THE BRIGHTON GAS FIRE AND EXPLOSION CATASTROPHE

Town of Brighton (Monroe County), N. Y.

September 21, 1951

Report by

THE NATIONAL BOARD OF FIRE UNDERWRITERS
85 John Street, New York 38, N. Y.
222 West Adams Street, Chicago 6, Ill.
Merchants Exchange Bldg., San Francisco 4, Calif.
and
THE NEW YORK FIRE INSURANCE RATING ORGANIZATION
85 John Street
New York 38, N. Y.

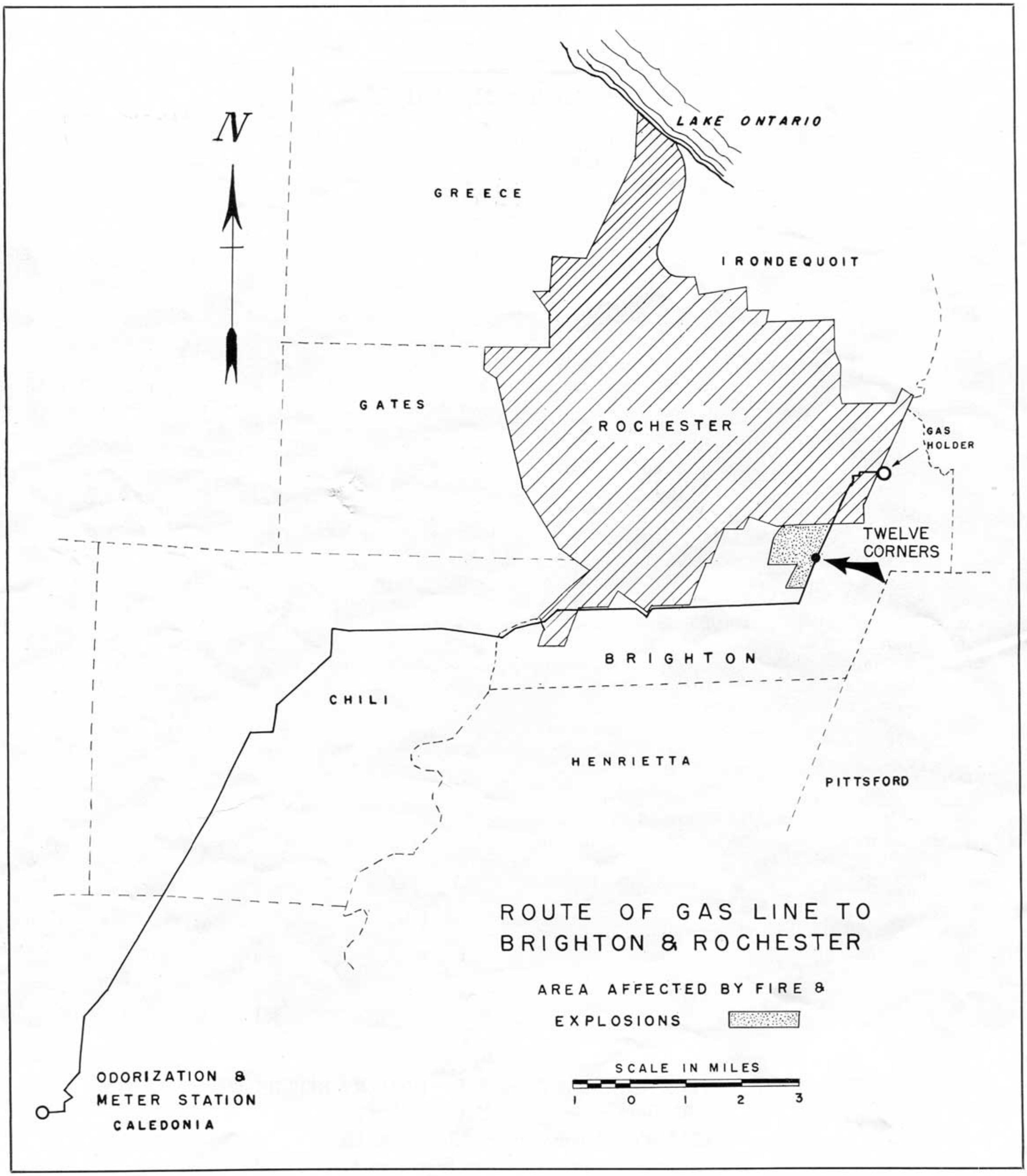


Fig. 1. Rochester-Brighton District.

FOREWORD

It is the fundamental premise of all forms of safety that every accident can be prevented. When the actual cause is discovered, mechanical safeguards can be designed and safer procedures can be developed to prevent recurrence of any mishap.

The publication and dissemination of technical reports dealing with contributory causes and events leading to fire and explosion accidents is therefore to be recognized as an important contribution in the promotion and maintenance of safety. Unless concerted effort is made to record them, significant facts of deficiencies and inadequacies in disastrous occurrences can often be forgotten and lost. Potential "danger points", thus ignored or underestimated, disappear unobserved or go unheeded, only to continue their treacherous existence as "hidden hazards".

The insurance and industrial interests have a common obligation to the public which they serve in providing the necessary guide posts leading to improved and greater security in our modern-day risks. These two important segments of our economy must share the cooperative responsibility of formulating precautionary rules and safe practice recommendations acceptable to public safety authorities.

This survey report on the Brighton catastrophe is presented with the foregoing view, and not with the purpose of affixing responsibility on any organization or individual. This unfortunate fire and explosion accident was unprecedented in the annals of fuel gas distribution and municipal servicing. The damaging of pressure regulators by explosion and collapse of an underground vault housing it, coupled with lack of over-pressure relief devices and "dead end" termination of street lateral mains, provided a unique set of circumstances. Although serious damage was sustained, the full portent of this disaster, because of its daytime occurrence, is not readily appreciated—a similar happening at a later hour or at night would have easily resulted in an appalling loss of life. The property damage would have been of more extensive proportions if this had occurred in a congested community.

The incredibility of hidden factors in such instances is indicated by a somewhat similar accident of gas regulator failure only two months later in Louisville, Ky. In this case a stone was found to have lodged in the seat of the regulator valve which prevented proper operation. About fifty fires broke out as a result of overpressuring of gas burning appliances. Because of the multiplicity of alarms received, considerable fire apparatus was dispatched to the district, bringing about prompt control of the situation—only three of the fires developed to serious proportions. Excessive pressure existed for a period of some twenty minutes, as the fire companies hurriedly cruised the streets putting out fires as quickly as they appeared. By good fortune, no explosions occurred. Records show that six relief valves operated during this period of the emergency, indicating that these devices are not entirely adequate. Investigation of the gas pipe line led to the discovery of several additional stones, some two inches in diameter, believed to have found their way into the system during construction many years ago.

Both of these experiences stress the need for constant review of danger potentials and a more concentrated safety approach in the preliminary stages of engineering construction and installation of gas distribution systems. It must be realized that unless safety considerations are included in the layout on the drawing board, such items later become a matter of increasing difficulty, if not prohibitive in cost. This should be a particularly timely consideration in the present program of long-distance natural gas transmission and conversion of services from manufactured gas.

Because of the ever-present explosion potential associated with uncontrolled combustible gases, it must be remembered that explosions, unlike fires, cannot be fought—they must be prevented. More actual damage can be done by an explosion in a matter of seconds than can be caused by a fire of many hours duration in the same area. The detailed accounts of the fire and explosion experiences covered in this report indicate that in such emergencies some useful time interval is generally present between the early inceptions of an emergency and that stage when it is considered "out of control". During this critical interval all emergency facilities present on the scene should be effectively directed toward prompt control of the threatening hazard. Firemen are generally first on the scene of emergency and fully appreciate, that with proper advance information, the period of danger can be shortened and damage lessened. This report points to the importance and need for fully familiarizing the fire services with proper procedures in gas emergencies and for coordinating their activities with the gas company field crews.

The gas utilities rank among the largest of our industrial groups. Their importance to our economic makeup must not be overlooked. The industry services nearly 30,000,000 residential gas customers with nearly 4¼ trillion cubic feet of natural gas and about 0.5 trillion cubic feet of manufactured and mixed gases annually. The relatively small number of accidents in handling this large quantity of gas through the numerous outlets indicated, certainly speaks for the technical proficiency of the industry. Most of the adverse experiences are traceable to unsafe practices and ordinary acts of human failure.

It is gratifying to state that beyond the understandable excitement, no panic was in evidence in this community of Brighton during the three-hour period of dire emergency. The orderly evacuation of a nearby school and the prompt action of heroic citizens averted what could have resulted in a holocaust. The value of the mutual aid plan arranged with nearby communities was also established in this severe test.

Acknowledgment is made of the valuable cooperation received in the course of this investigation from the following officials of the Town of Brighton: Harold S. Coyle, Town Attorney; Leonard A. Boniface, Town Supervisor; John H. Shirley, Building Inspector; C. Raymond Kerrigan, Chairman of Brighton Fire Commission; Fire Chief Alvin DeHollander and Police Chief Vincent P. Conklin, Elliot P. Ford, Acting Administrator of Civil Defense for Brighton and Harry W. Bareham, Assistant Director of Civil Defense, Office of Civil Defense and Civil Defense Advisory Council, City of Rochester. Appreciation is also expressed to B. H. Platt, Chief of Albany District, G. W. Jones, Chief, Gaseous Explosions Branch, and H. P. Greenwald, Regional Director, of the United States Bureau of Mines for their interest and technical guidance. The courtesies of the New York State Public Service Commission are also duly acknowledged.

