UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
HEALTH AND SAFETY ACTIVITY

HEALTH AND SAFETY REPORT

REPORT ON MAJOR HYDROGEN SULFIDE DISASTER
BARNETT COMPLEX MINE
OZARK-MAHONING COMPANY
ROSICLARE, POPE COUNTY, ILLINOIS

April 12, 1971

by

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METAL AND NONMETAL MINE HEALTH AND SAFETY
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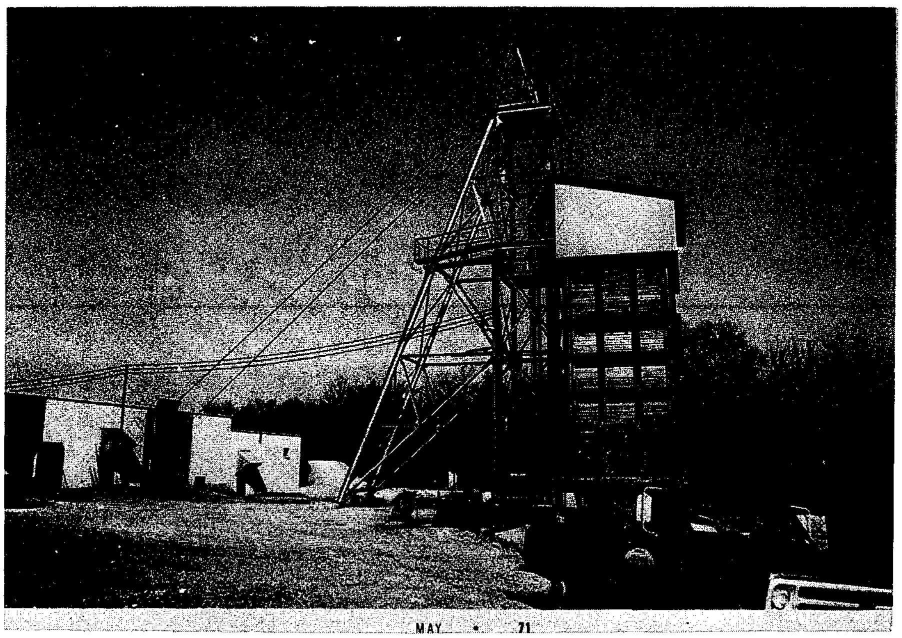

View of
Barnett Complex Mine Surface Plant

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SUMMARY

This report is based on an investigation made pursuant to Public Law 89-577, the Federal Metal and Nonmetallic Mine Safety Act.

Seven men died Monday, April 12, 1971, as result of exposure to hydrogen sulfide gas in advance workings on the 800-foot level of the Barnett Complex Mine, Ozark-Mahoning Company, Pope County, Illinois.

Drifting and test drilling operations to locate an ore vein were being conducted at the extreme end of the 800-foot south level, on Friday April 9. Near the end of the day shift, the third of three test holes struck a watercourse and water under high pressure was released into the drift. Work was discontinued in the area, and the water allowed to flow into the drift on the belief the body of water would soon be drained. Reportedly, hydrogen sulfide gas was not liberated on Friday; the two workers who were drilling did not smell the gas or suffer eye irritation.

The presence of hydrogen sulfide gas was first detected during the day shift on Saturday, when two miners, out of curiosity, went to the face to look at the water flow. The miners reported that the gas irritated their eyes and caused "tightness" in their chests.

At some time between the end of the second shift on Saturday and Monday morning, one of three fans in the auxiliary ventilation system for the 800 south level failed. What ventilation existed at the south end of the 800-foot level thereafter is unknown.

On Monday, April 12, installation of a replacement fan was completed shortly after noon. Before the fan was started, a miner went inby the fan to obtain measuring sticks. He was seen by the men installing the fan, but testimony is not clear as to his being aware of or warned of a potential danger. One man testified that he advised William E. Long not to go back there (where the gas was). In about a half hour, the miner's brother went into the area to look for him. When neither of the two men returned, other miners, without respiratory protection, attempted

rescue. At this time the replacement fan was started. In the course of events, five additional miners were overcome while several others, although repeatedly entering the drift and being affected by the gas, did escape by cutting into the ventilation tubing for fresh air.

At approximately 1:30 p.m., the Company officials notified the Illinois Department of Mines and Minerals of the accident.

About 2:00 p.m., an additional rescue attempt was made using hospital oxygen tanks and again shortly thereafter, when self-contained breathing apparatuses were obtained, but to no avail. A mine rescue team from Benton, Illinois, Illinois Department of Mines and Minerals arrived at 4:10 p.m. The seven victims were brought to the surface in four trips, the last by 5:45 p.m. Four still showed signs of life when they were removed from the shaft. The disaster area and the locations where the victims were found are shown in Appendix B.

GENERAL INFORMATION

The Barnett Complex Mine, an underground fluorspar-lead-zinc operation, is located adjacent to State Highway 146, six miles north of Golconda, Illinois. Ozark-Mahoning Company sank the Barnett shaft in 1966 and connected it to the sixth level of the Parkinson Mine, which then formed the present Barnett Complex Mine.

Name and addresses of Company officials are:

W. I. Weisman - President, Tulsa, Oklahoma
W. W. Fowler - Vice President, Rosiclare, Illinois
F. H. Hansen - Superintendent, Rosiclare, Illinois
Phillip W. Long - Foreman, Rosiclare, Illinois (victim)
Kenneth Clanton - Shift Leader, Rosiclare, Illinois

Twenty-two men were employed underground on two 8-hour shifts a day, six days a week. Day shift began at 7:00 a.m. and finished at 3:30 p.m. The afternoon shift started at 3:30 p.m. and ended at 11:00 p.m.

Ore production averaged approximately 250 tons a day. Principal products were fluorite, galena, and sphalerite.

The mine (see Appendix B) follows a vein system which strikes approximately N35 degrees E and dips steeply to the southeast. The vein ranges from 7 to 9 feet in thickness. Mine depths range from 366 feet at the Parkinson shaft, on the northeast extremity, to a depth of 800 feet in the southwest. The main hoisting shaft, known as the Barnett shaft, is situated in the hangingwall about 4,000 feet southwest from the Parkinson shaft. Both shafts are vertical. The main hoisting shaft is 8 by 13.5 feet in cross-section, about 875 feet deep, and serves as the exhaust for all mine air.

The Parkinson shaft is 8 by 12 feet in cross-section, 366 feet deep, and serves as the main air intake. It is connected at the bottom to the mine workings by a 900-foot drift running southwest and a 70-foot winze to the 600-foot level. Emergency hoisting facilities are provided in that shaft, and it serves as a second escapeway. Midway between the two shafts, a 12-inch borehole from the surface to the 600-foot level was utilized for blowing additional fresh air into the mine. Details on ventilation are given in a separate section of this report.

