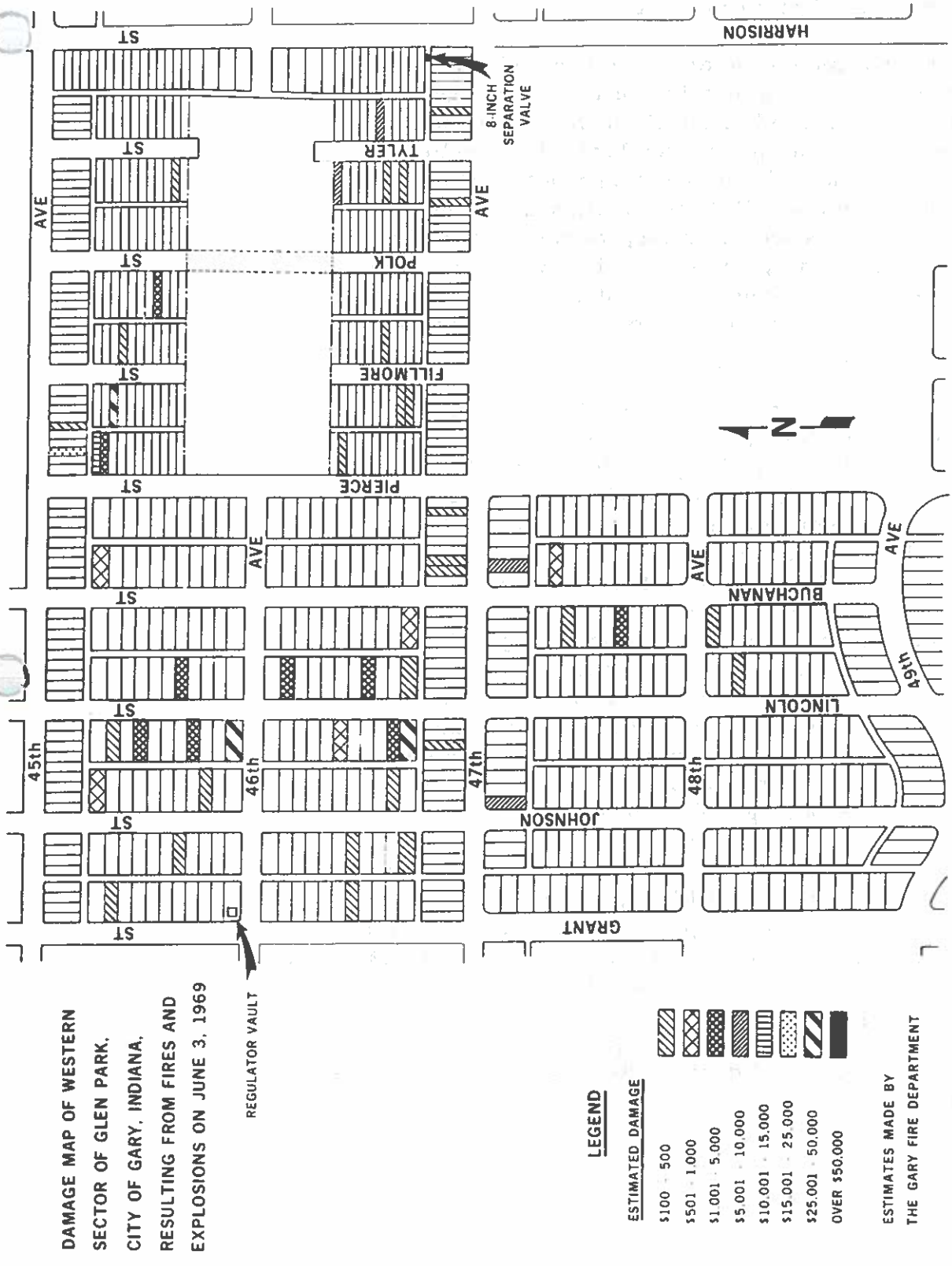

DAMAGE MAP OF WESTERN
SECTOR OF GLEN PARK,
CITY OF GARY, INDIANA,
RESULTING FROM FIRES AND
EXPLOSIONS ON JUNE 3, 1969
REGULATOR VAULT
8-INCH
SEPARATION
VALVE
HARRISON
TYLER
POLK
FILLMORE
PIERCE
BUCHANAN
LINCOLN
JOHNSON
GRANT
45th
46th
47th
48th
49th
ST
AVE
N
LEGEND
ESTIMATED DAMAGE
$100 - 500
$501 - 1,000
$1,001 - 5,000
$5,001 - 10,000
$10,001 - 15,000
$15,001 - 25,000
$25,001 - 50,000
OVER $50,000
ESTIMATES MADE BY
THE GARY FIRE DEPARTMENT

FIGURE 8

was estimated at about $350,000, with seven houses destroyed and 45 others damaged.

When firemen were at the "clean up" stage and the situation was completely controlled, the Gary Fire Chief proceeded to the Civil Defense Headquarters where the Mayor was located and called the State Fire Marshal in Indianapolis to discuss the situation. The State Fire Marshal, after being advised of the sequence of events, requested the Gary Fire Chief to prevent the removal of any items from the western area of Glen Park until a representative arrived. This included the damaged regulator and leaking gas pipe.

The State Deputy Fire Marshal arrived about 10:30 p.m. on June 3, and later took custody of the damaged regulator diaphragm, along with about 85 feet of 8-inch pipe from the vicinity of 47th Avenue and Washington Street in the eastern area of Glen Park, and about 50 feet of 4-inch pipe from the vicinity of 45th Avenue and Johnson Street in the western area of Glen Park. The first portion of pipe was being removed by NIPSCO personnel preparatory to being replaced with coated and wrapped pipe. This was the section of pipe that was found to be leaking soon after completion of the pressure increase in the eastern area. The second portion of pipe, which had developed leaks during the overpressure, was also replaced. (See photograph on page 33 .)

As noted in the photographs, one 35-foot length of 8-inch pipe contained 54 holes from corrosion. Another portion of 8-inch pipe contained nine holes in a 29-foot length; the holes varied in size from about 1/4 inch in diameter to 1 1/4 inch in diameter. When the aforementioned pipe was exposed at 47th Avenue and Washington Street, there were no leak clamps over the holes. Leak clamps were installed during attempts to make repairs at that location.