Data for this report were developed by Arthur Spiegelman, Senior Research Engineer, and Laurence M. Ford, Research Engineer, Research Division, National Board of Fire Underwriters. Particular appreciation for their collaborative effort is expressed to M. W. Woodworth, District Secretary, Rochester office, and K. O. Smith, Director, Special Risk Department, New York office, New York Fire Insurance Rating Organization; Howard M. Travis, Special Agent, Rochester District Incendiarism and Arson Department, National Board of Fire Underwriters, and to F. W. Westervelt, Jr., Director of Public Relations, General Adjustment Bureau, New York, N. Y. Photographs for this report have been provided through the courtesy of the Democrat & Chronicle and Rochester Times-Union. Other valuable technical data were obtained from The Rochester Gas and Electric Company.

LEWIS A. VINCENT, General Manager

National Board of Fire Underwriters

JOHN A. NEALE, Chief Engineer MATHEW M. BRAIDECH, Research Director

Committee on Fire Prevention and Engineering Standards

HOMER D. RICE, General Manager

The New York Fire Insurance Rating Organization

SUMMARY

Fires and explosions which resulted in the death of three people, injuries to some thirty others, the destruction of nineteen homes and serious damage to twenty-five additional buildings occurred in Brighton, N. Y., on the afternoon of September 21, 1951. The initial explosion, apparently resulting from an accumulation of gas, took place in a regulator vault of the gas distribution system. The regulators, damaged by the force of the explosion, opened wide and allowed high pressure gas to pass into a system designed to operate at a low pressure only.

This overloading of the system resulted in numerous gas leaks within buildings and malfunctioning of gas appliances; within a few minutes a series of explosions and fires took place in the affected area. Most of the destruction occurred during the first hour and a half.

The sound of explosions, the abnormal action of gas appliances, and the odor of leaking gas warned many persons to leave their homes. Prompt response by the gas company and by fire and police departments, both local and from neighboring communities, helped minimize the loss of life and property. Civil defense and other groups also contributed their services during the emergency, which was brought under control after about three hours.

Although the exact cause of the initial explosion within the regulator vault has not been fully determined, a number of suggestions have been made to prevent a recurrence of the accident. These include the need for ventilation of gas vaults, the placement of shut-off valves in accessible locations, the separation of pressure regulators when connected in series, the possible use of pressure relief valves on distribution systems, and periodic inspection of gas shut-off valves at individual services. The problems which occur during the conversion of the distribution system from manufactured gas to natural gas are also drawn to attention. A planning program for coordinating emergency action of the fire service and the gas utility field crews is also recommended for consideration.

INTRODUCTION

The Town of Brighton is a residential suburb in Monroe County, New York, adjoining the southeast part of the City of Rochester. It has a population of about 18,000 people and occupies approximately 9,000 acres. It is a typically modern community of well-built and adequately spaced residences, with practically no industry.

At about 1:20 P.M. on Friday, September 21, 1951, a 25-block section of this peaceful community was suddenly subjected to a series of disastrous fires and explosions. In simplest terms, this was the result of uncontrolled fuel gas accidentally released into a distribution system at a pressure far in excess of that which could be safely accommodated by the service accessories and domestic appliances. This escaping gas entered hundreds of homes in the affected area, completely destroying 19 by internal explosions and fires, badly damaging some 25 others and causing minor damage to many other dwellings. Two children were killed as one of the homes was blown to pieces and one elderly woman died as the result of a heart attack while hurriedly leaving her place of residence. About 30 persons reported various injuries.

The damage claims numbered nearly 400 and the total loss was estimated at nearly $1,000,000 of which $595,000 was insured damage.

An explosion and fire in the gas regulator vaults, located at the so-called "Twelve Corners" of the business district, formed by the crossing of the three main thoroughfares—Winton, Monroe, and Elmwood Avenues, which by itself would have been of minor consequence, were responsible for setting into motion this chain of events. The regulators or "governors" which were located in an underground vault were the only safety devices in this system to prevent the high pressure gas from entering the homes. The simultaneous failure of both the medium and low pressure regulators was a highly unusual circumstance which was primarily responsible for this catastrophe. Either of these regulators could have contained the excessive gas pressure from the high pressure feeder main.

The life loss was kept to a minimum by the occurrence of this disaster during an afternoon period when most of the children were at school and a great many people were away from home shopping or working. If this had occurred during the night when the occupants of the homes were asleep, the life loss would have been very great.

The cause of the explosion in the vault has been exhaustively investigated by variously interested authorities. The means for preventing such widespread destruction of homes have been subjected to careful analysis and several safeguarding steps have already been taken in the Brighton area which should prevent this from ever happening again. The gas utility promptly reconstructed and rearranged the two sets of regulators for improved safety, installed an emergency "blow-off" to automatically relieve the low pressure piping system of any abnormal pressure, and also provided individual service regulators at the premises of each consumer in the low-pressure area, similar to those already in use in the medium-pressure district.

GAS SUPPLY AND DISTRIBUTION IN BRIGHTON AREA

The Rochester Gas and Electric Corporation supplies gas to about 135,000 consumers throughout its system. The principal service area comprises the City of Rochester, whose 97,000 gas consumers are served with mixed gas produced from a mixture of manufactured gas and natural gas. The remaining consumers residing in the towns adjacent to the city, including the Town of Brighton, are serviced with straight natural gas. The mixed gas is transmitted at medium pressures from 3 to 12 psi (pounds per square inch) to 95 regulator stations maintained in various parts of the territory, which reduce the pressures to one-fifth psi before distribution through service laterals to the premises of customers. (As a result of the post-disaster survey, emergency relief vents were installed in 7 of these stations.)

By way of identification and comparison, the manufactured gas is composed of approximately 10-30% carbon monoxide (CO), 30-50% hydrogen (H_2), depending whether the source is coke ovens, or producer-gas or water-gas generators, and on their relative proportions in which the gases are mixed. Coal gas consists of about 25% methane (CH_4), in addition to the other components. Natural gas, on the other hand, is composed primarily of methane, along with some ethane (C_2H_6) and some minor higher hydrocarbon constituents related chemically to gasoline. Both types of gases are relatively light and have a similar escape tendency when released into air —natural gas has less than two-thirds the weight of air under the same conditions of temperature and pressure, manufactured gas, depending on its composition, may range from one-half to better than two-thirds the weight of air. Natural gas, when mixed with air, has an explosive range of approximate 5 to 15 per cent by volume, as compared to that of manufactured gas which may be as broad as 5 to 35 per cent. Natural gas has a heating value of about 1,000 BTU per cu. ft. whereas manufactured gas has around 500 BTU. The ignition temperatures are in the order of 1,000°F. Manufactured gas possesses a distinctive and readily recognizable odor, while most natural gases have only a faint or barely discernible odor characteristic, and for this reason require the addition of fouling chemical agents or odorants. Recognized safety practices call for the addition of approved odorants to indicate positively the presence of gas at a concentration in air of one-fifth the lower explosion limit.

The Rochester Gas & Electric Company purchases its supply of natural gas from the New York State Natural Gas Corporation. Delivery is made from a high-pressure transmission line at a metering station located 15 miles southwest of the city at the Monroe County line in the vicinity of Caledonia, where it is odorized as a "leak warning" safeguard by addition of mercaptans. This gas is carried at an approximate pressure of 100 psi northerly through a 14-inch line to a point near the southern boundary of the city. At this location, some of the gas is taken off into a 12-inch line through a regulator which reduces the pressure to about 30 psi (which is also designated as "high pressure"). The line runs east some nine miles along the south side of Rochester, then swings north into Brighton three miles to a gas holder (No. 10) on the eastern edge of Rochester.

At the intersection of the two busy highways, Winton and Monroe Avenues, gas is taken from the 30-pound line to supply the town through a regulator station (Station No. 57). This underground station was originally constructed in 1928 and enlarged to a three-sectioned vault with the necessary additional regulators in 1950, when this particular district was converted to straight natural gas.

Pressure Control and Regulator Arrangement
(See Fig. 2.)