Levels are driven on 100-foot vertical intervals, and ore is mined by a modified shrinkage-stoping method. With the exception of two work areas between the 600- and 700-foot levels, stoping had been completed between the Parkinson and the Barnett shafts. Floor pillars had been mined. Present production is mainly from stopes south of the Barnett shaft between the 700-foot and 800-foot levels.

In the course of normal mining operations inflows of water from drill holes, cracks, and vugs had been experienced from time to time. The bodies of water thus encountered usually drained off within the span of a few minutes to several hours. Although hydrogen sulfide gas, in low concentrations, occasionally was encountered in connection with these water inflows, the mine atmosphere was reported to be normally free of it.

Reportedly, water under high pressure had been encountered in the mine on two previous occasions. The first occurred when the Parkinson shaft was deepened in 1954. At that time a water flow was encountered from blast-round drill holes. Further sinking operations were discontinued, a concrete plug was poured at the bottom of the shaft, and a drift was driven along the strike of the orebody 900 feet southerly to the point from which the winze was sunk to the sixth level. High pressure water was encountered a second time on October 24, 1966, when a diamond drill hole intersected a water-bearing stratum in a short crosscut on the sixth level, about 800 feet north of the Barnett shaft, Reportedly, miners experienced some eye irritation from hydrogen sulfide gas on both of these occasions. However, no lasting harmful effects were experienced.

A Federal inspection was made of the Barnett Complex Mine under P. L. 89-577, September 9-10, 1970, at which time the eighth level south drift heading was approximately 450 feet away from the location where the hydrogen-sulfide-bearing water was encountered. That inspection did not reveal any conditions bearing on the disaster. A spot inspection to check abatements of violations cited September 9-10, 1970, was made February 10, 1971.

MINING METHODS, CONDITIONS, AND EQUIPMENT

Mining Method

Ore was mined by a modified stoping method with broken ore scraped to a chute instead of being extracted down draw-holes. Three-compartment timbered stope raises were driven on centers varying from 100 to 200 feet. The center compartments, normally 6 by 6 feet in cross-section, were used for manways. Sill pillars approximately 20 feet thick were left over the haulage drift for support. Stopes were mined by longitudinal slice cuts and varied in height depending on the vein. Floor pillars were left between the stopes and the level above them. Some of the 600- and 700-foot level sill and floor pillars had been extracted Haulageways and crosscuts were driven 6 by 8 feet in cross-section.

Explosives

Blastholes were loaded with premixed ANFO and bottom primed with a single stick of dynamite. Blasting caps, safety fuse, and igniter cord were used to initiate the primer. All blasting was done at 11:00 p.m., the end of the second shift.

Electricity

Electricity was furnished by the Southeastern Illinois Electric Company at 6,900-volts alternating current and was reduced to 440-, 220-, and 110-volts. The primary transformer station was pole-mounted on the surface. Electricity at 440-volts alternating current was transmitted underground through the Barnett shaft for the operation of pumps and auxiliary fans. Underground electric lighting was from a 110-volt circuit transformer off the 440-volt system.

All underground, 3-phase circuits were protected from overload and single phase operation by automatic unit disconnect switches. Each fan was provided with separate controls.

Mine Drainage

There were two sumps at the Barnett shaft, the larger one located on the 850-foot level and a smaller sump on the 800-foot level. All of the mine water draining to the Barnett shaft entered the 850-foot level sump. A 15-horsepower, centrifugal staging pump lifted the water to a smaller sump on the 8th level. A 110-horsepower, centrifugal pump, rated at 250 g.p.m., at a 900-foot head, pumped the water to the surface. These pumps were equipped with automatic controls. In the event that the capacity of these two pumps was exceeded; a manually-controlled, 200-horsepower, turbine pump, rated at 500 g.p.m., pumped water from the main sump directly to the surface.

Mine Rescue

No self-contained breathing apparatus or appropriate gas masks for protection against hydrogen sulfide were kept at the mine. The State of Illinois, however, maintained mine rescue stations at Eldorado and Benton, Illinois, approximately 42 and 62 miles distant, respectively.

Ventilation

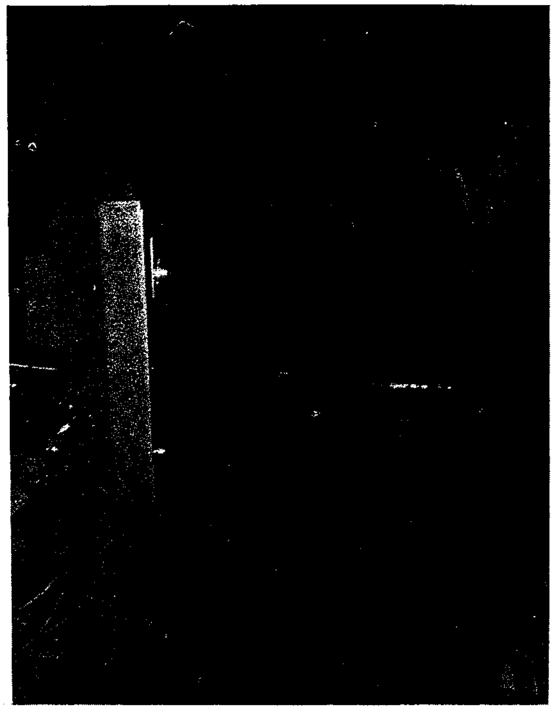
Mine ventilation (see Appendix C for details) was provided by a 25-horsepower axial-flow fan, offset mounted at the surface, which forced air down the Parkinson shaft to the 366-foot level. Fresh air traveled southward along that level and down a winze to the 600-foot level. Additional air entered the 600-foot level through a 12-inch-diameter borehole that had a 20-horsepower, squirrel cage, blower fan rated at 2,700 c.f.m., installed on surface.

The combined fresh air was coursed to 7N222S raise where it split. Approximately one-third of the air went down the raise to the 700-foot level; the rest traveled south through the 600-foot level and stopes above that level. Air doors on the 600- and 700-foot level shaft crosscuts limited air losses to the Barnett shaft. Another air door at the top of escape raise 8S6S on the 700-foot level also limited air short circuiting to the shaft through the raise.

The main fresh air supply for the mine was coursed south of the Barnett shaft along the levels and through open stopes on the 600- and 700-foot levels to 8S75S raise where the sill and floor pillars to the south had been extracted. The air then coursed downward as it swept through the open stopes to the south, thence northerly in the stopes between the 800- and 700-foot levels to 8S63S, 8S51S, and 8S39S raises where the air flowed into the main return on the 800-foot level and out the Barnett shaft.

An auxiliary fan-and-ventilation-tubing system was utilized to ventilate workings on the 800-foot level south of the main return air stream described above.