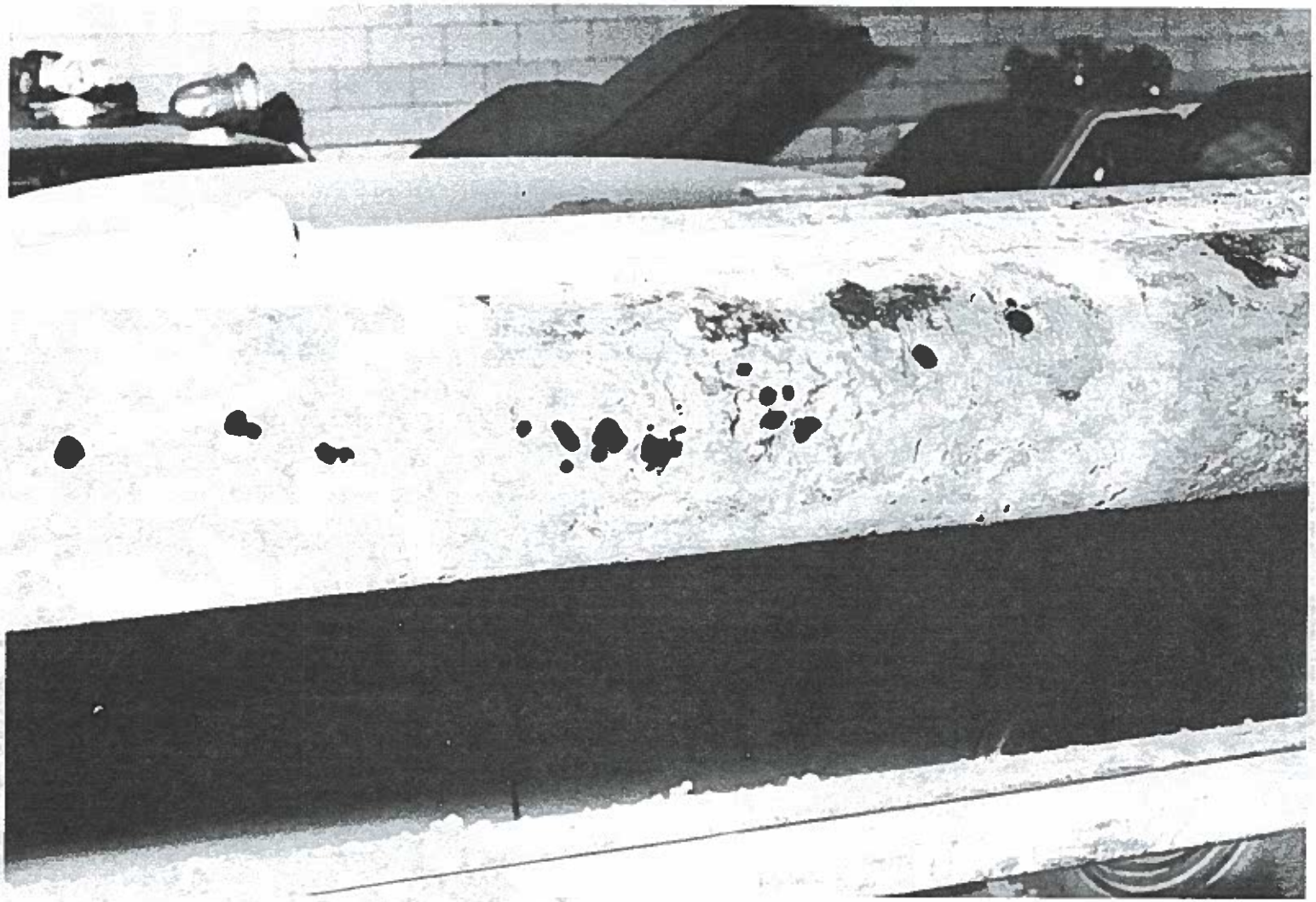


FIGURE 9

BADLY CORRODED 8-INCH PIPE
REMOVED FROM 47TH AVENUE AND WASHINGTON STREET
IN EASTERN SECTOR OF GLEN PARK

FIGURE 10

AERIAL VIEW LOOKING EAST
WESTERN SECTOR OF GLEN PARK DURING ACCIDENT

About 2 p.m. on June 3, the Gary Chief of Police arrived with the Mayor at the emergency command post near Glen Park. The NIPSCO District Manager was contacted by telephone by the Chief of Police who was advised of the boundaries of the affected western area. All police units then were instructed to check every house in the area and to alert all residents to evacuate. Assistance was received from the Indiana State Police, the Sheriff's Department, and Civil Defense units in patrolling the area and keeping it sealed off from traffic. Police officials were stationed at all damaged properties to secure them. At about 5:45 p.m., residents were allowed to return on foot, and vehicular traffic was permitted about 8 p.m. There were 80 Gary Police Officers and 26 State Police Officers active in the area between 4 p.m. and 8 p.m., with a smaller number remaining through the night for security purposes. During the next several days, while the area was being restored and debris being removed, security patrols were stationed to protect the area.

C. Activities After Accident

Leaking pipe and damaged meters were repaired or replaced as necessary in the western area of Glen Park. A new diaphragm was installed in the regulator at 46th Avenue and Grant Street to replace the one which had ruptured, and service was resumed in the western area. However, at the request of the Mayor of Gary, Indiana, NIPSCO removed the old regulator and installed two new regulators in series in the pit at 46th Avenue and Grant Street. One of the regulators is a monitoring regulator, placed ahead of the primary regulator, and is installed to protect the area in case of failure or malfunction of the primary regulator.

The monitoring regulator, during normal operation, receives gas at 20 p.s.i.g. at its inlet and allows the gas to pass through and exit at 20 p.s.i.g. The primary regulator then receives the gas at 20 p.s.i.g. and reduces it to 1/4 p.s.i.g. In case of a failure of the primary

regulator, pressure-sensing devices at the low-pressure end of the primary regulator cause the activation of the monitor regulator, which then reduces inlet pressure into the system from 20 p.s.i.g. to 1/4 p.s.i.g. The two regulators are preceded by an inlet control valve which is 9 inches from the monitoring regulator, and the valve is installed in the same pit as the regulators.

In the testimony, it was brought out that if one regulator is replaced with two new regulators, one being a monitoring regulator, that the new installation would have to meet the requirements of USAS B31.8. Section 846.22, Distribution Systems Valves, Section A, reads as follows:

> A valve shall be installed on the inlet piping of each regulator station controlling the flow or pressure of gas in a distribution system. The distance between the valve and the regulator or regulators shall be sufficient to permit the operation of the valve during an emergency such as a large gas leak or a fire in the station.

The piping diagram submitted by NIPSCO for the regulator station at 46th Avenue and Grant Street, which replaced the regulator which failed on June 3, is dated June 23, 1969. According to the code, this regulator station should now be in compliance with the code. A review of this print indicates that the inlet valve referred to in section 846.22 is not a sufficient distance from the regulator to permit the operation of this valve during an emergency. According to the print, the valve is approximately 9 inches from the regulator in the regulator pit (vault) itself. The print does not show any other valve on the inlet piping which might be considered a turnoff valve; however, one might exist, but, as stated, it is not shown. Reviewing the testimony, it is indicated that after a NIPSCO employee arrived at the scene, it took approximately 15 minutes to shut off the supply of gas to this regulator station.

He claimed he called for a crew which took 5 minutes to get there, another 10 minutes to remove the locked cover, enter the regulator pit, and have the two valves in question shut off (inlet and outlet).

It appears that if the two regulators replacing the one which failed at 46th Avenue and Grant Street are in the same pit with the inlet valve, the installation does not comply with the code as it should, since there does not appear to be a shutoff valve a safe distance from the regulators.

In fact, NIPSCO "Gas Standards," Standard No. REG 122-2, "Regulator Station-Design," under General Design Requirements, on page 1, states:

1. Fire Valves

> A fire valve shall be installed on the inlet to regulator stations, and shall be located a sufficient distance outside the regulator building or enclosure to permit operation of the valve during an emergency.

The same Standard on page 5, under "Regulation with Monitoring Regulator Pounds to Inches," states in part:

> When a monitor regulator ... is installed for overpressure protection, it shall be located separately from the operating regulator.

It was noted in the testimony that gas was leaking into the regulator pit at 46th Avenue and Grant Street because of the ruptured regulator diaphragm. It is quite possible that this leaking gas could have been ignited, causing an explosion and/or fire.

If this occurred, access to the shutoff valves located in the pit could have been prevented, thereby prolonging the time of flow of high 20 p. s. i. g. gas into low-pressure areas. It is also noted that if two regulators (one being of the monitoring type installed as a safety device to

reduce automatically the pressure if a failure occurred in the primary regulator) were installed in the same pit or building, as is now the case at 46th Avenue and Grant Street, a fire or explosion due to gas leaking from the primary regulator could cause damage to the other, rendering the safety device (monitor) inoperable.

At the Safety Board's hearing, a NIPSCO official testified that, should a sudden back pressure of 20 p.s.i.g. flow through the two new regulators, similar to the occurrence of June 3, it was probable that the diaphragm of both regulators would rupture and permit an overpressure in the western area. No other overpressure protection devices were installed in the western area.

On June 6 and 7, 1969, NIPSCO employed Century Geophysical Corporation to conduct flame ionization surveys in the eastern area of Glen Park. So many leaks were found in the 8-inch bare pipe operating at 20 p.s.i.g. under Broadway Street, ahead of the regulator at 47th Avenue and Broadway Street, that this pipe and the regulator were abandoned. Gas supply was then obtained from a regulator pit near 43rd Avenue and Washington Street. The leak survey disclosed 41 leaks in the eastern area, with 21 at meters or individual regulators, and 20 in the gas mains. Repairs to the leaks were completed on June 11, with clamps being used on the gas mains. The leaking 8-inch main at 47th Avenue and Washington Street, which caused the NIPSCO Assistant Foreman to have the 8-inch separation valve uncovered for possible use on June 3, was replaced with coated and wrapped 8-inch pipe, and several anodes were installed for corrosion protection, but without wires leading to curb boxes for future corrosion surveys.

In the eastern area, NIPSCO reduced pressure to 1 p.s.i.g. and held it at that level until September 9, 1969, when a staged increase in pressure was begun. Under the written plan adopted, pressure was raised from 1 to 5 p.s.i.g., where it was held for 24 hours while a complete flame ionization leak survey was conducted. Then pressure was raised to 15 p.s.i.g. and held for several hours while the area was walked, searching for gas leaks. Finally, pressure was

increased to 20 p.s.i.g. on September 12, 1969, and another complete check of the eastern area was made by conducting a flame ionization leak survey.