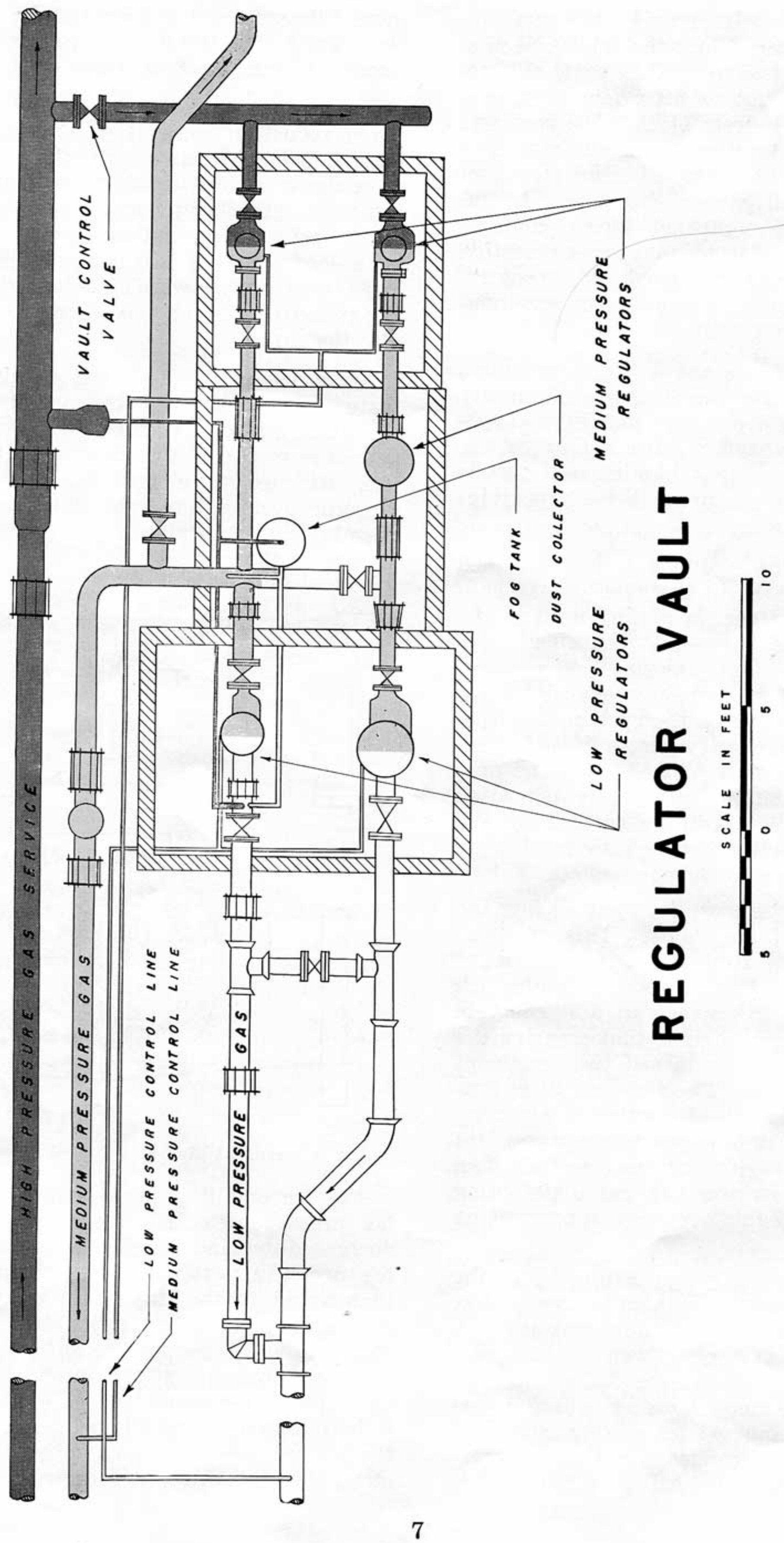
Two separate distribution service systems were utilized in the Brighton District, one operating at a medium pressure of 15 to 5 psi and the other at a low-pressure service of six inches of water column or about one-fifth psi.

The medium pressure distribution system served approximately 2,800 buildings, each of which had an individual regulator to reduce the line pressure to a level suitable for use in the domestic gas appliances. In addition, each installation was protected with a mercury-seal relief valve which would vent the system to the outside in case of excessive pressure within the line.

The low pressure distribution system served approximately 1,500 dwellings in the area. Individual pressure regulators were not provided for these buildings because gas in the system was normally at a low pressure. The street distribution laterals of this portion of the system terminated at "dead end" with no cross-connection between them.

At the time of the accident the piping and attendant equipment located in the regulator vault were arranged as follows. Two medium-pressure and two low-pressure regulators were set in pairs in a parallel position. Gas at 30 psi pressure was taken from the feeder main by an eight-inch pipe having a shut-off valve in a buried pit. This eight-inch pipe served as a short header from which two parallel six-inch lines ran into the first of three sections of the vault located under the sidewalk and adjacent to the street curbing. Either of the two lines could be used to supply the distribution system; customarily, one was used while the other was maintained as an alternate when maintenance work was in progress on the first.

The first section, approximately eight feet square and nearly seven feet high, housing the medium-pressure regulators, was constructed of eight-inch concrete blocks. To withstand possible loads and impact from passing trucks, the roof was purposely built of extra-heavy construction with 70 pound railroad rails placed flange to flange, covered with concrete to the street surface level. This section of the top was fitted with two large manholes having covers weighing 300 pounds each. These covers had no vents or other openings, except bar holes for lifting. The six-inch lines ran parallel to each other through this portion of the vault, each line connected to a pressure reducing regulator with necessary shut-off valves on each side of the unit. These first stage regulators reduced the gas pressure from 30 to a range of 15 to 5 psi, with the higher pressure setting for the peak loads of winter.



REGULATOR VAULT

FIG. 2.

The two six-inch lines carrying the medium-pressure gas next passed into the middle section of the three compartments. This part, slightly larger than the first but only six feet high, also was constructed of concrete block. The roof was identical to that of the first vault, but contained only one manhole. A dust collector was connected in the regularly operating line. Downstream from this, an eight-inch lateral containing a shut-off valve formed a cross-connection with the other line and continued out through a side wall of the vault to supply the medium-pressure distribution system.

This section also contained a "fogging tank", a device used to inject a fine oil spray into either the medium or the low-pressure distribution system. This spray was used to settle and arrest the dust in the gas by causing it to stick to the walls of the gas mains and to prevent the pipe joint caulking from drying out.

This dust removing equipment was installed following a change-over in the type of gas supplied. Manufactured gas, originally used in the distribution systems, normally contained sufficient entrained oil and tarry matter from processing to prevent dust from being carried by the gas. Natural gas, to which the system had been converted, is a relatively dry gas; mill scale, corrosion products, and dust formed from the drying out of accumulations previously deposited with manufactured gas will be carried by the gas and, unless removed, can cause trouble by plugging pilot lights and burner orifices.

The two medium-pressure lines passed into the last compartment of the vault. This one was eight and one-half by twelve feet in area, about six feet in height, and constructed of eight-inch thick brick walls. The steel rail and concrete roof construction was similar to that covering the other two sections and contained two manholes with three-piece covers. The two gas lines connected into the second pair of regulators which reduced the gas pressure to approximately one-fifth psi. Gas leaving the regulators was then fed into a connection on the low-pressure gas distribution mains. All of the regulators were supported on wooden blocks.

A recording pressure gauge connected to the medium-pressure line was mounted in a gauge box on a pedestal five feet above ground and near the vault. A three-inch vent pipe from the low-pressure regulator compartment extended up through the pedestal into the meter housing, where it was vented to the atmosphere; no other vents were provided. Recording gauges for the low-pressure main were also provided at a fire house, some 400 feet south and west of the regulator station; another on the medium-pressure system was located at the remote gas holder station.

The pressure regulators employed in this two-stage reduction were of a conventional weight-loaded, balanced valve type. They are reported to be designed to withstand a pressure of 125 psi, although operating normally at pressures around 30-50 psi. The medium-pressure units were beam-loaded and of larger size, while the smaller low-pressure units were stem-loaded. The operating principle of each type, however, was essentially the same.

Flow of gas through the regulator was adjusted by a throttling valve controlled by vertical motion of a shaft. (See Fig. 3) This valve shaft passed upward through the regulator casing and was attached to a flexible, oiled leather diaphragm over a gas-tight chamber; from this chamber a control pipe was connected to the outlet side of the regulator.

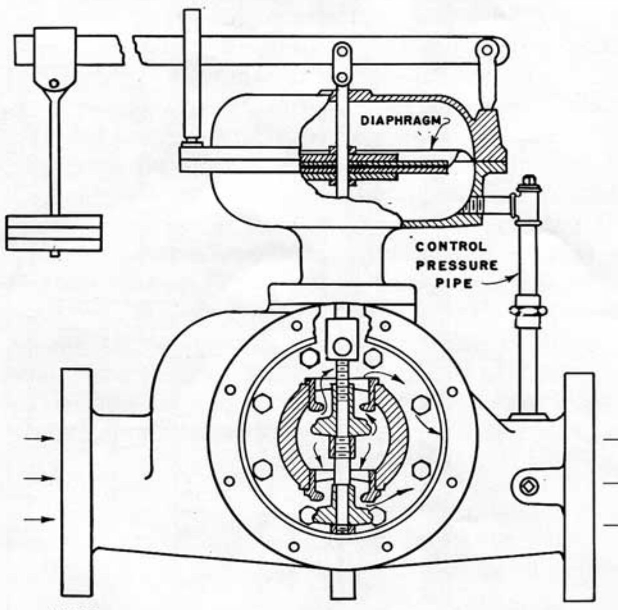


Fig. 3. Sectional View of a Typical Pressure Regulator.