A 25-horsepower, squirrel cage fan near the top of 8S75S raise forced air through 100 feet of 16-inch ventilation tubing installed in the raise to the 800-foot level. The connection to 408 feet of ventilation tubing on the 800-foot level was made with a 12-inch-diameter, steel elbow. At the end of the 16-inch tubing, a 65-foot length of 12-inch-diameter tubing terminated at a corrugated steel fan box. A 15-horsepower fan installed in the box forced the air through a 488-foot section of 12-inch-diameter tubing terminating at a second and similar



25-Horsepower, squirrel cage fan on 8S75S raise at 700 level which supplies air to the fans located on the 800-foot level; estimated capacity 8,300 c.f.m.

fan box. From the second fan box, another section of 12-inch-diameter ventilation tubing, 591 feet in length, coursed the air to a point 90 feet from the 800-foot level south face.

All air supplied by the auxiliary fan system to the south end of the mine on the 800-foot level traveled northward to exhaust up the Barnett shaft from the 800-foot level. A small portion was noted coursing up 8S97S and 8S75S raise into the stopes above. The latter condition provided a possible source of recirculation.

Because of air losses and recirculation, the full capacity of the ventilation system was not obtained. A considerable amount of air was lost at the Parkinson intake air shaft through the poorly-fitted cover over the collar of the shaft. Additional intake air escaped to the Barnett shaft under the air doors on the 600-foot and 700-foot levels and around the door in 8S6S raise.

The volume of air delivered to the 800-foot l vel south face through the flexible ventilation tubing was reduced considerably by friction and shock losses. The use of a 12-inch-diameter elbow to connect sections of 16-inch-diameter tubing, the installation of tubing through narrow spaces behind chute timbers, and support of the tubing by poorly-installed wire hangers increased resistance to air flow.

The use of squirrel cage fans not designed for in-line installation necessitated the use of the fan boxes which caused shock losses and lower volumes of delivered air.

The quality of the air was also affected by recirculation. Neither fan box was air tight, and at one box, the ventilation tubing terminated approximately two inches from the box.

STORY OF DISASTER AND RECOVERY OPERATIONS

Activities of Bureau of Mines Personnel

The Vincennes subdistrict office of the Bureau of Mines learned of the accident at 4:10 p.m., April 12, 1971, by means of a telephone call from a representative of the Vincennes Coal Mine Safety office, Bureau of Mines. Roy Bernard, Subdistrict Manager, Metal and Nonmetal Mine Health and Safety, immediately called the company's main offices at Rosiclare, Illinois, to verify the report.

The District Manager at Duluth, Minnesota, was then notified, and after obtaining available respiratory protection equipment and gas detectors, the subdistrict manager and metal and nonmetal mine inspectors, Frank Delimba and Donald Morris, left for the mine, arriving at 7:00 p.m.

After notifying the Metal and Nonmetal Mine Health and Safety office at Washington, D. C., the District Manager made travel arrangements, arriving at the mine at 4:00 p.m., April 13. Stanley M. Jarrett, Assistant Director--Metal and Nonmetal Mine Health and Safety, arrived at the mine early that evening. Henry P. Wheeler, Jr., Deputy Director, and James Westfield, Special Investigator, both of Washington, D. C., arrived that night.

An imminent danger order, citing a dangerous accumulation of hydrogen sulfide gas, was issued April 12, 1971. This order issued under section 8(a) of the Federal Metal and Nonmetallic Mine Safety Act required that all persons be withdrawn from, and prohibited from entering the Barnett Mine, except those needed for rehabilitation, exploration, and recovery work.

H. P. Wheeler, Jr., Deputy Director, was at the scene April 13-14; S. M. Jarrett, Assistant Director; James Westfield, Special Investigator; R. O. Pynnonen, District Manager; and R. L. Bernard, Subdistrict Manager, were there April 13-21.

Metal and nonmetal mine inspectors, Reino Mattson and Donald Johnson, and mining engineer, Jack Gill, assisted with the investigation and recovery operations at various times during the weeks following the disaster.

All rescue operations and removal of the bodies by the Illinois State mine rescue crew from Benton had been completed before the arrival of Bureau of Mines personnel. Bureau employees conducted an investigation of the accident, assisted in recovery operations, and participated in conferences with company and State personnel regarding recovery operations.

Mine Conditions Prior to the Accident

The 800-foot south level had been driven 2,350 feet from the Barnett shaft when the ore vein was lost because of a fault. When the main drift being driven southeasterly failed to intersect ore, a new drift about 75 feet outby the face was started in a southwesterly direction. This heading had been advanced approximately 75 feet.

On Friday afternoon, April 9, 1971, Phillip W. Long, mine foreman, and Ward Palmer, miner, struck a watercourse while drilling a test hole in the right rib of the new drift. The pressure of the water forced the drill steel partly out of the hole until the drill machine jammed against the opposite rib. The men had drilled three holes, the third intersecting the watercourse. This occurred at about 2:30 p.m., and reportedly, this initial water release did not contain hydrogen sulfide as neither man reported smelling the gas or suffering eye irritation.

Mr. Long reported the inflow of water to the Rosiclare office that evening and to Mr. Forest Hansen, mine superintendent, on Saturday morning. The presence of hydrogen sulfide was not detected until Saturday morning when two miners, as a matter of curiosity, went to the face to look at the water. The miners reported that the gas irritated their eyes and caused "tightness" in their chests. Other miners also visited the face during that day and on the afternoon shift. Only one man reported prolonged discomfort as a result of the exposure; his eyes continued watering after he left the area, whereupon he went to the surface, obtained relief by use of eyedrops, and returned underground where he worked the balance of his shift. When Mr. Long talked to Mr. Hansen on Saturday, he reported the presence of gas. Mr. Hansen, reportedly, told him not to take any chances with the gas until the degree of hazard could be determined, and that it was to be his decision whether or not to work in the area. It is reported to have been Mr. Long's decision not to work in the area on Saturday.

On Sunday, the mine had been idle, except that pumping operations required a man to go to the 8th level shaft station to operate the manually-controlled pump. At some time between the end of the afternoon shift on Saturday, April 10, and Monday morning, April 12, the inby fan on the 800-foot level became inoperative because its drive motor burned out. The inoperative fan in the ventilation tube system greatly increased the resistance in the system and as a result, probably very little air reached the 800-foot level south face.

Story of Disaster

On Monday morning, April 12, 1971, the day shift went underground at 7:00 a.m. Normal mining operations were resumed in the stopes and two men were assigned to remove the faulty inby fan (see Appendix D). Another fan was obtained from the company's West Green property and delivered to the Barnett Mine.

Testimony did not establish that the miners were explicitly prohibited from entering exploration workings of the 800 south drift. However, it does imply that the foreman and the lead man talked to most if not all of the men, telling them that there would be no work in that 800 S location. K. Clanton testified that he had advised William E. Long not to go back there.

Three men, Gale Bates, H. Dutton, and J. Jenkins, were assigned to install the new fan late in the morning and completed the installation at about 12:30 p.m. Shortly before they completed the installation, at about 12 noon, William E. Long, a miner working in 85 stope came by, saying he was going a short distance inby the fan to get a "slide stick to measure timber." The stick was supposed to have been at a manway being developed just inby the fan. Just as the fan installation was completed, Philip W. Long arrived and a short while later, G. Davis, William E. Long's partner, arrived looking for him. When Foreman Phillip W. Long learned his brother had gone toward the face, he immediately went to look for him taking a small battery-powered locomotive. A short time later K. Clanton, shift leader, arrived, having learned that William E. Long had gone inby the fan and had not returned.