NIPSCO conducted a pipe-to-soil corrosion potential survey prior to the staged pressure increase in August 1969. Basically, this type of survey is conducted by placing electrodes on the surface of the ground, a short distance apart, directly over bare gas pipe buried in the ground. Readings are then taken to ascertain whether there is a difference in electrical potential or voltage between them. The electrodes are then moved in "leapfrog" fashion along the surface over the pipeline, and continuous readings are made of the indications at the location of each electrode. When high negative readings are obtained, the pipe is exposed for examination to determine the amount of corrosion present. Tests of the resistance of the soil to electric current flow are frequently conducted. Such determinations assist in estimating the amount of corrosion to be expected due to galvanic action. In a sense, bare steel pipe in soils which readily conduct current, such as certain types of clay, will be potentially subject to more corrosion than in soils more resistive to current flow. The reason for installing anodes of magnesium or other materials adjacent to bare steel pipe is to create a flow of current from the anodes through the soil to the pipe, then along the pipe to a wire connecting the anode to the pipe. In the electrical circuit created, the anode is corroded or destroyed rather than the pipe.

At the Board's hearing, an expert witness described the numerous holes in samples of leaking pipe removed from the eastern area of Glen Park as being the result of galvanic corrosion rather than from bacterial action.

On June 4, the Mayor of Gary, Indiana, convened an investigative Task Force to inquire into the circumstances of the accident. Representatives of the State Fire Marshal's Office, State Police, County Prosecutor's Office, and Gary Fire and Police Departments were on the Task Force which submitted its report to the Mayor. In the report, it is stated that recognition was taken of the technical investigation being conducted by the Safety Board and the Office of Pipeline Safety

and that the recommendations of the Task Force were non-technical. Ten of the 11 recommendations are listed below. The 11th recommendation pertained to recognition of acts of heroism by persons at the accident scene; that recommendation would be acted upon by the City authorities.

GARY TASK FORCE RECOMMENDATIONS:

1. That NIPSCO install outside speakers on their trucks so that in the event a crew is working, they can hear dispatches without having to go to the truck to make periodical checks.

2. That each regulator location be equipped with a safety backup system instead of having one regulator, as is the present practice of NIPSCO. Install two regulators at least 25 feet apart so that in the event of a failure of one regulator, the other will prevent abnormal increases in pressure to the service area.

3. Checking of all old pipes by an independent survey once a year, upgrading the pressure in 5-pound increments with leak surveys in between increments in pressure.

4. Checking of all new pipes by an independent survey every 5 years, upgrading the pressure in 5-pound increments with leak surveys in between increments in pressure.

5. That all gas cutoffs be located outside the house and made easily accessible to the average housewife; also, that regulators be attached to meters to prevent excessive increases in pressure.

6. That NIPSCO meter readers show people the proper way to shut off gas.

7. That the City Engineer's Office be supplied with all information concerning pipe work and excavation done by NIPSCO as prescribed by the Municipal Code, 2-504, Subsection F.

8. That NIPSCO purchase and distribute to homeowners a simple wrench to aid in shutting off gas at the meter.

9. That NIPSCO notify the Fire Department whenever a changeover is to be made.

10. That the Gary Fire Department instructor be permitted to attend NIPSCO's Gas Regulator School.

The Safety Board considered the above recommendations in drafting its recommendations in this report.

D. Federal, State, City and NIPSCO relationships

Prior to August 12, 1968, there was no Federal jurisdiction over the safety standards for transmission and distribution of gas by pipeline within the United States and Puerto Rico except for the jurisdiction of the Federal Power Commission under the Natural Gas Act (15 U. S. C. 717 et seq.) over interstate transmission facilities. The jurisdiction of the Federal Power Commission continues as before, but is not pertinent to this report.

On August 12, 1968, after extensive hearings, the Natural Gas Pipeline Safety Act of 1968 (49 U. S. C. 1659 et seq.) became Federal law. Hereafter in this report, it is referred to as the Act. The Act authorized the Secretary of Transportation to prescribe safety standards for the transportation of natural and other gas by pipeline and contains provisions to permit the States, the District of Columbia, and Puerto Rico to administer such safety standards under certain conditions. Hereafter, the word "State" includes the District of Columbia and Puerto Rico. The Secretary of Transportation placed the responsibility for enforcing the Act in the Office of Pipeline Safety of the Department of Transportation.

Portions of the Act pertinent to this report are listed below and are stated in general terms as follows:

(a) Within 3 months after August 12, 1968, the Secretary of Transportation would adopt, by order, as interim Federal safety standards for pipeline facilities and the transportation of gas in each State, those State standards in effect on August 12, 1968.

(b) For any State in which no such standards were in effect, the Secretary of Transportation would establish, by order, minimum Federal safety standards which are those common to a majority of States having safety standards.

(c) Any State agency may adopt such additional or more stringent standards for pipeline facilities and the transportation of gas, not subject to the jurisdiction of the Federal Power Commission under the Natural Gas Act, as are not incompatible with the Federal minimum standards.

(d) Not later than August 12, 1970, and from time to time thereafter, the Secretary of Transportation shall, by order, establish minimum Federal safety standards for the transportation of gas and pipeline facilities. Such standards may apply to the design, installation, inspection, testing, construction, extension, operation, replacement, and maintenance of pipeline facilities.

(e) Such standards as in "d" above affecting the design, installation, construction, initial inspection, and initial testing shall not be applicable to pipeline facilities in existence on the date such standards are adopted. Standards which do apply to existing installations include subsequent inspection and testing, and operation, extension, replacement, and maintenance of pipeline facilities.

(f) Whenever the Secretary of Transportation shall find a particular facility to be hazardous to life or property, he shall be empowered to require the person operating the facility to take such steps necessary to remove such hazards.

(g) The Secretary of Transportation shall establish a Technical Pipeline Safety Standards Committee of 15 persons, with representation from State and Federal Governments, the natural gas industry, and the general public.

(h) The provisions of the Act, except for authority of the Secretary of Transportation to act when a particular facility is found to be hazardous to life and property, shall not apply to States which submit an annual certification to the Secretary that the State agency: (1) has regulatory jurisdiction over safety standards and practices; (2) has adopted each Federal safety standard applicable as of the date of certification; (3) is enforcing such standards; (4) has authority to require record maintenance, reporting, and inspection and filing for approval of plans of inspection and maintenance; and (5) State law provides for enforcement by injunctive and monetary sanctions similar to those in the Act.

(i) Annual State Certifications are to include, among other things, reports of all accidents or incidents during the preceding year involving personal injury requiring hospitalization, fatality, or property damage exceeding $1,000, and the State's report of investigation.

(j) The Secretary may, on reasonable notice, take such action as he deems appropriate to insure compliance by the States, including assertion of Federal jurisdiction.

On November 12, 1968, the Office of Pipeline Safety of DOT published Part 190 - Interim Minimum Federal Safety Standards for the Transportation of Natural and Other Gas by Pipeline - of Chapter 1, Title 49, Code of Federal Regulations. These regulations were established after a review of information obtained from all States concerning their safety standards in effect on August 12, 1968. Only three States had no standards in effect. It was determined that for the majority of States, the standards contained in the 1968 edition of the United States of America Standards Institute "Standard Code for Pressure Piping - Gas Transmission and Distribution Piping Systems - USAS B31.8" were in effect. This code is hereafter referred to as USAS B31.8.

The Office of Pipeline Safety established USAS B31.8-1968 as the interim Minimum Federal Standard for States having no safety standards in effect on August 12, 1968. For the other States, forms were distributed to State agencies to be used in making certifications or agreements for enforcement of the interim Federal Safety Standards. Part 190 of Title 49 C.F.R. contains a number of prescriptions for State enforcement of interim Federal Standards as applied to publicly-owned facilities and certain interstate pipelines within the State, which are not pertinent to this report, and are therefore not discussed. There are also provisions for the execution of agreements by States to perform a large portion of the supervision and inspection of gas pipeline facilities subject to Federal Standards when those States are unable to submit certifications indicating that all minimum criteria in the Act are being met. The provisions for such agreements are also not pertinent to this report.

On December 13, 1968, the State of Indiana Public Service Commission submitted a Certificate to the Secretary under the prescriptions in Part 190 of Title 49 C.F.R. On May 28, 1969, the Office of Pipeline Safety accepted the Certificate of the State of Indiana for the period ending December 31, 1969. The Certificate stated, in general, that the State of Indiana:

(a) Had regulatory jurisdiction over the safety standards and practices of all pipeline facilities and transportation of gas within Indiana, except for those subject to the Federal Power Commission.

(b) Had adopted each Federal Safety Standard in effect on the date of the Certificate.

(c) Was enforcing each Federal Safety Standard as in "b", above.

(d) Had authority to require maintenance of records, reports, and information.