Any increase in pressure within the line on the low pressure or outlet side, as would result from decreased demand for gas, would therefore raise the pressure within the gas chamber. This in turn would lift the diaphragm and the valve stem connected to it. This upward movement would close the valve, reduce the flow of gas, and thus lower the pressure at the outlet of the regulator. Conversely, increased use of gas from the distribution system would reduce the pressure in the control line and gas chamber, lower the valve stem, open the valve, and increase the flow of gas.

To provide means of regulating the gas pressure by counteracting the upward force of gas on the diaphragm, a counterbalancing downward force on the valve stem was provided by a system of weights. In the regulators used for low-pressure service, weights were stacked directly on top of the valve stem and protected by a metal housing. The medium-pressure regulators used an external lever and weight system to provide the adjustable downward thrust.

Removal of the weights from either type of regulator would close the throttling valve and restrict the discharge of gas. Rupture of the control pipe (which would remove all pressure from below the regulator diaphragm), a downward force on the lever arm of the high-pressure regulator, any damage to the low-pressure regulator casing which would force down the weights, or any increased downward pressure on the diaphragm would have the opposite effect and open the throttling valve wide.

REGULATIONS ON NATURAL GAS TRANSMISSION PIPE LINES AND DISTRIBUTION SYSTEMS

The standards and safe operating practices for the transmission and distribution of gas through pipe lines to consumers are described in two publications. The first, "Standard of The National Board of Fire Underwriters for the Installation of Gas Piping and Gas Appliances in Buildings" (NBFU Pamphlet No. 54, 1950), represents basic minimum standards governing the installation of gas piping and gas appliance in buildings. It covers the design, fabrication, installation, test and operation of systems for fuel gases such as natural gas, manufactured gas, liquefied petroleum gas-air, or mixtures thereof, but does not apply to undiluted liquefied petroleum gas. The second of these publications is the "Code For Pressure Piping" (ASA B. 31.1, 1951), which is published by the American Society of Mechanical Engineers. It was formulated under the general auspices of the American Standards Association and contains seven sections, three of which are applicable to gas piping systems. This particular code provides specifications for construction metals, fabrication including pipe thickness and assembly details as to fittings, caulking and jointing, and recommendations for pressure reducing and automatic pressure-relief safety devices and corrosion protection.

Prior to the disaster, the Town of Brighton and the Public Service Commission of the State of New York had no standards or regulations for the operation of this type of gas system. It was expected that the best operating practices of the industry were being adhered to and the enforcement of these standards was generally left up to the local utility involved. However, the Commission, like those in many other states, reserves the right to pass on the efficiency and safety of any system and to investigate all accidents which may occur in the transportation of gas. It is within its power to order such reasonable improvements as will best serve the public interest, health, and safety.

The Public Service Commission held a five-month inquiry and two public hearings on September 27th and November 19th, and issued a 25-page report on its findings on February 13, 1952. It subsequently directed its engineers to conduct a statewide survey into the safety of transmission and distribution systems of forty-four companies which supply natural, manufactured and mixed gas to New York's 3,700,000 services in homes, businesses and industries. A report of the U. S. Bureau of Mines, covering its independent investigations (which included results from 1,170 questionnaires on consumer complaints on pilot light and burner variation troubles), was issued on November 27th.

STORY OF THE EXPLOSIONS AND FIRES

On the day of the accident and prior thereto, construction work in connection with two projects was being performed in the "Twelve Corners" area. A corrosion protection program on the gas mains around the regulator station required an open excavation adjacent to the vault for a number of days. On September 19th, the first compartment of the vault was entered in connection with this corrosion project. When the workmen left the vault that afternoon, there was no reported evidence of any gas leakage. On completion of this work, the contractor's workmen

FIG. 4. Brighton firemen controlling fire with water spray around regulator vault after explosion. Note heat wave blur on building toward right of center background.

backfilled the excavation and began replacing the cement sidewalk over this area, a portion of which extended over the vault.

Use of the oil fogging equipment on the medium and low-pressure distribution systems had been discontinued and disconnected the year before, at the time the dust filter was installed. During the year the vaults were entered frequently, on an average of several times each month, to clean out the filter, to adjust the regulators, and to perform routine maintenance.

At 10:00 A.M. on the fateful Friday, September 21st, the chart of the recording pressure gauge was routinely changed; no odor of gas was noticed by the gas company employee making the change. At about 12:45 P.M. on this same day, a town sewer contractor conducted some rock blasting with dynamite within 350 feet of the regulator vault, but the charge was relatively small. This construction program had been in progress in the adjacent community for nearly ten months and around the "Twelve Corners" for about five months.

Shortly before 1:00 P.M. a sewer construction worker passing the vaults noticed an odor of gas, but thinking nothing of it, he reported it to no one. The new sidewalk had been laid that morning next to the vault; according to testimony, at about 1:15 P.M. one of the workmen set out kerosene warning lanterns to guard the fresh cement.

Within a few seconds an explosion rocked the vault. The roof and manhole covers of one section of the vault and portions of the others were blown into the air. The heavy debris of steel reinforcing rails fell back into the vault and ruptured all control pipes, and otherwise fouled or damaged the regulators. Fire ensued immediately at the broken connections.

Charts from the pressure recorders gave evidence of sharp pressure rise beyond the range of the instrument in both medium and low-pressure lines at approximately 1:20 P.M. and a corresponding drop in the high-pressure transmission main at the same time.

As a result of the damage to the equipment, the regulating valves were pushed down to the wide open position; gas from the 30-pound line flowed through the medium and low-pressure systems without appreciable reduction in pressure. The actual pressure transmitted to the distribution mains is not known; due to friction losses in the valves and piping, it was something less than that in the main feeder line. Because the area served by the regulators was relatively small, and as there was no cross-connection with other nearby low-pressure distribution systems which could have bled off some of the gas, the pressure rise was rapid.

The surge of pressure had no noticeable effect on homes receiving gas from the medium-pressure system. The individual pressure regulators on each building functioned as they were supposed to, reducing and maintaining the pressure to its normal value.

The effects of excessive pressure on the low-pressure system, on the contrary, were sudden and disastrous. In many cases, where burners or pilot lights were in operation, torch-like flames roared up to a height of two feet or more. Some stove burners lighted, though the gas was shut off. In other cases the surge of pressure extinguished the pilots and allowed unburned gas to escape. Flame came out of automatic water heaters and completely enveloped the tanks, and in some instances ignited the floor rafters. Furnaces, which were shut down because of the mild weather, flared into life. In one case, fire first destroyed the heater, then ignited the basement ceiling above it.

The most serious effects, however, resulted from failure of numerous gas meters. These meters were of the usual tin box type, having light sheet steel cases and soldered joints. They could stand at most only a few pounds pressure. Under the abnormal stress to which the distribution system was subjected, more than twelve per cent of the meter cases in the affected area failed. Fortunately, the majority of leaks were relatively small, but a number resulted in the formation of explosive mixtures within the buildings.

A few minutes after the failure of the regulators, the first home exploded, killing two children and severely burning a woman who was in it. At short intervals thereafter other houses

FIG. 5. View of low-pressure regulator chamber after flooding and extinction of flame, showing steel rail reinforcement of damaged roof. Note wire netting and sidewalk construction forms in foreground.