Clanton took G. Davis with him and went to search for the two Long brothers. They found both men down, lying on the drift floor at a point approximately 110 feet from the face and well beyond the point where the measuring stick should have been. At this point, Clanton and Davis were forced back by the effects of the gas. They then proceeded back to the fan and advised the three men there that the two Long brothers were overcome, and if additional men went in, that they should not take any chances and to be careful. Bates was sent back to the shaft to get a big locomotive, and the fan was started in an attempt to force fresh air back to the unconscious men. Clanton and Davis proceeded towards the shaft to warn the men in the stopes and to get help.

In successive attempts various men entered and reentered the affected area. They all suffered the effects of the gas to some degree and five additional men were overcome. In these attempts a second, larger locomotive was used, carrying three workers into the gas-laden drift. They placed two men on the motors and got out to a point just inby 8S175S raise before being overcome by the hydrogen sulfide gas. Restarting the inby fan tended to force high concentrations of hydrogen sulfide outward from the South 800 face area toward the main shaft in addition to diluting gas in the face area with fresh air.

V. English, M. Ewell, W. Palmer, H. Dutton, and C. Long attempted to help but were forced back by the effects of the gas. They were able to make their way back to the shaft by slitting the ventilation tubing and taking advantage of the fresh air from it.

A. Long arrived on surface at approximately 1:15 p.m., and notified the hoistman. The hoistman notified the Rosiclare office of the accident, and they in turn called the Benton mine rescue station. The hospital in Rosiclare was notified of the accident at this time, also. All but the seven victims made their way to surface by 2:00 p.m.

A discussion of the physical properties and physiological effects of hydrogen sulfide is presented in Appendix E.

Rescue Operations

Dr. A. Z. Goldstein and an ambulance from the Rosiclare hospital arrived at the scene at approximately 1:30 p.m.

An attempt to rescue the men was made about 2:00 p.m. by F. Hansen, superintendent; H. Winters, foreman; B. Perry, chief geologist; and V. English, miner, wearing hospital oxygen tanks and masks. They were able to proceed only 800 feet from the shaft when they ran out of oxygen. At 3:15 p.m., Elmer Crouch, Captain, Paducah Fire Department, who had heard the need for rescue apparatus, arrived at the scene with demand-type, self-contained breathing apparatus (MSA Model 401 Air-mask). Another rescue attempt was made by F. Hansen, B. Perry, and D. Russel, a Civil Defense representative, using the self-contained breathing apparatus. The three men in the rescue party had just reached the fallen men when the warning bells on their apparatus sounded and they had to withdraw.

The Benton rescue team of the Illinois Department of Mines and Minerals arrived at 4:10 p.m., with McCaa two-hour apparatus and removed the victims in four trips. The last of the victims was brought to the surface by 5:45 p.m. Four of the seven men were still alive when brought to surface, but two died shortly thereafter. The other two died in a Rosiclare hospital that evening.

Recovery Operations

On April 13, an exploratory team headed by State officials encountered 200 p.p.m. hydrogen sulfide 700 feet from the shaft on the 8th level. A decision was made to recall the Benton rescue team to check the condition of the fans and ventilation tubing. The teams arrived at 2:15 p.m., and the first crew entered the mine at 3:45 p.m. The ventilation fans were found to be inoperative and four more trips were made underground to start the fans and pump water from the sump.

A meeting was held at 9:45 a.m., April 14, 1971, with State, company, and Federal officials. The company decided at this meeting to bore a 24-inch-diameter borehole from surface to a point just outby the face on the 8th level. After the meeting, an exploratory trip was made underground by company, State, and Federal officials. The condition of the ventilation tubing and fan boxes was found to be poor, and it was decided to recall the Benton rescue team to repair them, as the concentration of hydrogen sulfide was found to be +600 p.p.m. about 200 feet outby the face. The teams arrived at 2:45 p.m., and the first team went underground at 3:35 p.m., and the last crew came up at 6:33 p.m., finishing the job. The water was allowed to run freely and the fans were run continuously from April 15, 1971, until April 23, 1971. There was no recovery work done during this period.

A meeting with top management personnel requested by Mr. S. M. Jarrett was held on April 21, 1971, to discuss future mine recovery operations and subsequent mining operations. Persons attending the meeting included the following:

<u>Ozark-Mahoning Company</u>

W. W. Fowler	Vice President
F. Hansen	General Superintendent
B. Perry	Chief Geologist
H. Winter	Mine Foreman

<u>Illinois Department of Mines and Minerals</u>

D. L. Gulley	Director
D. McReaken	Inspector-at-Large
A. Black	Metal Mine Inspector

<u>Bureau of Mines</u>

S. M. Jarrett	Assistant Director--Metal and Nonmetal Mine Health and Safety
R. O. Pynnonen	District Manager
R. L. Bernard	Subdistrict Manager

The following mine recovery procedures were recommended and accepted by mine management:

1. In reestablishing ventilation in the mine, the damaged 12-inch diameter ventilation tubing on the 800-foot level should be replaced by 16-inch tubing. Raises and other openings allowing recirculation of air from the 800 to the 700-foot levels should be bratticed. The adequacy of the existing fans should be checked and the fan boxes on the 800-foot level should be repaired to avoid recirculation.

2. A ventilation map, drawn to 100 feet to the inch scale, should be prepared with control points established to measure ventilation currents and record gas concentrations. These positions would be recorded on the

map and on drift walls. Daily readings should be made at the control points and recorded in writing in order to track progress. Readings should also be taken at all advance development faces. Supervisors should investigate and record any report of "burning of eyes" or other indication of hydrogen sulfide gas concentrations. Signs should be posted barring entry to workers. Only properly equipped mine rescue groups should be allowed beyond such signs.

3. A Federal or State inspector should supervise recovery procedures. Gas concentrations at the established control points would be measured and kept in a written log.

4. The inflow of water bearing the hydrogen sulfide gas should be controlled. For that purpose, a sketch of a "hole packer" to be fabricated would be provided. If the hydrogen sulfide gas could not be sufficiently controlled by air dilution, the gas-bearing water should be piped to the shaft.

5. Before any development is undertaken, particularly on the 800-foot level, test holes in the face and in the flanks of development drifts should be drilled to detect bodies of water and to avoid possible inundation. Because of the record of high-pressure water at different locations in the mine, additional pumping capacity was recommended. It was pointed out that if the standby pump should fail for any reason, the entire mine could be flooded.

On April 24, 1971, new 16-inch-diameter tubing was installed from a point of 408 feet inby 8S75S raise to within 10 feet of the face of the 8th level, bypassing the two fan boxes. This provided continuous 16-inch diameter tubing from the 7th level fan to the face except for a 14-inch-diameter elbow at the bottom of 8S75S raise. This elbow was later changed to a 16-inch-diameter elbow. With these changes, approximately 2,000 c.f.m. was reaching the face.