(e) Required the filing for approval of inspection and maintenance plans by each person in the State who owned or operated pipeline facilities not subject to the Federal Power Commission.

The State of Indiana has in force Senate Enrolled Act No. 479, entitled "An Act Concerning Safety Standards and Annual Inspections of Transportation of Gas and Pipeline Facilities and Prescribing Penalties." Many of the provisions in that Act, which became effective on March 15, 1969, are patterned after the Gas Pipeline Safety Act of 1968. The Indiana Public Service Commission "Rules and Standards of Service for the Gas Public Utilities of Indiana," dated April 28, 1964, were revised and reissued on August 23, 1968. In the 1964 Rules, the 1963 edition of B31.8 was the prescribed standard.

In the revised rules of the State of Indiana Public Service Commission, it is prescribed that the 1968 edition of USAS B31.8 is the effective standard for the State. Among the rules is a requirement that in distribution systems such as existed in Glen Park, leakage surveys are to be made as frequently as experience indicates they are necessary, but not less than every 5 years, and reports of such surveys are to be submitted to the Commission. It is also prescribed that an operation and maintenance plan shall be filed with the Commission by each operating company and that such companies shall operate and maintain facilities in compliance with the plan and keep appropriate records.

In compliance with the Indiana Public Service Commission's Rules and Regulations, NIPSCO filed its Gas Operations and Maintenance Plan on March 12, 1969. In the section of the plan entitled "Distribution Piping Maintenance," requirements are as follows:

1. Patrolling

A list will be maintained in each operating district of those locations where experience indicates abnormal physical movement or abnormal

loading could cause failure or leakage. These locations must be patrolled at least once each year, or oftener, as determined by district supervisors. A record of the patrol reports for these locations will be maintained in each district.

2. Leakage Surveys and Routine Procedures

Northern Indiana Public Service Company will survey its distribution system as follows:

(a) At least once a year a gas detector survey shall be conducted in business districts, involving tests of the atmosphere in gas, electric, telephone, sewer and water system manholes, at cracks in pavement and sidewalks and other locations providing an opportunity for finding gas leaks.

(b) Major buildings not included in the downtown office and commercial area shall be surveyed annually with a gas detector. This survey shall include areas involving public assembly buildings such as: churches, hospitals, large office buildings, etc.

(c) By law, it is required that inspection of gas service lines to schools be made annually between June 1 and September 1. A gas detector survey shall be conducted between June 1 and August 15 on the service to all schools up to and including the meter. A written report of this survey shall be made to the appropriate superintendent of school(s) (or equivalent) on or before August 15.

(d) A survey shall be conducted annually on all arterial medium and higher pressure mains. All manholes along those mains shall be tested with combustible gas indicators.

(e) A survey shall be made of all remaining mains and services at least once in every five (5) years by one or a combination of the following:

Vegetation Survey - A leakage survey made for the purpose of finding leaks in underground gas piping by observing vegetation. Any suspicious locations shall then be checked with a gas detector.

Gas Detector Survey - A leakage survey made by testing with a combustible gas detector the atmosphere in water meter boxes, street vaults of all types, cracks in pavement and other available locations where access to the soil under pavement is provided.

Bar Test Survey - A leakage survey made by driving or boring holes at regular intervals along the route of an underground gas pipe and testing the atmosphere in the holes with a combustible gas detector or other suitable device.

(f) In advance of street repaving with a permanent pavement, the mains and services within the street limits shall be tested for leaks by use of bar holes and gas detection instruments and, where necessary, the system is to be repaired or replaced at that time.

(g) Records shall be kept of the leakage surveys conducted.

Locations where leak indications are found during leak surveys will be reported to district supervisors. Files of leak indication reports will be maintained, and indicated locations will be investigated promptly.

All leak reports relating to customer complaints, emergency incidents and claim cases shall be investigated promptly.

Particular care must be exercised and caution taken in promptly repairing any leakage near public buildings such as hospitals, schools, stores, restaurants, hotels, apartment buildings, office buildings, etc.

Appropriate files and records shall be maintained covering the date and time the leak is reported, the kind and classification of the leak, the severity of the leak, the location, the cause, the repairs made, the date of the repairs and the condition of the pipe or fitting.

At intervals not greater than five (5) years, random spot checks will be scheduled adequate to sample the corrosion conditions in each type of construction in each district. Records of these inspections shall be maintained.

As mentioned previously, NIPSCO had flame ionization surveys conducted over portions of the 20 p.s.i.g. mains in the eastern sector of Glen Park in 1967, 1968, and 1969, prior to the pressure increase. Technically, since the NIPSCO plan became effective on March 12, 1969, completion of the leakage surveys was not required until a year later for the 20 p.s.i.g. mains, and for 5 years for the residential distribution system. There was no requirement in the 1964 Indiana Public Service Commission Rules with respect to leakage surveys. Those rules pertained primarily to economic provisions, with very little mentioned with respect to pipeline safety other than the requirement that the 1963 version of USAS B31.8 be the standard.

The 8-inch and 4-inch bare steel pipe in the eastern sector of Glen Park was installed mainly between 1924 and 1941. It operated at low pressure until the pressure was raised to 20 p.s.i.g. on June 3. Apparently, the bare steel mains had been corroded for some time, but the earth and hard corrosion products around the mains stopped the gas from leaking while the system was operating at low pressure. However, when gas at 20 p.s.i.g. was introduced into the system, the barrier containing the gas was blown away, allowing the gas to escape where it was detected by people in the street. Ninty-five feet of 8-inch bare steel pipe was removed from the intersection of Washington Street and 47th Avenue. One 4-foot section of this pipe contained 18 corrosion holes varying in size from about 1/4 inch to more than 1 inch in diameter. In addition, there were 39 more holes having the same range in size in the remaining 91 feet of pipe. The corrosion action had taken place primarily along the bottom of the main.

It is not NIPSCO's policy to conduct pipe-to-soil potential surveys to locate corroding areas in its distribution system, which would enable the company to take corrosion preventative measures. NIPSCO depends on leak surveys which are effective only after the pipe wall has been penetrated, allowing the gas to leak out and subsequently be detected. If sections of the pipe are replaced due to conditions found through these leakage surveys, the new pipe is coated and cathodically protected and isolated from the adjacent bare pipe by insulating couplings. However, no test leads are installed for checking in subsequent years to determine if the pipe is cathodically protected or to check anode current outputs.

The National Association of Corrosion Engineers has recently adopted a comprehensive corrosion standard which recommends practices intended to serve as a guide for establishing minimum requirements for control of corrosion for new piping systems, existing bare piping systems, and existing coated piping systems. This standard is entitled "Control of External Corrosion on Underground or Submerged Metallic Piping Systems."

In the NIPSCO Gas Operations and Maintenance Plan of March 12, 1969, it is required that the Gas Transmission and Storage Department will maintain and carry out a systematic, periodic inspection and test program to insure that transmission and distribution system regulator stations are properly maintained in safe condition. Inspections and tests are to be made at least once a year and results recorded. An inspection for correct operation was made at the regulator station at 46th Avenue and Grant Street in the western area, prior to the pressure increase in the eastern area of Glen Park. However, as noted above in respect to leakage surveys, the NIPSCO plan had been in effect only since March 12, and 1 year from that date was the date for completion of inspection of regulator stations under NIPSCO standards.

The City of Gary, Indiana, has no regulations with respect to safety of gas operations. There is a provision in the Municipal Code of the City of Gary, 1960, in Chapter 5, City Civil Engineer, requiring that he keep an accurate record of pipelines of private and public corporations, but no such record could be found. In connection with plans for building, zoning, and permits for construction, the City of Gary did not have knowledge of the location and identity of gas pipelines to ensure that unsafe conditions were prevented.

In summary, on June 3, 1969, NIPSCO operations in the Glen Park area of Gary, Indiana, were subject to the requirements of USAS B31.8, 1968 edition, and were subject to the State of Indiana Rules and Regulations for Operation of Gas Utilities, dated August 23, 1968. In turn, the State of Indiana, by the acceptance of its Certificate to the Office of Pipeline Safety of DOT, was enforcing the Interim Minimum Federal Safety Standards for gas operations in Indiana.

Acting under its authority in the Act, the Office of Pipeline Safety (OPS) dispatched a representative to the accident scene in Glen Park on June 3, and that person traveled with the Safety Board's representative. Basic information was obtained by OPS at the scene for evaluation and appropriate action as authorized by the Act.