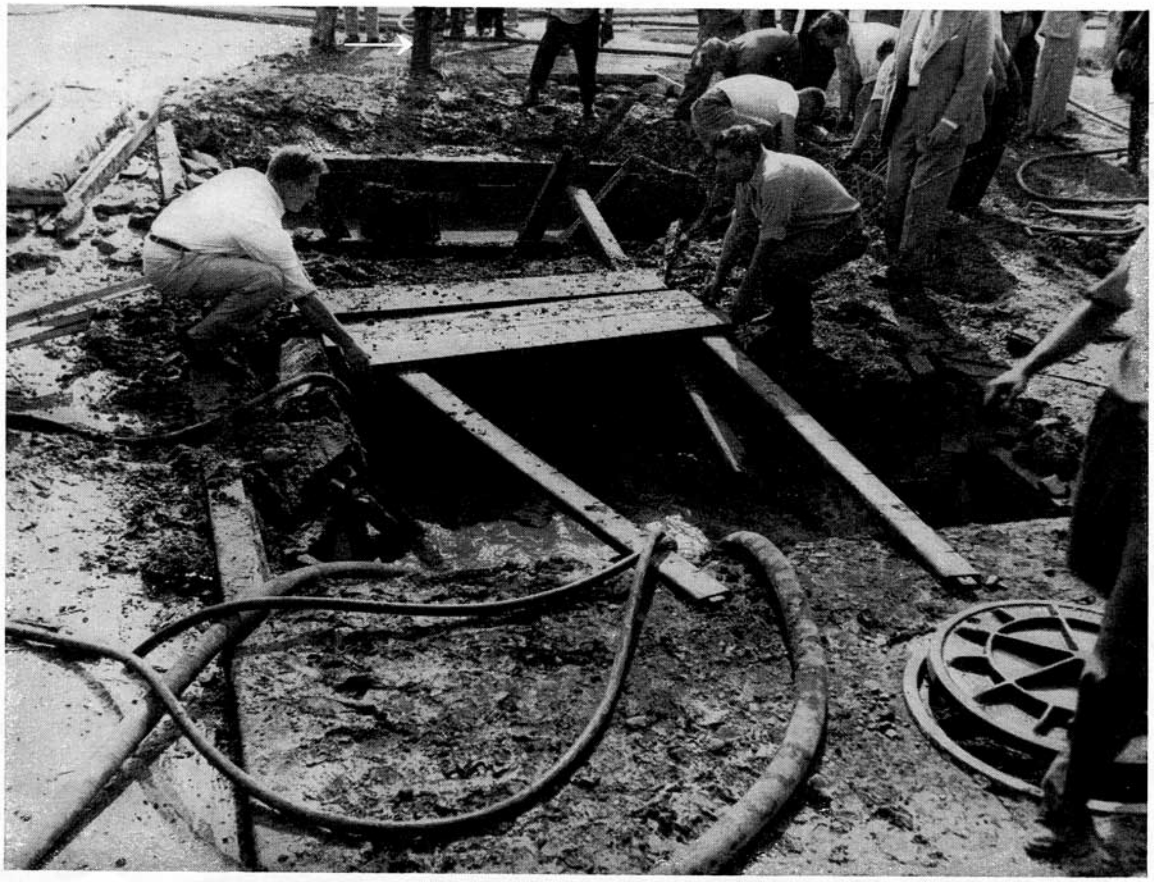


FIG. 6. Use of hose lines to flood gas-main drip connections to control gas flow and permit repair work. Note manhole cover over medium-pressure regulator chamber and gauge box pedestal (vent) left of center background (note arrow), beyond low-pressure chamber.

FIG. 7. Interior of regulator vault. Low-pressure regulators in foreground; fogging tank and cross-connection to medium-pressure system in adjacent vault.

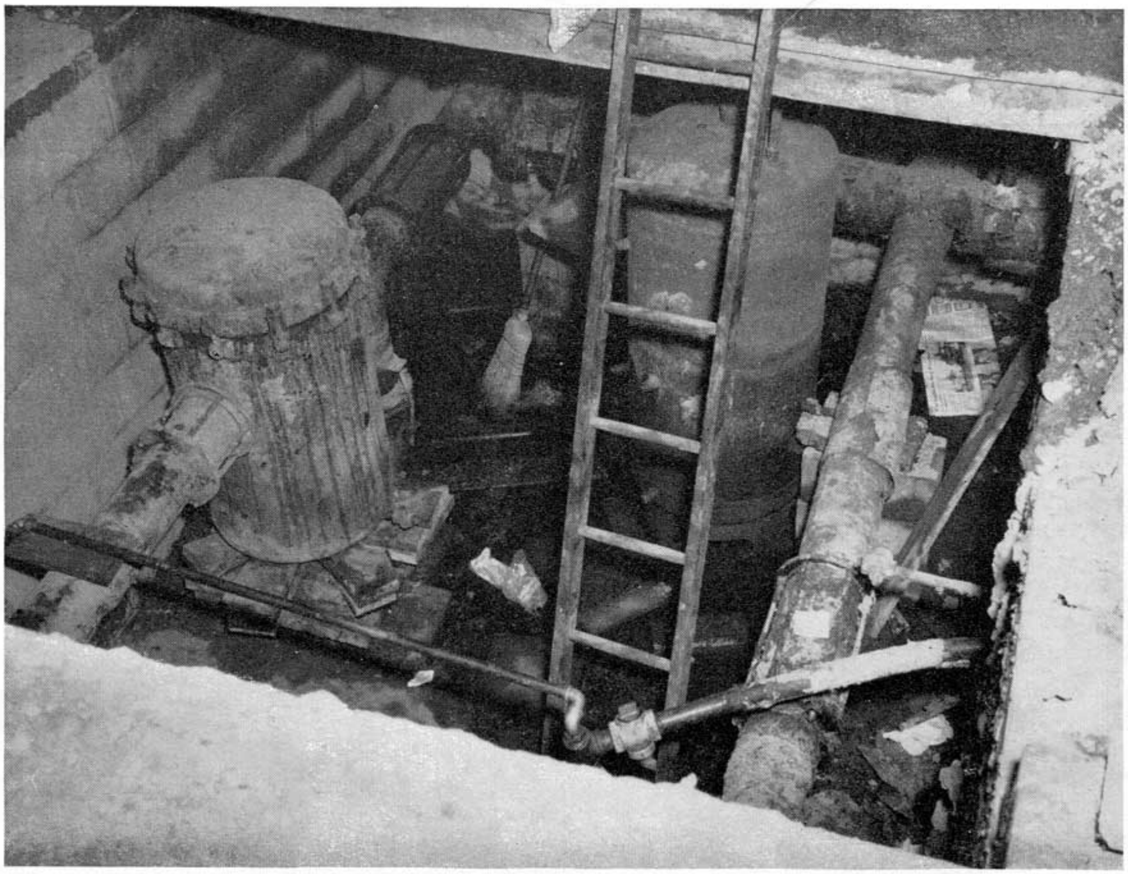


Fig. 8. Central chamber of regulator vault, looking toward low-pressure chamber, showing filter unit on left and fogging tank on right.

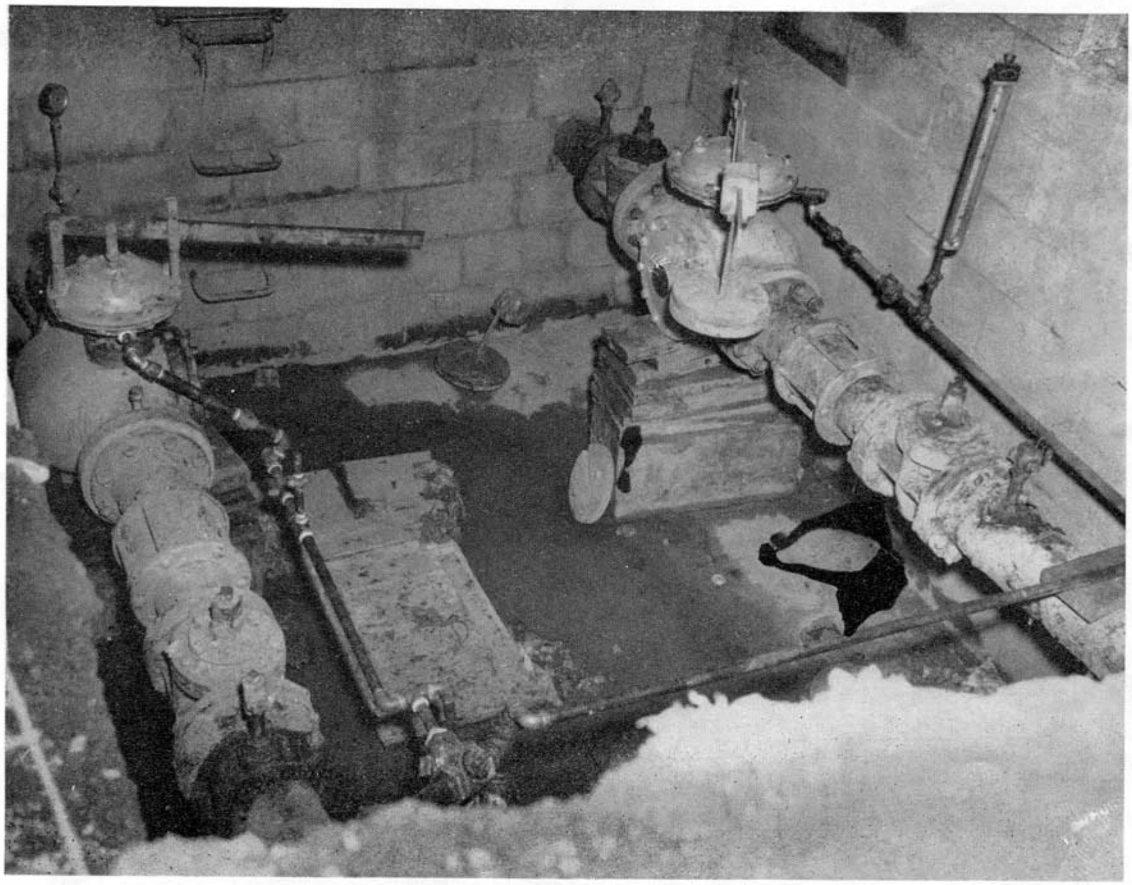


Fig. 9. Interior of medium-pressure regulator chamber; note weighted beams and reconstructed diaphragm pressure control piping.