On April 24, 1971, a packer with a shut-off valve was installed in the drill hole, enabling the water from the face to be controlled.

Packer with a shut-off valve installed
in drill hole to control water flow.

Water from the drill hole was run into the waterline and to the sump on April 30, 1971, but due to restrictions in the waterline, only 7 g.p.m. reached the sump. A 2-inch plastic line was then installed between the packer and the sump on May 4, 1971, which increased the flow to 75 g.p.m. With the water contained in the pipe, the concentration of hydrogen-sulfide gas dropped to 6 p.p.m. at the face with only a trace being evident in the remainder of the drift.

The original imminent danger order was canceled and revised with a new imminent danger order on May 7, 1971, allowing mining operations to resume on the 7th level, but debarring work except for rehabilitation on the 8th level south drift.

By this time, surveying and other arrangements had been completed by the company to drill a ventilation borehole from the surface to a point near the face of the drift. The drift was checked twice daily for leaks in the plastic pipe and packer, and to obtain pressure readings on the packer. The pressure on the packer was 80 p.s.i. on May 4, 1971, and had declined to 70 p.s.i. on May 7, 1971.

INVESTIGATION OF CAUSE OF DISASTER

Concurrent but separate investigations of the disaster were made by the Illinois Department of Mines and Minerals and the United States Bureau of Mines.

The Bureau of Mines investigation consisted of an examination of the underground workings on the 800-foot level south drift and a ventilation survey of the entire mine.

A joint informal hearing was held April 13, 1971, by the Illinois Department of Mines and Minerals, Company officials, and the Bureau of Mines.

A coroner's inquest into the deaths of the five men who died on the mine property was held on the morning of April 19, 1971. The jury ruled the deaths resulted from inhaled hydrogen sulfide gas fumes.

The Bureau of Mines conducted a separate investigation from that of the Illinois Department of Mines and Minerals. Following is a listing of those who participated in these investigations.

United States Bureau of Mines

Stanley M. Jarrett	- Assistant Director--Metal and Nonmetal Mine Health and Safety
James Westfield	- Special Investigator
R. O. Pynnonen	- District Manager, North Central District, Metal and Nonmetal Mine Health and Safety
R. L. Bernard	- Subdistrict Manager, North Central District, Vincennes Subdistrict Office, Metal and Nonmetal Mine Health and Safety

Illinois Department of Mines and Minerals

David L. Gulley	- Director
Robert H. Rath	- Technical Advisor
Dayton McReaken	- Inspector-at-Large

CAUSE OF DISASTER

The disaster was caused by:

1. The failure of mine officials and workers to recognize the lethal character of concentrated hydrogen sulfide gas owing in part to intermittent exposure to the gas over a period of years in quantities which produced no lasting harmful effects. (The last previously-known fatality in a metal mine due to hydrogen sulfide gas occurred in 1925.)

2. While the forced ventilation system in the mine was satisfactory for normal operations, the system on the eighth level proved to be inadequate for the unusual situation which was created by (1) the prolonged inflow of water containing hydrogen sulfide and (2) the failure of one of the inline fans.

3. The area was not "dangered off" as a follow up to any oral warnings that may have been given to the men, and checks were not made on the concentrations of hydrogen sulfide in the eighth level south drift at the start of the day shift, April 12, 1971.

4. The failure of mine management and workers to realize that, until the fans had been operated for a length of time sufficient to assure removal of concentrations of the gas, the entire 800 South drift was hazardous.

RECOMMENDATIONS

The following recommendations were made for prevention of a similar occurrence at this mine:

1. All personnel should be trained in the characteristics, toxicity, and detection of hydrogen sulfide.

2. When hydrogen sulfide is smelled or otherwise detected, it should be immediately reported to supervisors. The area should be checked for gas concentrations by supervisors and the event recorded. If a hazardous concentration of the gas is found, the area should be barricaded and posted until the situation is corrected. When a change in ventilation could reduce a normally safe place to a hazardous one, that place should be barricaded and posted against entry.

3. Only Bureau of Mines approved breathing apparatus should be used to attempt a rescue underground. These devices should be self-contained breathing apparatus; hose masks; or No. 6, type "N" or hydrogen-sulfide-protective-type canister gas masks.

4. A rescue station with at least 10 two-hour breathing apparatus or equivalent should be established.

5. Personnel should be trained in the use of emergency breathing apparatus, detection of gases, and emergency procedures.

6. Before any development is undertaken, test holes in the face and ribs of the drift should be drilled to detect high-pressure water.

7. An improved mine ventilation system has been proposed (see Appendix E) and should be implemented.

8. Manways and ore chutes to mined-out stopes should be bratticed off so that the available ventilation current can be most effectively used.

9. Ventilation control points should be established and readings should be taken and recorded at specified intervals.

10. A minimum of 3,000 c.f.m. of fresh air should be brought to all development headings.

11. A qualified safety engineer should be hired by the company to establish and maintain an effective safety program.

NOTE: All of the foregoing recommendations have been implemented except for numbers 6 and 10 because there has been no further development work since the disaster.

ACKNOWLEDGMENT

The cooperation and courtesies extended by the officials and miners of the Ozark-Mahoning Company, Inc., and by officials and mine rescue team members of the Illinois Department of Mines and Minerals in providing information and assistance with the investigation is gratefully acknowledged. Also, the writers acknowledge and commend the mine rescue team members of the Illinois Department of Mines and Minerals for the efficient manner in which they conducted rescue and recovery operations following the disaster.

Submitted by:

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APPENDIX A

Victims of Mine Disaster, Barnett Complex Mine

Ozark-Mahoning Company

April 12, 1971

Name and Social Security Number	Age	Dependents	Occupation	Years Mining Experience
Randel T. Belford 324-28-0663	34	Wife, 2 Children	Mechanic	5-1/2
Gale D. Bates 349-22-1087	42	Wife, 3 Children	Driller	13-1/2
Jerry L. Jenkins 344-34-1068	30	Wife, 3 Children	Electrician	7
Phillip W. Long 344-24-5810	39	Wife, 1 Child	Mine Foreman	20-3/4
William E. Long 344-34-0102	31	Wife, 3 Children	Timberman	9
James R. Lane 325-24-7859	42	Wife, 5 Children	Driller	17
Orval V. Holbrook 354-20-2335	47	Wife, 1 Child	Motorman	28

APPENDIX F

Characteristics of Hydrogen Sulfide Gas

Hydrogen Sulfide

Hydrogen sulfide, H_2S, (sulfureted hydrogen, hydrogen monosulfide, referred to as "stink damp" by miners) is a colorless, highly toxic, and irritant gas which has an extremely unpleasant, rotten-egg odor at low concentrations and a sweetish odor at higher concentrations. Since its specific gravity (1.19) is somewhat higher than that of air (1.00), it tends to accumulate in deep cavities such as vats, tanks, ditches, ravines, and cellars. Its molecular weight is 34.20, melting point $-83.8^{\circ}C$, and boiling point $-60.2^{\circ}C$. The lower limit of flammability in air is 4.3% and the upper limit is 45.5%. Hydrogen sulfide forms explosive mixtures with air or oxygen and is dangerously flammable upon ignition. Water at room temperature absorbs approximately three times its own volume of the gas. It is also soluble in petroleum solvents, crude petroleum, and carbon disulfide.