NIPSCO was requested to hold pressure in the eastern area after the accident to a maximum of 1 p.s.i.g. until pipe-to-soil corrosion potential surveys were completed and a written plan was approved for raising pressure in stages with a series of leakage surveys at different pressures being required. NIPSCO complied and has completed all requirements, and has raised operating pressure in the eastern area to 20 p.s.i.g. as of September 12, 1969.

The Chairman of the Indiana Public Service Commission was advised of the Glen Park accident about 4 p.m. on June 3. Prior advice had been received by the Commission from NIPSCO soon after the accident. The Governor was notified and the State Police were contacted to determine if communications were in effect with the accident area. About 5:15 p.m., the Commission Chairman talked to a NIPSCO representative who stated that the affected area was isolated and that the balance of the distribution system had not been affected.

On the morning of June 4, a Commission Engineer proceeded to Gary and held discussions with NIPSCO officials and the State Police. In view of the action of the NIPSCO crewmember who opened the separation valve without instructions, the Commission began an immediate review of NIPSCO work rules in discussions with NIPSCO personnel. During the next several days, there was frequent telephone contact with NIPSCO personnel, and an accident report was received from NIPSCO in conformance with State requirements. Copies of work rules were obtained from other gas companies in the State for review.

During his appearance as a witness at the Safety Board's hearing, the Chairman of the Indiana Public Service Commission gave the following information:

(a) NIPSCO was not required to submit a plan of the pressure increase for approval, and none was submitted.

(b) The Commission has under consideration additional regulations in relation to pipeline

safety in the matter of work rules, fail-safe techniques and installations, testing of systems for gas leaks, and other possible measures to determine conditions of pipe prior to pressure increases.

(c) The Commission was conducting its own investigation.

(d) The Commission in the past had not conducted on-scene operations and safety investigations, except after accidents.

(e) The Commission has not prescribed any safety checklist for conversions of distribution systems.

The Chairman of the Commission also stated there were a number of aspects of the Glen Park accident that he desired to inquire into to determine steps to take for increased safety in pipeline operations.

E. Prior Regulator Failures

During the investigation, it was ascertained that on January 31, 1965, and on February 16, 1966, there were overpressurizations causing fires and damage to properties as the result of failures of low-pressure distribution system regulators. In the first case, several houses were involved, with little or no damage. The Fire Department turned off valves at meters and notified NIPSCO. In the second case, 12 houses were involved, with furnace explosions, flames shooting out from appliances, and fires in the buildings. Damage was substantial in many houses, but not of the magnitude in Glen Park on June 3. No one was killed or injured severely in either case. The cause of both incidents was the formation of ice in the regulators, preventing complete closure of regulator valves. As in the Glen Park case, there were no overpressure protection devices except the regulators which were not designed to "fail-safe." Fortunately, the degree of overpressure in these cases was apparently small and the regulators were repaired soon after malfunction.

F. Emergency Notification of Gas System Failures

A review of the telephone book for Gary, Indiana, (including Glen Park) discloses that there is no emergency listing of NIPSCO in the front of the book as found for gas company listings in a number of telephone books in the United States. In many locations, citizens in an emergency instinctively rush to the emergency listings on the reverse of the cover page of telephone books or adjacent to the cover page. It is apparent that inclusion of emergency 24-hour numbers for gas companies, along with police, fire departments, etc., would assist residents in expediting reports of gas emergencies.

G. Industry Standard USAS B31.8 and NIPSCO Practices

1. The Industry Standard - USAS B31.8

The United States of America Standards Institute Code B31.8, "Gas Transmission and Distribution Piping Systems," is the basic safety standard in effect in Indiana and in almost all other States. It is sponsored by the American Society of Mechanical Engineers (ASME). The code is prepared and revised by the USA Standards Committee B31 "Code for Pressure Piping," which prepares standards for eight other uses of pressure piping in addition to gas transmission and distribution.

Section 8 (B31.8) is concerned with Gas Transmission and Distribution Piping Systems. When the 1968 edition was issued, there were 66 members on the Section 8 Committee. The Committee is made up primarily of persons from gas transmission and distribution companies. There are also representatives of manufacturers, government agencies, consultants, contractors, private individuals of recognized skill and research, educational and professional institutions, or societies. Thirty-six, or 54 percent of the membership on this

Section 8 Committee, represent gas utilities. Sixteen represent contractors or manufacturers of products supplying the gas industry, four are from consulting firms, four from regulatory agencies, and six from research institutes, schools, or professional associations. The Section 8 Committee has eight subgroups. The subgroups operate in the fields of Distribution, Facility Failures, Materials, Mechanical Design and Fabrications, Research, and Transmission and Compressor Stations. In addition, there is a Review group. A corrosion subgroup has recently been added. Committee members act as individuals, but their relationships to their organizations are detailed in Committee documents.

All proposed changes, revisions, and additions to the Code are submitted to all Committee members for letter ballot. A consensus, rather than a majority of members, is desired to effect a change. This does not mean that all members must approve a change, but it does provide for each dissenting member to be heard.

After approval by the Section 8 Committee, the proposal is reviewed by a number of other ASME committees and recommended that the United States of America Standards Institute (USASI) take responsibility for its technical content. If approved, it becomes a USASI standard.

The B31.8 Committee operates on a continuing basis to keep the Code up to date and meets according to necessity, but at least once or twice a year.

The introduction of USAS B31.8-1968 states in part:

> "The Code for Pressure Piping sets forth engineering requirements deemed necessary for safe design and construction of piping systems. While safety is a basic consideration of this code, other factors may impose additional requirements."

In the area of existing facilities, it states:

> "It is not intended that this code be applied retroactively to existing installations insofar as design, fabrication, installation, established operating pressure (except as provided for in Chap. V), and testing are concerned. It is intended, however, that the provisions of this code shall be applicable to the operation, maintenance, and up-rating of existing installations."

In the area of operations and maintenance, it states:

> "Provisions of this code shall be applicable to operating and maintenance procedures of existing installations, and when existing installations are up-rated."

By a review of the testimony and exhibits, it is indicated that NIPSCO's distribution practices in the Glen Park area of Gary, Indiana, appeared to be in conformance with USAS B31.8-1968. While note is made of this conformance, it only serves to point up a number of areas of USAS B31.8-1968 which were inadequate to prevent the explosion and fires that occurred in Gary on June 3, 1969. The appropriate sections which require strengthening are as follows:

Section 845.4 - Control and Limiting of Gas Pressure in Low-Pressure Distribution Systems

Section 845.44 - Conversion of Low-Pressure Distribution Systems to High-Pressure Distribution Systems

Section 851.2 - External Corrosion of Pipelines

Special discussions and analysis of the above sections are dealt with in more appropriate portions of this report.

A review has been made of the records and minutes of recent meetings of the B31.8 Committee, and it has been found that proposals have been made to make the sections mentioned above more stringent. In fact, a separate chapter has been proposed to deal with corrosion problems.

One of the main deficiencies of USAS B31.8-1968 is that, while it is applicable to operating and maintenance of existing installation, it is not intended to be retroactive to these existing facilities as far as design, fabrication, or installation are concerned. In other words, it requires that certain standards must be met if a new facility is installed, but the fact that an installation below these standards may be hazardous is not considered. While this philosophy may be economical in certain areas of the system, such as buried pipe, it cannot be justified in all instances, especially where parts of the system are accessible and can be replaced. The newer standard which provides for control and limiting of gas pressure by redundant regulators, relief valves, and separation of shutoff valves is a prime example of an area of the Code which could be made retroactive to such systems as that in Gary.

The National Association of Corrosion Engineers has recently adopted a recommended practice for "Control of External Corrosion on Underground or Submerged Metallic Piping Systems." The standard serves as a guide for establishing minimum requirements for control of corrosion in new piping systems, existing coated piping systems, and existing bare piping systems. It was prepared by 80 corrosion engineers working over an 18-month period.

It was brought out in the testimony that the B31.8 Committee has been considering for some time, an addition to the Code which would require overpressure

protection equipment on low-pressure systems constructed before the Code became effective. However, it was the view of a few committee members that evidence of failures had not been found which would warrant such an addition to the Code. This proposal is still under discussion. It was pointed out that the B31.8 Committee facility failure subgroup reviews all accidents to see if a lesson could be learned. The philosophy that analyzable hazards must be demonstrated to be actual hazards by the occurrence of an accident is not a modern approach to accident prevention.

It is noted in the testimony that regulations in the Code dealing with corrosion were quite inadequate. The B31.8 Committee has also been working for several years on a separate chapter to be added to the Code covering corrosion control.

2. NIPSCO Gas Standards

The NIPSCO "Gas Standards" is a standard consisting of more than 650 pages written by a Gas Standards Committee made up of NIPSCO employees.