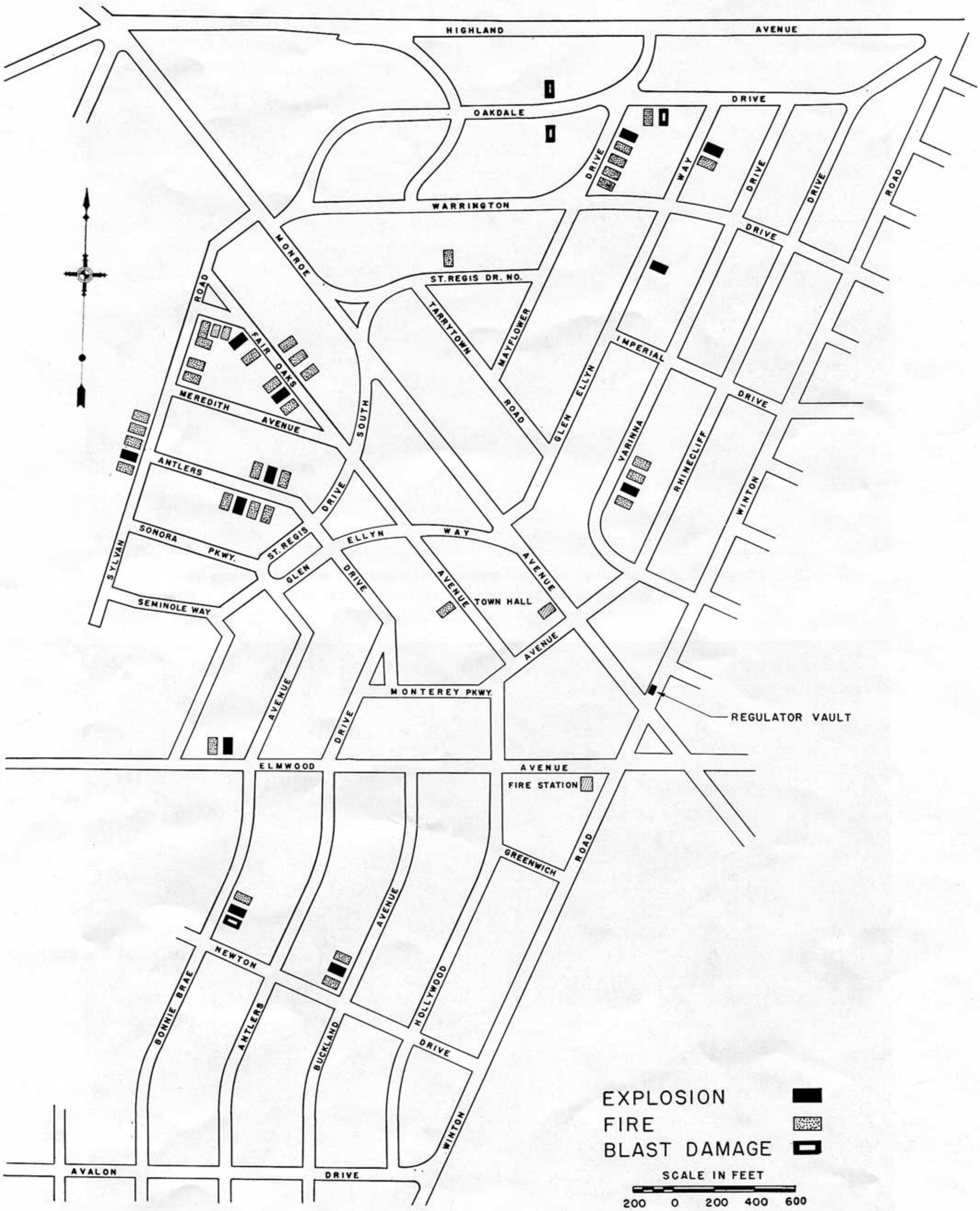


Fig. 10. Damage Map of Low-pressure District in Brighton.

throughout the area were shattered by explosions which in most cases completely demolished the buildings.

Alarmed by the unusual actions of the gas appliances, through the rumbling and hissing sounds and strong smell of leaking gas, by the noise of the explosions, and by warnings spread by the police and fire departments, most of the residents left their homes and did not return until hours after the danger was over. For this reason no additional fatalities or severe injuries were suffered as a direct result of the explosions, although one woman died of a heart attack brought on during the excitement of the events. Newspapers and radio stations carried frequent announcements detailing the emergency measures and advising victims what steps were being taken to alleviate the situation.

As the gas leaked into the dwellings, some of the apprehensive householders hurriedly shut off their gas supply at the meters. Volunteers and members of the various emergency services which responded also went from house to house to make certain that the gas was shut off; one fireman alone turned off inside gas cocks in more than forty houses. Doors and windows were opened to provide ventilation; and, in many cases where gas concentrations were believed to be so high as to make entry unsafe, glass was knocked out of the window frames. Opened windows, due to warm weather, probably minimized much of the destruction.

Fire broke out in the splintered debris of many of the demolished buildings and, extending to adjacent dwellings, caused much additional damage. As might be expected these exposure fires involved the sides of the neighboring buildings, catching under projecting eaves, or, passing through shattered windows, spread to the roofs and upper stories. Still other fires resulted from the abnormal operation of gas appliances.

The 2,300 students at Brighton's elementary and high schools were ordered to the athletic field behind the school buildings. They were kept under supervision of school officials until the area was declared safe by the emergency authorities.

No records are available as to the order in which buildings exploded or fires started, but they occurred in rapid sequence. Within an hour and a half, nineteen houses were totally destroyed, fourteen more were seriously damaged, some to such an extent that rebuilding is impractical, and at least eleven more were damaged to a lesser extent.

Operations of the Gas Company Emergency Units

At approximately 1:25 P.M. the gas company received notice over a direct wire from the police department that the manhole at Monroe Avenue and Winton Road was on fire. Another report told of increased pressure within homes served by the low-pressure system. The company shortwave communication system was used to alert and direct all personnel.

Gas company crews were immediately dispatched to the scene by radio and attempted to shut off the gas supply. The force of the explosion in the vaults had been sufficient to displace the valve box on the eight-inch inlet valve to the regulators, making it impossible to close the valve with the shut-off key. The gas company crews at once started to dig up the valve; firemen arriving earlier provided water spray protection with a fire hose.

At the same time, with the aid of firemen, hose lines were connected to drip connections on the gas mains and flooded them with water in an attempt to seal off the flow of gas. They also closed a twelve-inch valve on the main line in an effort to reduce the pressure at the regulators, but it is possible that feed-back of gas from the rest of the system helped sustain the pressure. The shut-off valve at the vault was closed at approximately 2:09 P.M. This shut off the gas supply in the entire low and medium-pressure systems.

Other crews of the gas company checked each house in the low-pressure area as promptly as possible, closing all stop-cocks which had not already been shut by the householders or volunteer workers. All houses in the low-pressure area were then given a systematic recheck which was completed by about 7:00 P.M. Electric power, which had been turned off as a precautionary measure at approximately 2:30 P.M., was switched back on in the low-pressure area about 7:15 P.M.

The adjacent medium-pressure area was also inspected by gas company employees; many services were discovered shut off at the stop-cock. Here the gas was turned back on, the appliances lighted, and the installations tested. Electric service was restored about midnight.

Lines leading to the destroyed or badly damaged houses were cut off in the street; this was accomplished by about 5:00 A.M. the morning following the explosion. The gas company promptly posted one-page notices and instructions in the local newspapers, advising the citizens of the stricken area of safeguards and progress in restoration of services; and warning con-

Fig. 11. Antlers Drive—Houses destroyed by explosions and damaged by exposure fires.

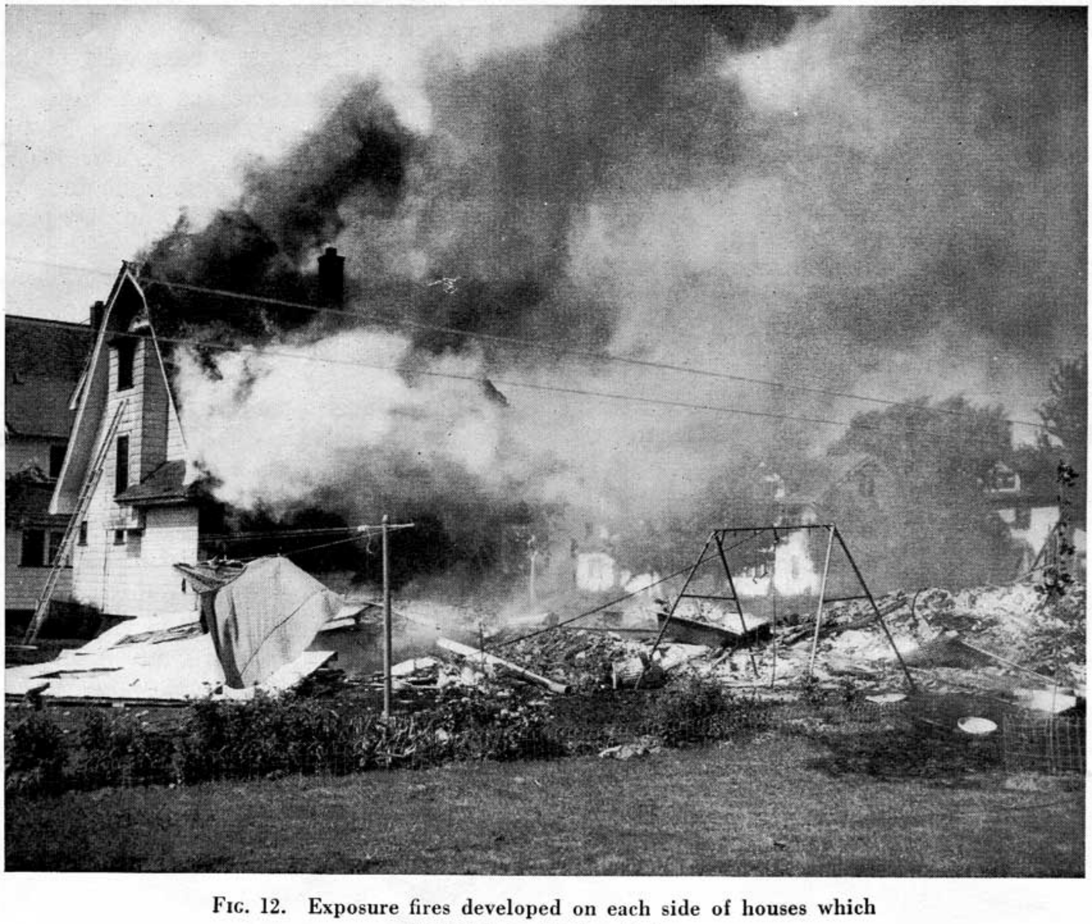


Fig. 12. Exposure fires developed on each side of houses which exploded on Antlers Drive.