Briefly, the principal sources of hydrogen sulfide that are of importance from the viewpoint of hazards are: gypsum mines, sulfur mines and wells, caissons and tunnels, natural gas production and refining of high-sulfur petroleum, sewers and other places where organic matter decomposes in confined spaces, blasting with black powder and blasting with other explosives in heavy sulfide ore, gas manufacture, low temperature carbonization of coal, manufacture of chemicals, dyes, and pigments, vulcanization of rubber, glue manufacture, tanning, spinning of viscous rayon, and treatment of sewage.

In addition to these places of primary importance, the gas occurs in the water of some mineral springs, rock-fissure gases, volcanic gases, and from bacterial action in brackish waters. Some of these, however, are associated with the important sources of hazards mentioned above, as the occurrence of hydrogen sulfide bearing water in gypsum mines, rock strata gases in mines and tunnels, and bacterial action or decomposition of organic matter in sewers.

The gas may be liberated to the air directly from the original source or place where it is generated or, due to its solubility in water and oil, it may be transported in solution great distances from its original source and then escape and create dangerous atmospheres at unsuspected places. Crude oil charged with hydrogen sulfide will tend to give off the gas to the air from the time it leaves the well until it is refined. Waste water that has been in contact with hydrogen sulfide in industrial processes, as petroleum refining and production of sulphur from wells, will act as a vehicle to transport hydrogen sulphide from inaccessible to accessible places or to the air of drains and sewers or other confined spaces from which the gas may find its way to places frequented by persons. In mines, tunnels, and caissons the presence of the gas may be due entirely to the inflow of hydrogen-sulfide bearing water and its escape therefrom into the air.

Hydrogen sulfide does not always present a health hazard in the situations cited, but the possible occurrence of a health hazard is worthy of consideration when investigating injury or accident from exposure to gas at such places, and in the planning and designing of industrial and engineering equipment and projects where the gas might jeopardize the health and safety of persons.

W. P. Yant[1/] made measurement of the odor intensity under strictly controlled conditions and reported the odor intensities obtained for various concentrations as shown in the following table:

Odor Intensities For Various Concentrations of H_2S

	Concentrations of H_2S in air	
Intensity of odor	Parts per million	Percent by volume
No odor	0.022	0.0000022
Detectable; minimum perceptible odor ..	0.13	0.000013
Faint; a weak odor, readily perceptible	0.77	0.000077
Easily noticeable; moderate intensity..	4.6	0.00046
Strong; cogent, forceful, not intolerable	27.0	0.0027

Hydrogen sulfide has a distinctive, unpleasant odor in low concentrations. However, the sense of smell is not a reliable indicator of the presence of hydrogen sulfide because the gas has a tendency to numb the olfactory receptors and this can occur very rapidly at higher concentrations.

The gas has two apparent physiological actions - subacute and acute poisoning. The former is a direct irritating action of the gas on the moist body tissues of the eyes and the lining of the respiratory tract. On the other hand, acute poisoning is the result of a toxic action on the nervous system produced by the

1/ Yant, W. P. Hydrogen Sulfide in Industry, Occurrence, Effects, and Treatment. American Journal of Public Health, Vol. XX, No. 6, June 1930.

absorption and presence of hydrogen sulfide in the blood. Unconsciousness and respiratory failure usually occurs within a few seconds after exposure and the important reaction is paralysis of respiration followed in five to 10 minutes by cardiac failure. There are no warning symptoms and no pain. Death from acute poisoning is due primarily to asphyxia. Death is as rapid as in poisoning by cyanide.

Briefly, the physiological response attending the exposure to various concentrations in air is as follows:

Concentration of hydrogen sulfide, percent by volume	Effects
0.005 to 0.010	Subacute poisoning - slight symptoms, such as mild conjunctivitis (eye irritation) and respiratory-tract irritation after one hour exposure.
0.02 to 0.03	Subacute poisoning - marked conjunctivitis and respiratory-tract irritation after one hour exposure.
0.05 to 0.07	Subacute poisoning - dangerous in one-half to one hour.
0.07 to 0.10	Possibly acute poisoning - rapid unconsciousness and cessation of respiration.
0.10 to 0.20	Acute poisoning - rapid unconsciousness, cessation of respiration and death in a few minutes.

The treatment of subacute hydrogen sulfide poisoning varies with the part affected, the degree of poisoning, and the existence of secondary complications. This necessarily makes the treatment symptomatic and leaves the physician to his choice of procedure for the particular condition. In view of the complications which may arise the treatment of subacute poisoning, even the mildest form, should always be carefully performed by a competent physician.

In acute poisoning unconsciousness and cessation of respiration usually occurs in a few seconds to a minute after exposure, followed in 5 to 10 minutes by cardiac failure and death, primarily due to asphyxia. In order to save life, rescue must be effected and artificial respiration applied within a few minutes after the exposure occurs. Also, the rescue and treatment must be effected by fellow workmen because time does not permit summoning aid or transporting the victim to a hospital.

The major steps in the treatment of acute poisoning are: (1) get the patient into fresh air; and (2) give artificial respiration immediately if breathing has ceased, become markedly labored or impaired.

Experience has repeatedly shown that if rescue is effected and artificial respiration applied within a few minutes after the victim is overcome, life can be saved almost invariably. On the other hand, experience has also shown that a delay of 10 to 15 minutes jeopardizes the chances of recovery, though this should not be taken as an excuse for laxity in carrying out the prescribed treatment.

The importance of self-protection of those attempting to effect rescue should be emphasized. Cases are on record where the first, second, and even the third person going to the rescue of fellow workmen have all been overcome. The rescuer should always calmly, but expeditiously, plan the procedure, using all available means for self-protection. He should remember that he can hold his breath and remain conscious and unharmed much longer than the time required for the gas to render him unconscious if he breathes an atmosphere that contains enough hydrogen sulfide to cause acute poisoning. He should never enter a confined place, such as a tank, a derrick cellar, or a sewer, unless he uses at least a life line held by two attendants in fresh air, who are capable of giving artificial respiration, because it is very likely that he will be rendered unconscious. If suitable respiratory protective equipment is available it should be used in conjunction with the life line.

Suitable types of respiratory protective devices in the forms of canister gas masks, hose masks, and self-contained oxygen breathing apparatus are available. Each type of device has its field of use and its limitations. The devices used should be approved by the Bureau of Mines.