The purpose of the Standard is indicated on its cover page; it states, in part:

> This Standard Book is the property of the Northern Indiana Public Service Company, and is to be used as a guide by those employees who are engaged in ordering, purchasing, storing, or issuing material and the methods to be used by those employees engaged in gas construction.

The Standard includes specification, materials, procedures, and methods of installing and maintaining gas facilities. In some instances, its requirements are similar to USAS B31.8, but in most cases, it exceeds B31.8 in scope and detail. For example, Section 855.1 of B31.8, "Maintenance of Pressure Limiting and Pressure Regulating Stations," requires

" ... systematic, periodic inspection and suitable tests ... " regarding the mechanical condition, adequacy, and pressure control.

However, NIPSCO's "Gas Standards" require that each regulator station receive at least one preventive overhaul each year and a preventive inspection approximately 6 months after the annual overhaul. The Standard lists the actual steps to be taken, such as: check all regulator diaphragms for leakage, through vent; check for leak; etc. This Standard also requires that the diaphragm be inspected at least once every 5 years and be replaced if found defective.

The B31.8 Code, it was brought out in the testimony, is a minimum standard for NIPSCO in many areas. Its "Gas Standards" is a more specific and detailed document and more of an operating manual than a code.

While B31.8 clearly indicates that the Code should not generally be applied retroactively to existing facilities, NIPSCO's "Gas Standards" does not have any specific statement in that regard.

3. Crew Assignments

As a part of a new employee's initial hiring procedure, he is supplied with a copy of NIPSCO's Safety Manual. A NIPSCO official testified that, within a short period of time, each employee is tested to determine whether he has read the parts of the manual which apply to his job. If he fails to pass this test, he takes it a second time. If he fails the test a second time, his employment with NIPSCO is terminated. A new employee receives verbal instruction from his supervisor, and begins a continuing program of training which consists of formal instruction by use of manuals and subsequent tests. He also obtains on-the-job training and attends safety meetings and specific courses, such as a 1-day course named "Lubricated Plug Valves" which is conducted in the field.

The three members of the crew which were working at the 8-inch sectionalizing valve had the folowing history with NIPSCO:

One crewmember, during 3 years with NIPSCO, was in the Gas Department for 2 months, and with the crew for 2 weeks. He indicated he had received books to study, but had received no formal training, nor had he ever received a test on the material he was given to study.

Another crewmember was with NIPSCO for 4 months, and with the crew for 2 weeks. He indicated that he received books to study and received one test on safety, but after the accident of June 3.

The crewmember, who opened the valve, worked for NIPSCO for 10 years. He had worked in the construction department most of the time prior to joining the crew, about 3 1/2 months before the accident. He had attended safety meetings and had taken a test on the safety manual. He did not, however, attend special courses, such as the one on valves mentioned above.

III. CONCLUSIONS AND CAUSE

(Listed after conclusions are page numbers in this report which contain facts leading to conclusions.)

A. The Board concludes that:

1. The NIPSCO crewmember who opened the separation valve in Glen Park about 1:20 p.m., on June 3, took that action independently, contrary to instructions from his superiors, and in violation of the requirements in the NIPSCO Safety Manual. His apparent confusion as to whether he was opening or closing the valve could have been avoided if the gauges had been used at the valve, as they were at the time the valve was closed to isolate the eastern and western areas of Glen Park during that morning. (Pages 12, 17, 18.)

2. The separation valve was open only for about 1 minute, but the flow of gas at 20 p.s.i.g. into the 1/4 p.s.i.g. distribution system ruptured the diaphragm of the regulator at 46th Avenue and Grant Street. This permitted gas at 20 p.s.i.g. to flow into the 1/4 p.s.i.g. system for 30 to 45 minutes until the shutoff valve at the regulator was closed. This flow occurred because the regulator was not designed to "fail-safe" and there were no other pressure-limiting devices installed on the low-pressure system in the western area of Glen Park. (Pages 17, 19 to 25.)

3. The regulator station at 46th Avenue and Grant Street did not conform to the provisions in NIPSCO's "Gas Standards" in that a fire valve was not installed outside of the pit and, further, in that the regulator was of a type that would fail in an open position without provision for additional pressure-limiting devices. (Pages 21, 37.)

   This regulator station was not in conflict with the requirements of USAS B31.8 since that Code is not retroactive to existing installations insofar as design, fabrication, installation, and testing at the time of construction are concerned. (Page 19.)

4. A delay of about 15 minutes occurred in shutting off the flow of gas into the western area of Glen Park because the inlet valve was located in the regulator pit at 46th Avenue and Grant Street. The heavy steel covers could not be opened by the NIPSCO Assistant Foreman and it was necessary for him to wait for a crew. If a crew had been stationed at that regulator, instant action could have been taken to shut off the inlet gas at 20 p.s.i.g. (Pages 36, 37.)

5. The medium pressure gas at 20 p.s.i.g. in the low-pressure (1/4 p.s.i.g.) system in the western area of Glen Park caused pilot lights and burner flames to extend for a number of feet and ignite combustibles in many houses. When pilot lights blew out, gas accumulations in houses were ignited and exploded violently. As the result, seven houses were destroyed and 45 were damaged. There were no deaths, but nine persons, including five firemen, were injured. Damage was estimated at $350,000. (Page 25.)

6. Many residents of Glen Park were not aware of steps to take in a gas emergency to safeguard themselves and their properties, and did not know how to shut off the supply of gas. Residents and Gary firemen did not have correct wrenches to shut off gas at meters. (Page 25.)

7. The establishment by the Mayor of Gary of a "rumor line" telephone number as explained on broadcast radio and TV programs was of much help in allaying fear and panic of the residents during the emergency. (Page 27.)

8. The conversion of the eastern area of Glen Park was undertaken without a written plan, and there was no written requirement for it. In this accident, it is apparent that several unforeseen events, with different degrees and forms of hazard, required corresponding preventive or corrective action. If a written plan had been formulated describing the stages of conversion, the possible types of failures, the resulting hazards, and the measures to forestall all probabilities, it is likely that the separation valve would have been discussed, for that was the point of maximum danger to

the western area. The action of the NISPCO Assistant Foreman, in ordering the separation valve uncovered and a crew to stand by until further orders, was predicated upon being ready with a supply of 1/4 p.s.i.g. gas for the eastern area if it were necessary because of the large amount of gas being lost due to leaks, and the necessity to reduce pressure for repairs. A complete written plan for the conversion would be expected to cover actions to take in the event of leaks due to the increased pressure because such leaks are to be anticipated and would include consideration of the possibilities of personnel error. Further, such a plan would be expected to specify the steps to be taken to reduce the pressure if required to repair the leaks. Lacking such a plan, the decision exposed the entire western area to the danger of overpressure in the event of a single personnel failure. The hazard involved in allowing the gas pressure to drop in the eastern zone was loss of service which implies the expenditure of many man-hours to restore service and some hazards localized to individual houses. Such a single personnel failure did occur when a crewmember incorrectly opened the valve. (Pages 11, 16, 17.

9. NIPSCO did not comply fully with the provisions of Section 845.44 of USAS B31.8 during the conversion of the eastern area of Glen Park. In particular, the entire area to be converted was not given a leakage survey prior to increase of pressure and no specific tests were conducted to determine condition of the gas mains after pressure was raised to 6 p.s.i.g. Finally, after pressure reached 20 p.s.i.g., the area was walked looking for leaks, but more reliable surveys such as by leakmobile or bar test were not conducted. (Pages 13 to 15.)

10. The regulator at 46th Avenue and Grant Street which failed on June 3 was replaced with two new regulators in series, with one being a monitor regulator. However, the shutoff valve on the 20 p.s.i.g. inlet piping is located 9 inches from the monitor regulator in the same pit. This installation does not comply with USAS B31.8 and NIPSCO's "Gas Standards" which both require the gas inlet shutoff valve to be located at a distance from the regulator sufficient to permit operation of the valve during an emergency. (Pages 35 to 38.)

11. Lacking additional overpressure protection devices, the two new regulators at 46th Avenue and Grant Street are potentially vulnerable to having their diaphragms ruptured by back pressure. Such an action could cause an uninterrupted flow of 20 p. s. i. g. gas into the area as on June 3. (Page 38.)

12. Section 850.6 of USAS B31.8 required that NIPSCO, under its "Emergency Plan," establish liaison with appropriate public officials with respect to the plan. NIPSCO does have an Emergency Plan, but the Gary Fire Chief had not been contacted by NIPSCO with respect to the plan. During the emergency on June 3, the Fire Department could not obtain information by telephone to NIPSCO respecting the extent of the potential area for fires and explosions. There is no evidence that NIPSCO contacted the Fire Department to inform them as to the extent of the disaster. (Pages 26, 27 .)