Fig. 13. Typical situations which faced volunteer firemen; fire outbreak in left dwelling brought under control, effort being made to prevent spread of fire from debris of a nearby blasted house.

Fig. 14. Blast and fire destruction on Varinna Drive.

FIG. 15. Complete destruction of houses hindered both the search for possible explosion victims and the fire fighting. (Bonnie Brae Drive)

sumers in particular not to turn the gas service cock back on without company aid, once it was turned off.

On the following day, Saturday, September 22nd, approximately 1,200 of the meters in the affected area were replaced by new ones; the following day the remainder were changed. During this period, the low-pressure distribution system was divided into five small sections. Restoration of service, section by section, was then commenced on September 23rd. Three parts were completed that day and the remainder on the following day.

As gas was admitted to each section, the mains were thoroughly purged until 100 per cent natural gas was obtained. Pressure was kept at a low level until all manholes were checked for leakage. Gradually the pressure was raised to the operating level and rechecks made of all manholes. Gas repairmen continually patrolled the streets during the restoration operations.

When the tests indicated no leakage from the section, the turn-on of meters within the area was started. As each house was visited, the meter was turned on, appliances lighted, and a check made for leaks. Once work was completed in one section, purging of the next section was started. This work was finished at approximately 8:30 P.M. on Monday, September 24th.

As an added safety precaution, a leak survey was made of all gas services and mains within 500 feet of any house where an explosion or other damage had taken place. At intervals of 15 feet along the piping, small holes were drilled into the ground to a depth of three to three and one-half feet. With the aid of a combustible gas indicator leakage was sought at the bore holes.

During the period from September 23rd to 28th, when the survey was made, one small leak in a main was located. A similar investigation was made two weeks later, but no leaks were revealed by this second survey.

To prevent a recurrence of the accident a number of steps were immediately taken by the gas company. The two sets of regulators were placed in two new vaults separated from each other by

160 feet, while the fogging equipment was placed in a third vault between the two. Shut-off valves were installed at sufficient distance from the vaults to be still accessible in case of fire or explosion within a vault.

Improved ventilation was provided for each of the vaults by installation of dual vent pipes, one to exhaust any gas from the vault and the other to supply fresh air. Vent lines were also run from the top of the regulator diaphragm cases.

Individual regulators with built-in, mercury-seal pressure relieving devices were also installed in all homes on the low-pressure distribution system in response to official requests. Although this is not the customary practice for low-pressure systems, the company, contemplating a rise in pressure in the near future, acceded to this procedure. In order to keep the house regulators operating satisfactorily, pressure on the system was then raised to about two pounds per square inch.

Additional safety was provided by placing a large dead-weight type relief valve in the distribution system, approximately 150 feet downstream from the main regulators. This blow-off valve is designed to prevent excessive pressure build-up in the system.

Operations of the Fire Departments

The Brighton Fire Department, which is part paid and part volunteer, maintains three fire houses. One fire house is located at "Twelve Corners" within sight of the regulator vault. When the first explosion occurred the firemen on duty transmitted an alarm from the nearest box then responded to the fire, along with a second Brighton company. This was the normal box alarm response. Using spray nozzles they attempted to control the fire in the vault and protect the adjacent exposures.

Following the first explosion in a dwelling, the third Brighton company responded to the resulting fires, remaining at the scene until 7:30 P.M. Meanwhile, outside aid was being sought under the Monroe County Mutual Aid Plan. At 1:36 P.M. the first company from the City of Rochester was called; within an hour and a half twenty-one

FIG. 16. Remains of foundation of a destroyed home. Note water heater in corner, damaged meter and service shut-off cock on the right (note arrow).

Fig. 17. Damage to this two-family dwelling at the corner of Sylvan Road and Fair Oaks Avenue was limited by a dividing wall extending only to the attic.

Fig. 18. Exposure fires were frequently severe as this photo taken at Fair Oaks Avenue shows.

Fig. 19. Effects of explosion and fire at Oakdale and Mayflower Drives.

Fig. 20. Another example of fire exposure damage on Mayflower Drive.

engine companies and a ladder company had responded from that city and fifteen other companies had been sent from other towns in the county. Five additional companies were sent into Rochester to fill in at vacated fire stations.

A temporary headquarters for the fire services was set up at the "Twelve Corners" fire station and as the fire companies arrived from out of town, they were assigned to a pool maintained at the headquarters. When reports of subsequent fires or explosion were received, equipment was dispatched from this central pool. In some cases apparatus was sent out as explosions were heard, rather than waiting for alarms to be received through more normal channels.

By four o'clock the worst was over; the explosions had stopped sometime before, and the fires were under control. Prior to 8:00 P.M., with the exception of several emergency trucks having lighting equipment, all county fire trucks were sent back to their respective towns. Most Rochester companies were also released, but three were kept in the pool as a precautionary measure until Tuesday afternoon, September 25th.

For various reasons, during the evening of September 21st, fire companies responded eight additional times to the scenes of the fires and explosions. Some rekindles were to be expected due to the extensive nature of the fires and the haste with which they were extinguished and left, as companies responded to subsequent fires.

Although no additional fires and explosions occurred on the following days, the fire department did not return to its normal operational status until late on September 25th, because of uncertainties as to what might happen while utilities were being re-established and the area cleaned up.

Operations of the Police Department

Shortly after the explosion at "Twelve Corners", the Brighton Police Department responded to the alarm and, realizing the seriousness of the problem, then sent out a call for additional help. Within a short time more than one hundred trained police officers from state, county, and municipal departments were on the scene. In addition, a unit of the Air Force Police and of the National Guard provided nearly one hundred more men. Seventy-five auxiliary police as well as twenty-five members of the regular force were sent from Rochester; some additional manpower was supplied by uniformed guards from nearby industrial plants and private watchmen services. A total of nearly three hundred law enforcement officers was finally mobilized.

First arriving police were sent to warn the residents and to shut off gas and electricity and vacate their homes. A police car equipped with a mobile public address system toured the area warning the people to shut off the gas supply, to open doors and windows and to leave their homes; in at least one case, a house exploded within minutes after the occupants, heeding these warnings, left the building.

The traffic problem was particularly severe; as news of the accident spread, hundreds of curious persons rushed to the scene, clogged the nearby roads and in general impeded the response of emergency equipment from outlying areas. As more help became available, barricades were established at all entrances to the affected area. Non-essential traffic was stopped and written passes from the Police Department were required for anyone who needed to enter the area. These barricades were maintained for three days and nights until more normal conditions had been restored. The police also formed patrol units to prevent possible looting of property.

An emergency truck equipped with an electric generator was provided by the state police. This supplied power for the police radio and to the police and civil defense headquarters in the Brighton Town Hall, the regular power having been shut off throughout the area as an emergency precaution.

Communications at the disaster scene were provided largely by the use of two-way radio. Radio equipped motorcycles proved particularly useful to the police forces because of their mobility under difficult traffic conditions. In addition to the normal communications operated by the police departments, a mobile transmitter and several radio equipped cars were supplied by a communications unit of the U. S. Civil Air Patrol. Similar equipment was furnished by the Rochester Civil Defense Organization.

Operations of Other Agencies

As the need for additional help became apparent, the Brighton Civil Defense forces were activated about an hour after the disaster struck. Although civil defense workers could not be alerted officially under existing laws, the Assistant Director of Civil Defense for Rochester requested, by means of commercial radio, that auxiliary fire and policemen report to the temporary headquarters at Brighton. Civil defense workers from surrounding towns also volunteered their services.

Altogether nearly six hundred volunteer workers, mostly auxiliary policemen, air raid wardens, and members of veterans organizations responded. The majority were assigned to police duties directing traffic, manning the barricades, or patrolling the stricken area with members of the uniformed forces. The available manpower was divided into 4 or 8-hour shifts in order to give adequate protection and at the same time provide relief for the workers.