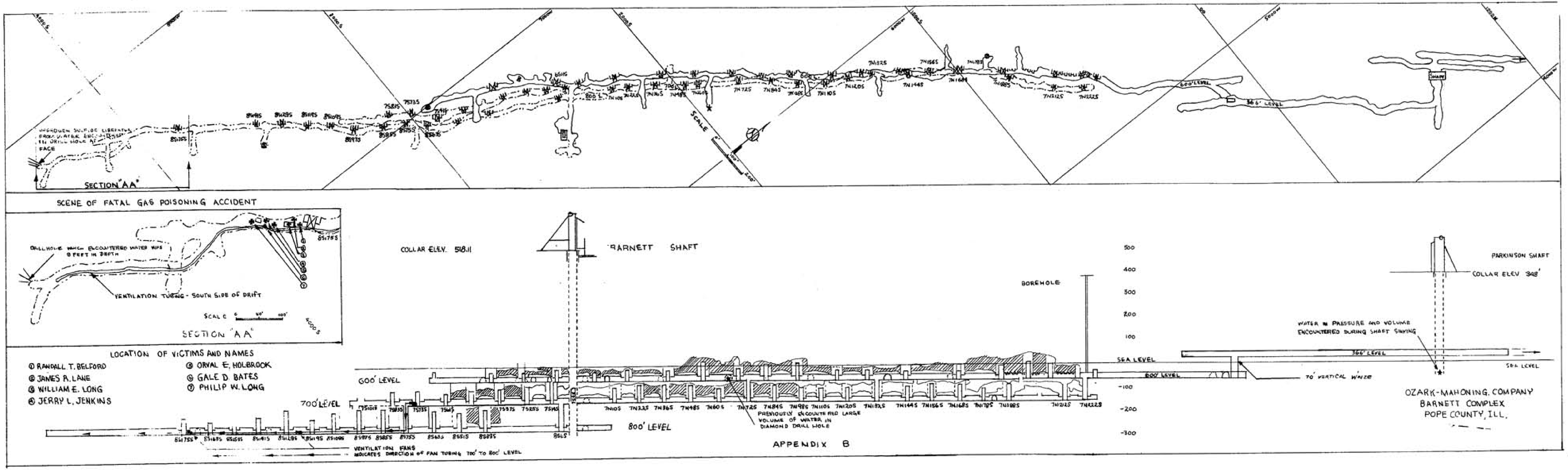
The training of workmen to avoid exposure; the design of equipment to eliminate places of exposure; the use of respiratory protective devices for performing operations in contaminated atmospheres and for emergency work; and the training of workmen in methods of emergency treatment will markedly lessen industrial hazards from hydrogen sulfide.

The threshold limit value of hydrogen sulfide, as adopted by the American Conference of Governmental Industrial Hygienists for 1970, is 10 parts of gas per million parts of contaminated air by volume.

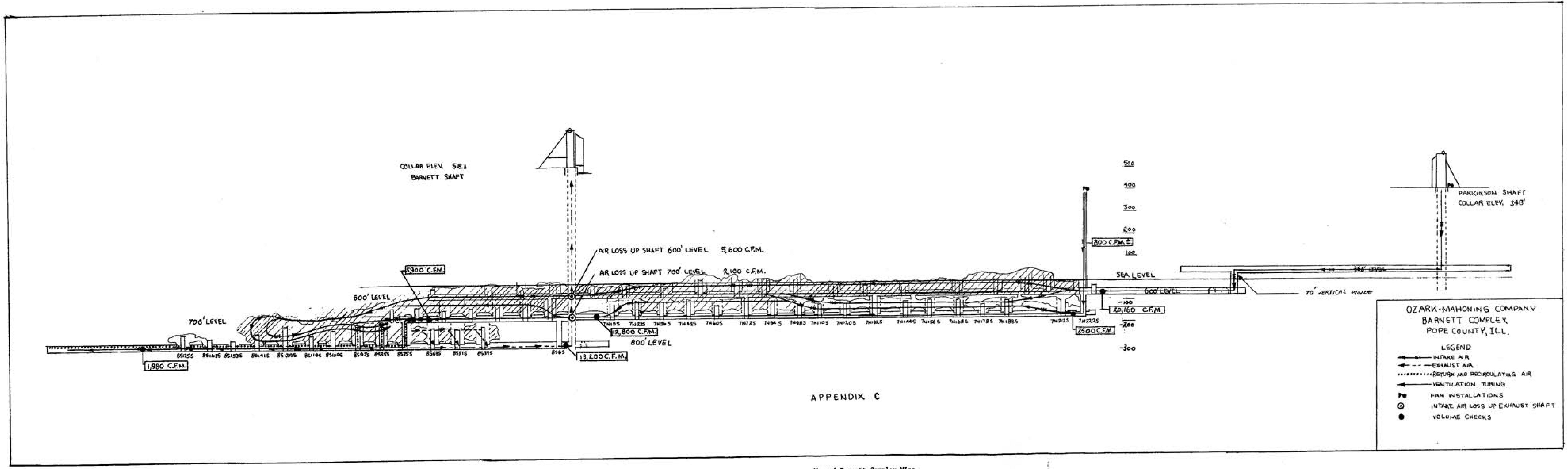
Note: Most of the material reported above was condensed from a paper by W. P. Yant, on Hydrogen Sulfide in Industry, Occurrence, Effects, and Treatment, that was presented in the Industrial Hygiene Section of the American Public Health Association at its Fifty-eighth Annual Meeting of at Minneapolis, Minnesota, October 4, 1929. This was published in the American Journal of Public Health, Vol. XX, No. 6, June 1930. At the time Mr. Yant was a Supervising Chemist, Health Laboratory Section, U. S. Bureau of Mines, Experiment Station, Pittsburgh, Pennsylvania.

Also, considerable data was taken from IC 7329 entitled, Hydrogen Sulfide Poisoning as a Hazard in the Production of Oil by Sara J. Davenport, July 1945.