13. While the NIPSCO training program for employees is quite comprehensive in scope, it is noted that the three members of the crew at the separation valve had little formal training. Two crewmembers had not been given a test to determine their knowledge of the NIPSCO Safety Manual prior to June 3. The crewmember who opened the separation valve by mistake had been given training and examinations on the Safety Manual and stated his familiarity with its provisions. (Pages 58 to 59.)

14. Considering the conditions surrounding the accident in Gary, USAS B31.8 is inadequate in the following areas:

    (a) Control and Limiting of Gas Pressure in Low Pressure Distribution Systems.

    (b) Conversion of Low Pressure Distribution Systems to High Pressure Distribution Systems.

    (c) External Corrosion of Pipelines. (Pages 55 to 57.)

15. A comprehensive standard entitled "Control of External Corrosion on Underground or Submerged Metallic Piping Systems," recently issued by the National Association of Corrosion Engineers, is now available for use in connection with formulation of Federal, State, and gas industry standards. (Pages 49, 56.)

16. Comprehensive standards for design and construction of new installations are prescribed in USAS B31.8, but that Code states that its provisions are not to be applied retroactively to existing installations insofar as design, fabrication, installation, and established operating pressure are concerned. (Pages 54, 55.)

17. The City Engineer of Gary, Indiana, did not have a record of gas pipelines in the city as required by the Code of the City of Gary, 1960. (Page 50.)

18. Insofar as possible, all gas shutoff valves should be located outside of buildings for ready access to shut off gas in emergencies. (Page 25.)

19. In the Gary telephone book, there is no specific listing of an emergency number for NIPSCO. In particular, there is no listing of NIPSCO with the special list of emergency numbers in the front of the telephone book. (Page 53.)

B. Cause

The Board finds that the probable cause of this accident was a combination of personnel error and system inadequacy. Involved were the inadvertent opening of a separation valve by a gas company employee allowing gas at 20 p.s.i.g. to flow into a 1/4 p.s.i.g. system and a system which could not control adequately such an increase in pressure owing to the lack of overpressure protection devices. Thereafter, the increase in pressure caused the failure of a regulator diaphragm which allowed an 80-fold overpressure in the low-pressure system to become continuous for 30 to 45 minutes.

Significant contributing causal factors were:

1. The inaccessibility of the shutoff valve for the regulator which failed.

2. The lack of a systematic review of the hazards in the conversion operation which could have revealed the hazardous condition in which one human error could produce catastrophe, coupled with the lack of a written plan for the conversion.

3. The absence in Code B31.8 of any specification of safeguards to be employed at separation (isolation) valves during pressure conversions.

4. The lack of complete leakage surveys, before and during the pressure increase in the eastern area, which would have probably disclosed the leaking condition of the pipe and avoided the major leaks which occurred on June 3, 1969.

The relationship of the detailed causal factors involved in this accident is diagrammed in Appendix 1. The above statement of cause is derived from the relationships of the diagram.

IV. RECOMMENDATIONS

(Listed after the recommendations are numbers of conclusions upon which such recommendations are based.)

The Safety Board recommends that:

1. The Office of Pipeline Safety of the Department of Transportation take the following actions:

   (a) Conduct a study to determine the feasibility of requiring that pressure regulators in series be placed in separate vaults or buildings for protection against fires and explosions, and determine the minimum distance of separation of regulators. (Conclusion 3.)

   (b) Include in its proposed standards a requirement that before valves separating gas systems of different pressures are operated, gauges be tapped in on both sides of the valve so that changes in pressure before, during, and after operation of the valves can be determined. (Conclusion 1.)

   (c) Include in its proposed standards a specified minimum safe distance between a regulator and its shutoff valve, and a requirement that emergency shutoff valves be placed in underground valve boxes or other readily accessible locations separate from regulator vaults or enclosures. (Conclusion 3.)

   (d) Include in its proposed standards a requirement that gas companies establish educational programs to enable customers and the general public to recognize gas emergency situations and, further, to provide necessary information to notify companies immediately. (Conclusion 6.)

(e) Use the corrosion standards of the National Association of Corrosion Engineers entitled "Control of External Corrosion in Underground or Submerged Metallic Pipeline Systems" as a guideline in formulating Federal standards. (Conclusion 15.)

(f) Conduct a study to determine the feasibility of requiring gas shutoff valves on all services, located outside of buildings in readily accessible locations for use in emergencies. Further, use the results of such study in formulating Federal standards and in consultations with the States in connection with their standards for existing systems. (Conclusion 18.)

(g) Include in its proposed standards a requirement that relief devices be provided for low-pressure distribution systems which could be overpressured by interconnected high-pressure gas. If relief devices would present a hazard, an automatic shutoff device should be installed at each unprotected source of high-pressure gas. It is not intended that this recommendation apply to high-pressure gas connected to a low-pressure system by means of a regulator station provided with a suitable device to prevent accidental overpressuring. (Conclusion 2.)

(h) Include in its proposed standards a requirement that surveys be made of existing systems to determine the extent of corrosion damage and to replace or further cathodically protect those facilities found corroded beyond a specified minimum and, further, use the National Association of Corrosion Engineers standard as a guide. (Conclusion 15.)

(i) Include in its proposed standards a requirement that existing regulator stations be upgraded to comply with the USAS B31.8 standards for newly constructed regulator stations. (Conclusions 2, 3.)

(j) Include in its proposed standards a requirement that a leakage survey, as presently defined in section 852.21 of USAS B31.8, be conducted prior to conversion of low-pressure distribution systems to higher pressure systems; also, that such surveys be conducted at one or more pressure increments and, finally, after the desired pressure has been attained. (Conclusion 9.)

(k) Include in its proposed standards the requirement that all gas utilities use written plans for conversions of low-pressure distribution systems to higher pressure. (Conclusion 8.)

2. The Indiana Public Service Commission take the following actions:

(a) Review the training procedures used by NIPSCO to determine their adequacy. (Conclusion 13.)

(b) Determine whether NIPSCO's Emergency Plan complies with section 850.6 of USAS B31.8 "Emergency Plan." This plan should include direct communications between NIPSCO and the fire and police departments in emergencies. (Conclusion 12.)

(c) Review NIPSCO's facilities and require correction of all regulators supplying distribution systems if those regulator stations are not in compliance with USAS B31.8, section 846.22 for new installations, and NIPSCO's "Gas Standards." (Conclusions 10, 11.)

3. NIPSCO take the following actions:

(a) Meet with representatives of the various police and fire departments in the area which it serves in order to acquaint them with the hazards and characteristics of natural gas and methods used to control emergencies. (Conclusions 12, 6.)

(b) Establish an educational program which would enable its customers and the general public to recognize a gas emergency situation, promptly notify NIPSCO, and take measures to reduce hazards of an emergency. (Conclusion 6.)

(c) Install relief devices on all its low-pressure distribution systems which could be over-pressured by interconnected high-pressure gas. If relief devices would present a hazard, an automatic shutoff device should be installed at each unprotected source of high-pressure gas. It is not intended that this recommendation apply to high-pressure gas connected to a low-pressure system by means of a regulator station provided with a suitable device to prevent accidental overpressuring. (Conclusion 2.)

(d) Furnish information to the City Engineer of Gary with respect to location of all gas lines in the city. (Conclusion 17.)

4. The USAS B31.8 Committee take the following actions:

(a) Include in its standards a requirement that relief devices be provided for low-pressure distribution systems which could be over-pressured by interconnected high-pressure gas. If relief devices would present a hazard, an automatic shutoff device should be installed at each unprotected source of high-pressure gas. It is not intended that this recommendation apply to high-pressure gas connected to a low-pressure system by means of a regulator station provided with a suitable device to prevent accidental overpressuring. (Conclusion 2.)

(b) Include in its standards a requirement that surveys be made of existing systems to determine the extent of corrosion damage

and to replace or further cathodically protect those facilities found corroded beyond a specified minimum, and further, use the National Association of Corrosion Engineers Standards as a guideline. (Conclusion 15.)

(c) Include in its standards a requirement providing that existing regulator stations be upgraded to comply with the standards for newly constructed regulator stations. (Conclusion 2.)

(d) Include in its standards an additional requirement that a leakage survey, as defined in section 852.21 of USAS B31.8, be conducted prior to conversion of low-pressure distribution systems to higher pressure systems, that such surveys be conducted at one or more pressure increments, and, finally, after the desired pressure has been attained. (Conclusion 9.)