Civil defense workers in conjunction with the Red Cross established and maintained continuous canteens at both the fire and civil defense headquarters. Civil defense communication units also supplied two-way radio facilities, while Boy Scouts furnished messenger service. Food and shelter were provided for many of the families in the involved area who were not able to reoccupy their homes due to damage or the possibility of further trouble. Local hotels opened their doors to the residents of the section in an effort to provide immediate assistance.

CONCLUSIONS AND RECOMMENDATIONS

The aim of this report is to present a factual compilation of causes and events leading up to the series of fires and explosions which resulted in an unprecedented catastrophe. The data contained herein should provide significant lessons and serve to point out necessary precautionary rules, regulations and recommendations that, if heeded, will lessen the chance of recurrence of such mishaps.

Investigations conducted to date have fairly well established that this unfortunate accident was the result of an unusual combination of circumstances: the formation of an explosive gas-air mixture within the regulator vault, the untimely presence of a source of ignition, the resultant explosion within the vault chamber which led to its structural collapse, the damage and subsequent failure of the pressure regulators, the lack of overpressure emergency relief in the low-pressure system, the inability to quickly shut off the flow of gas and the failure of the service accessories and appliances to withstand the increased pressures. It is significant to note that the equipment employed to control gas pressures is so designed that it will generally "fail" in the open position—contrary in principle to most safeguarding devices.

Although it is agreed that the explosion of the accumulated gas initiated the entire sequence of fires and explosions in the homes of the stricken area, the cause of the explosion within the vault was not established with certainty. It was not possible to determine the exact point of gas leakage because much of the piping and equipment in the vault chambers was subject to shock and fracture, and, of necessity, was removed or replaced to restore the needed gas service. Although gasoline vapor, sewer gas, and high explosives were mentioned during the course of the investigation, no evidence showing the presence of these materials was produced. The possibility of loosening of pipe joints inside and outside of the vaults by traffic vibration or shock transmitted from the rock blasting associated with sewer construction has been considered. The escape of 75 to 225 cubic feet of gas into this 1,500 cu. ft. vault would have been sufficient to create a mixture within the flammable or explosive range.

Various possible causes of ignition were advanced as initiators of the vault explosion. These ranged from careless smoking, discarding of glowing matches and cigarettes, sparks or backfiring exhausts from passing motor vehicles to sparks due to stray earth currents from nearby electric power services or installations and static electricity. The most plausible reports of witnesses, however, point to the open flame of kerosene warning lanterns placed near the sidewalk construction, adjacent to the vault, as the likely source of ignition.

It appears evident from the 1,170 questionnaires submitted by the U. S. Bureau of Mines to the residents of the affected area that excessive gas pressure surged throughout the whole low-pressure district within a very short period of time. The chance release of gas into some homes and not into others was determined by the seam strength of the individual meters, incidental pressure relieving due to operation of sufficient burners on gas appliances, and prompt turning off, in some instances, of service cocks at the meters. Lack of ignition sources in many homes filled with escaping gas undoubtedly reduced the number of explosions. It is interesting to note in connection with the odorization program that 80% of the observers in this survey associated the presence of gas odors with leaking gas. Although 44 homes were destroyed or damaged, investigations showed that gas meters in at least 172 homes were ruptured in varying degree (twelve per cent of the meters in the area were found to leak under 2 psi air pressure), allowing the gas to form potentially explosive mixtures. The exact pressure which was reached in the system is a matter of conjecture. A recording gauge on the 30-pound supply line indicated that the pressure dropped to 20 psi within a few minutes of the explosion and then made a slower drop to about 15 psi where it remained for about 30 minutes. Even though this pressure may have been further reduced by frictional effects of the pipe line, it was excessively high for the meters and appliances connected into the low-pressure system. It can be readily appreciated that the losses could have been much worse if the gas was not shut off in many of the homes during this emergency.

Many people erroneously believed that the replacement of manufactured gas by the natural gas was the direct cause of this disaster. A comparative study of these two gases would indicate no material difference insofar as their escape tendencies are concerned, while the explosive range of natural gas is not as broad as that of manufactured gas. Given a similar set of circumstances, the manufactured gas could have produced equally disastrous effects.

One of the unique features believed to have contributed materially to the seriousness of the Brighton accident was the isolated arrangement of the lateral mains in the low-pressure distribution system described as a "dead-ended" branched-tree pattern. Normally, in distribution systems of large cities, all parts of the network of mains are interconnected to form looped grids. This presents an extensive array of piping with a very large volume, so that in event of any regulator failure, the pressure energy is relieved or dissipated with a relative slow buildup and without serious consequences.

Despite the fact that the regulation of underground distribution systems in cities, towns, and villages has been a subject of serious study for many years, varied practices with regard to their installation and operation continue to exist with the different gas utilities around the country.

The Brighton experience should serve to sharply focus interest on a number of technical features which appear worthy of fullest attention by public authorities, insurance and safety groups, as well as gas utility managements in general. The following items of design, layout, construction and operation of key control equipment are believed to be of sufficient importance to warrant engineering reappraisal and concentrated safety evaluation, with the end view of developing and promulgating appropriate and uniform safety standards:

1. Design, construction, and location of vault enclosures and arrangement of pressure regulators.
   a. Preferential use of above-ground vaults wherever possible. Use of monolithic construction of underground vaults as a safeguard against damage to equipment and piping accessories by structural collapse. Remote and protected location with regard to secondary hazards of traffic vibration and outside ignition sources.
   b. Adequate provisions for drainage of underground vaults to eliminate possible interference with pressure regulation, due to hydrostatic head effect of accumulations of water over top of control diaphragm.
   c. Stable anchorages, fire-resistive footings and supports for regulators, piping, and relief devices to minimize stresses and strains on jointings of equipment assembly, all of which require periodic alignment checks.
   d. Provisions for complete and continuous ventilation of vaults—consider dual vent stacks for positive displacement, one at the top fitted with a wind exhauster for updraft to draw off gas-fouled air and the other delivering fresh air downward toward the bottom of the vault.
   e. Direct venting of regulator diaphragm casings to divert safely any leaks occurring within the control device, to an unconfined point outside of the vault.
   f. Substitution of light-weight, quick-opening trap doors for manhole covers, of a size to afford adequate emergency venting on explosion. Such access openings should be fitted with locked basket-barricades to ward off malicious tampering.
   g. Separation of multi-stage pressure regulators by housing in individual vaults with adequate space between to minimize any adverse influence of one regulator unit upon another.
   h. Use of coarse wire screen of suitable mesh size or other device designed to stop foreign materials from entering and fouling the valve mechanisms of regulators, and so arranged as not to interfere with automatic operation of units being protected.

i. Location of exterior shut-off valves remote from regulator vault to provide accessibility for prompt use in emergencies.

j. Conformance of electrical equipment installed or employed in regulator vaults with the National Electrical Code requirements for hazardous locations (Sec. 500—Class 1, Division 1).

2. Auxiliary safeguards in distribution systems for protection of consumers at all times against the hazards of abnormal gas pressure.

   a. Utilization of telemetering and remote recording devices for communication to central control stations.

   b. Construction and installation in a safe location for atmospheric venting of an automatic master "blow off" or relief valve in service mains to prevent overpressuring of low-pressure distribution system in event of regulator failure.

   c. Installation of individual service regulators and emergency vents, wherever satisfactory operation can be obtained, to provide a secondary defense against excessive pressures on consumers' premises.

   d. Provision at meters for an easily operable shut-off cock having a permanently affixed indication of method of operation (showing direction of rotation) and a warning of the hazards of turning on gas by anyone except authorized servicemen.

   e. Advisability of providing curb shut-off cocks on consumers' premises.

Comments and additional suggestions, timely to gas distribution and servicing operations, which should be considered as information for guidance material, include:

1. Gas utility companies which are in the process of introducing natural gas into a system which formerly held manufactured gas are faced with the problem of making a complete safety survey before and during conversion, along with additional checkups and maintenance of the system afterwards. Many important factors require attention during this changeover, such as, leak detection, reconditioning of bell-and-spigot joints with anti-leak agents (because of drying out action of jute or hemp packing by relatively dry natural gas), checking of meter and regulator diaphragms, dedusting by oil-fogging and filtering (to eliminate pilot and orifice clogging), odorizing, and in some instances increased pressure problems.

2. A definite program for periodic inspection and testing of key equipment, including relief valves, pressure regulators, and all emergency controls, should be conducted with reasonable frequency as a part of regular maintenance operations. Odorization control and testing for combustible gases in manholes of electric and gas service systems should be made an important part of this activity.

3. More rigid controls should be maintained by municipalities over blasting or heavy construction operations such as pile driving and bulldozer excavation in the vicinity of gas mains. The enactment of local ordinances requiring proper notice to be given of such operations to all utilities concerned is suggested.

4. Closer liaison should be established between the fire chief and the utility safety official. To enable the firemen to act more effectively in their line of duty, mutually approved procedures should be developed to cope with all types of gas emergencies. The manual, "The Fireman and Electrical Equipment", prepared and distributed through the cooperative action of a group of Michigan power utilities, University of Michigan and the International Association of Fire Chiefs, New York, N. Y., typifies such a worthy undertaking. A similar treatise on gas services would be a timely contribution to greater safety.