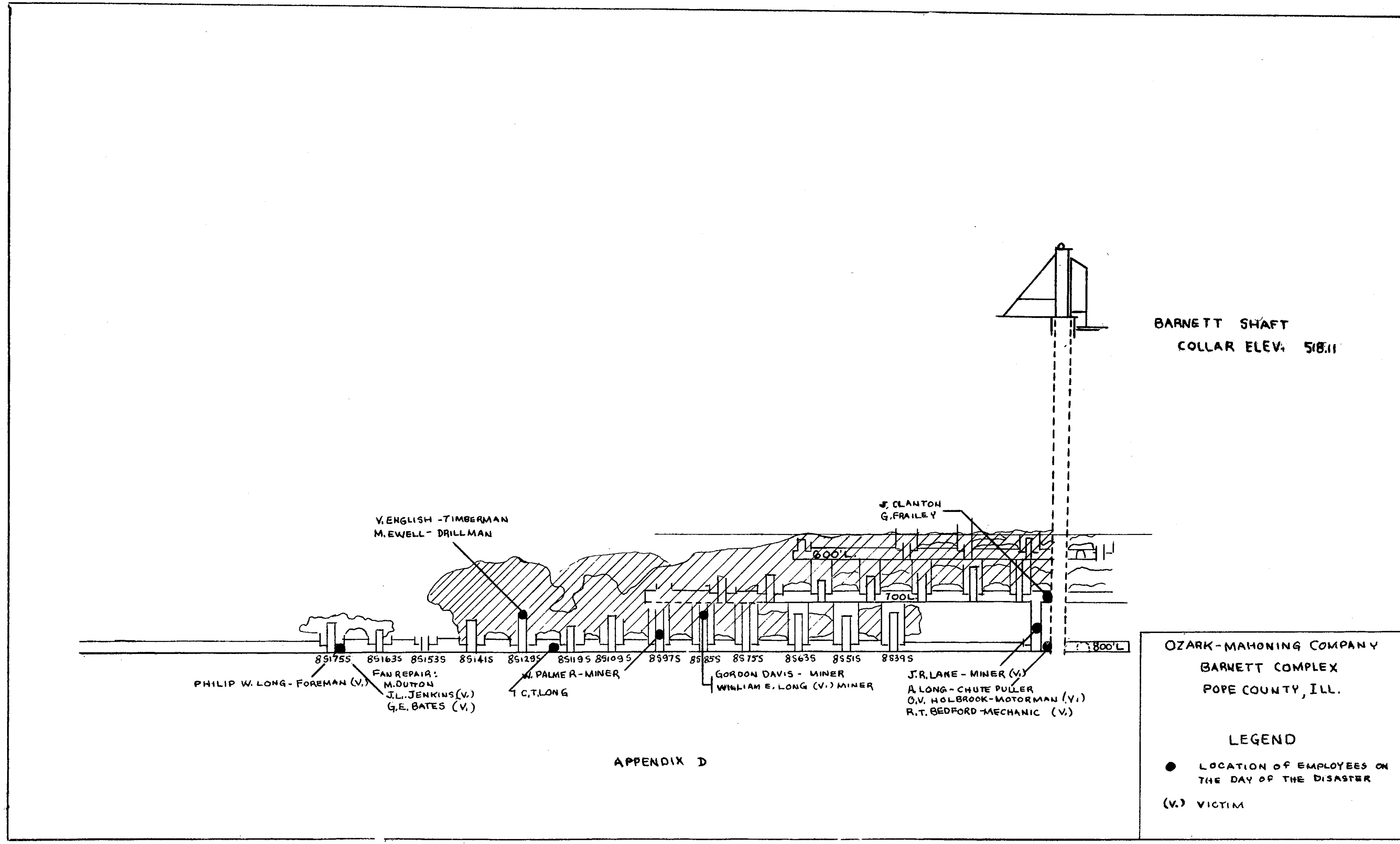
Although more recent Industrial Toxicology textbooks were consulted, the information presented by Mr. Yant was the most comprehensive and far reaching.



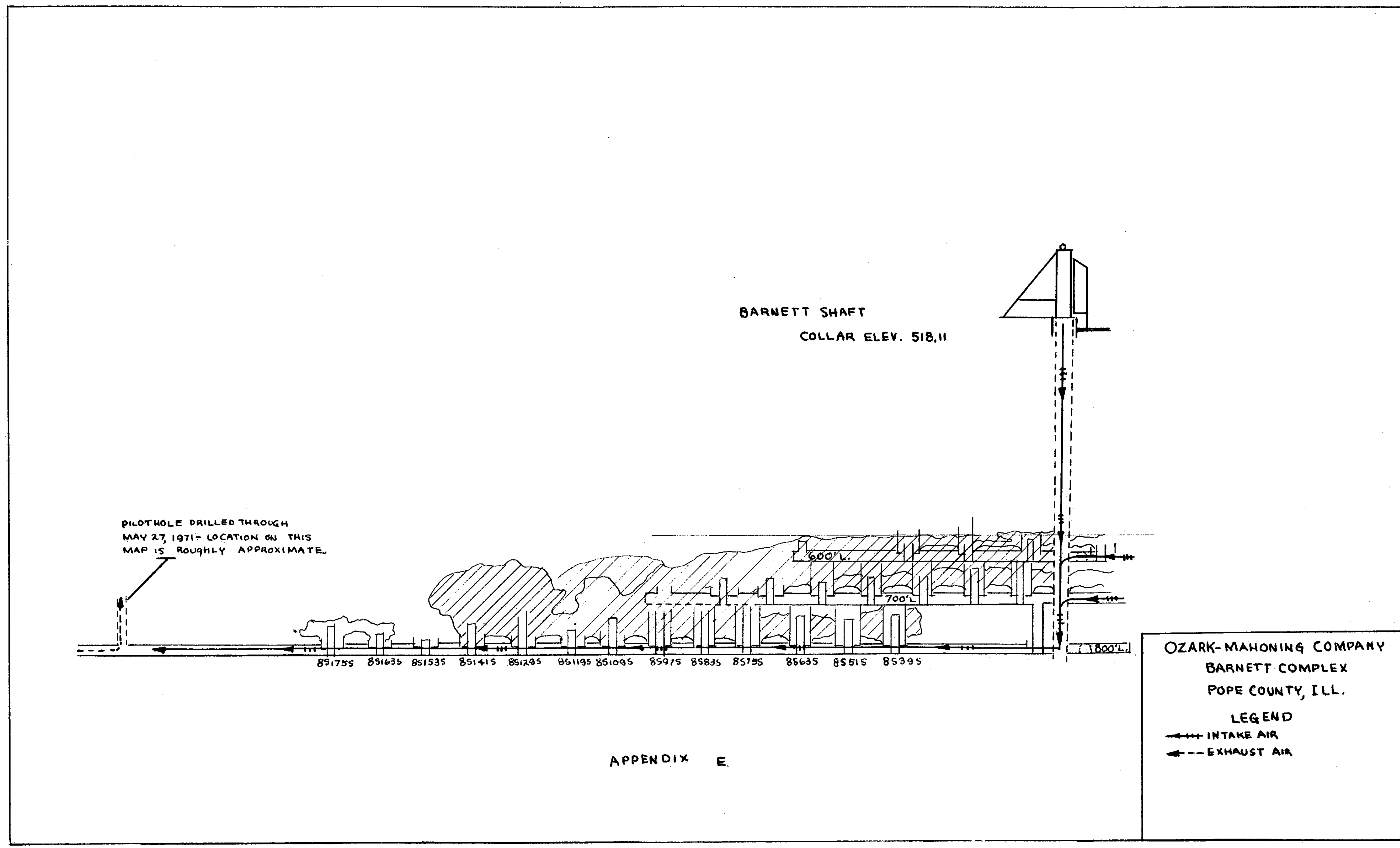
Map of Barnett Complex Mine Showing Disaster Area and Location of Victims



Map of Barnett Complex Mine
Showing Ventilation



Map of Barnett Complex Mine Showing Location
of Workers Prior to Disaster



Map of Barnett Complex Mine Showing Proposed
Change in Ventilation