5. All States, the District of Columbia, and Puerto Rico take the following actions:

(a) Include in their standards a provision that existing regulator stations supplying low-pressure distribution systems be upgraded to comply with the standards for newly constructed regulator stations as specified in USAS B31.8. (Conclusion 2.)

(b) Include in their standards a requirement that relief devices be provided for low-pressure distribution systems which could be overpressured by interconnected high-pressure gas. If relief devices would present a hazard, an automatic shutoff device should be installed at each unprotected source of high-pressure gas. It is not intended that this recommendation apply to high-pressure gas connected to a low-pressure system by means of a regulator station provided with a suitable device to prevent accidental overpressuring. (Conclusion 2.)

(c) Foster the use of "rumor line" telephone numbers throughout the States in cities and communities for use in emergencies to obtain accurate information and to reduce fear and panic. (Conclusion 7.)

(d) Institute a program with telephone companies to list emergency numbers for gas companies, along with listings for police, fire, FBI, etc. (Conclusion 19.)

(e) Require all gas utilities to use written plans for conversions of low-pressure distribution systems to higher pressure to insure that appropriate safety precautions are taken to protect the public. (Conclusion 8.)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

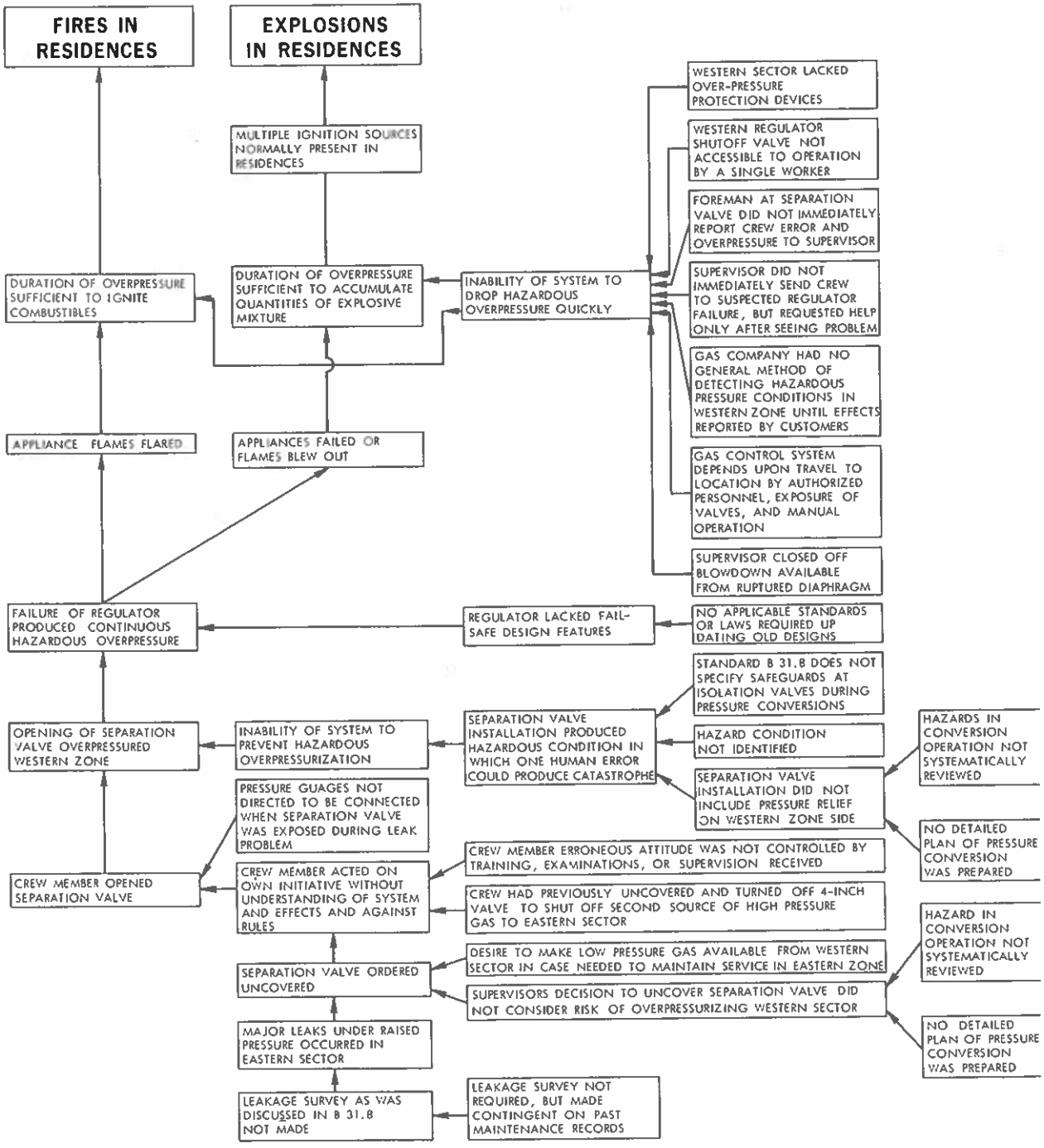
/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

December 4, 1969

APPENDIX I

RELATIONSHIP OF EVENTS AND CAUSAL FACTORS



APPENDIX II

SUMMARY OF RECENT NATURAL GAS PIPELINE ACCIDENTS

On the night of January 8, 1968, a crew repairing a water leak in a street in Reading, Pennsylvania, pulled a gas service line operating at 30 p.s.i.g. from its connection to the gas main. The pipe did not break where it was hit, and the crew was not aware of the actual damage. About 2 hours later, an explosion occurred in a building in front of the break, killing all nine occupants of the two semidetached houses which comprised the structure.

On January 15, 1968, a 12-inch main line, which had been in operation since 1927, carrying 125 p.s.i.g., ruptured in the Village of Garden City, Long Island, New York. No fire or explosions occurred, and there were no injuries or property damage. Due to the time that elapsed in shutting down the line, dirt and other debris were scattered more than a hundred feet. Several hundred residents were evacuated as a precautionary measure.

On January 30, 1968, gas explosions occurred in a shopping area in the borough of Ingram, Pennsylvania. Six of eight persons in one building were killed, and the other two injured. Of 12 men working on a nearby street, two were killed and nine injured. Additional injuries of varying degrees of severity were suffered by occupants of passing cars and pedestrians in the vicinity. Extensive property damage also resulted.

On March 15, 1968, a 30-inch high-pressure transmission line near Edna, Texas, ruptured and caught fire. There were no casualties, but there was some property damage. The accident caused a traffic block on a nearby highway for several miles in both directions. It was almost impossible for law enforcement officers and emergency equipment to reach the scene of the accident. The line was shut down in approximately 45 minutes to 1 hour following the rupture.

Explosions and fire took the lives of 41, and injured over 100 other persons in downtown Richmond, Indiana, on April 16, 1968. Property damage was estimated at over $10 million; this catastrophic

accident apparently resulted from a combination of exploding gas and stored ammunition. Gas accumulation from leaks was not ruled out as a possible cause.

A residential area in San Jose, California, experienced the consequences of a gas leak on May 8, 1968. Four houses were demolished and over 20 others damaged. Several persons were injured. Damage to property was estimated at $1 million.

On May 29, 1968, a gas explosion occurred in the Hapeville Day Nursery in Hapeville, Georgia. Fire immediately engulfed the frame dwelling. A bulldozer working at the front of the building had broken a 1-inch gas line. Seven children and two adults were killed, and three children severely injured.

On October 15, 1968, a leak in a 3-inch feeder gas line caused an explosion on 42nd Street near 8th Avenue in New York City. Two persons were seriously injured, and six others sustained lesser injuries.

On November 6, 1968, a high-pressure line ruptured near Del Ray Beach, Florida, along Sunshine Parkway. There were no explosions or fire.

In November of 1968, a gas leak caused explosions and fire in Mankato, Minnesota. One house was demolished and several others damaged. Eight persons were injured.

On January 3 of this year, gas explosions and fires occurred along a 4-block section of Delancey Street in Manhattan, New York. There was some property damage, and several hundred people were evacuated. Four people received minor injuries. The fires burned for more than 7 hours before the gas could be shut off.

On September 9, 1969, a 14-inch natural gas pipeline, operating under more than 600 p.s.i.g., ruptured in a suburban community north of Houston, Texas. About 10 minutes later, explosion and fires occurred, destroying 13 houses and damaging 11 others. Eight people were injured and, miraculosly, there were no fatalities. A number of destroyed houses had been built within 25 feet of the pipeline which was installed nearly 30 years ago.