Belle Isle Mine
Cargill, Inc
Franklin, St. Mary Parish, Louisiana
June 8, 1979

FINAL REPORT OF MINE EXPLOSION DISASTER
BELLE ISLE MINE
CARGILL, INC.
FRANKLIN, ST. MARY PARISH, LOUISIANA

June 8, 1979

BY

H. G. Plimpton
Subdistrict Manager
Salt Lake City, Utah

Ralph K. Foster
Mining Engineer
Denver, Colorado

John S. Risbeck
Supervisory Mining Engineer
Rolla, Missouri

Roy P. Rutherford
Mine Technical Specialist (Electrical)
Denver, Colorado

Richard F. King
Supervisory Mine Specialist
Denver, Colorado

Gary L. Buffington
Mine Specialist
Birmingham, Alabama

Warren C. Traweek
Mine Specialist
Tucson, Arizona

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SHOP TRUCK

A pick-up type truck used by maintenance personnel for supply and repair purposes.

SKIP

A conveyance attached to a wire rope (cable) and hoisting mechanism used for removal of rock or ore from an incline or vertical shaft mine.

SKIP POCKETS

An underground storage bin in which ore or waste rock is placed prior to being hoisted to the surface.

STOPE

An underground excavation resulting from actual mining of ore as distinguished from other excavations.

TUNNEL

Term used at the Belle Isle Mine to differentiate lower level entries from upper level entries. The upper level entries and tunnels are vertically separated by a 40-foot salt pillar.

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INTRODUCTION

This is an investigation report of a mine explosion disaster that occurred June 8, 1979, at the Belle Isle Mine, Cargill, Inc., near Franklin, St. Mary Parish, Louisiana, MSHA mine I.D. Number 16-00246. The investigation is made pursuant to the provisions of the Federal Mine Safety and Health Act of 1977, Public Law 91-173, as amended by Public Law 95-164 (30 USC 801 et. seq.).

The investigation was authorized by Thomas J. Shepich, Administrator, Metal and Nonmetal Mine Safety and Health, Mine Safety and Health Administration. The purposes of this investigation were: to determine the location and cause of the explosion, including conditions and practices at the Belle Isle Mine that resulted in the explosion; to make recommendations to prevent a similar occurrence; and, to examine the MSHA's related policies and practices.

Briefly, for the reasons set forth in this report, the investigators believe that the underground explosion was initiated in 8 Main Entry East near Room 10 where an explosive mixture of flammable gas was ignited by burning electrical conductor insulation, or arcing electrical wires, or both.

SUMMARY

On Friday, June 8, 1979, an outburst of flammable gases and salt occurred following a face blast in 8 Main Entry East at about 2300 hours, and a gas explosion occurred in the mine approximately 10 minutes later. At the time of the explosion, 22 persons were in the mine. Ten persons were on the upper level and twelve persons were on the lower level. Seventeen persons were rescued and five persons died as a result of the explosion.

A few minutes before 2300 hours, near the end of the shift, all employees left their working places with the exception of two men who were designated to initiate blasts in three working places charged with explosives. Twelve of the employees attended a scheduled meeting and eight employees were enroute to the No. 1 Shaft to be hoisted to the surface. The blasts were initiated from 7 Main Entry East at Room 13 by the two designated employees, and approximately 10 minutes later the explosion occurred. According to the autopsy reports, four of the fatalities occurred as a result of acute pulmonary hemorrhage secondary to alveolar rupture due to the air blast in the mine explosion. The fifth victim apparently died from a combination of acute pulmonary hemorrhage and carbon monoxide poisoning (See Appendixes C and D). The autopsy report on the fifth victim showed a carboxhemoglobin saturation of 75 percent. Three victims were found within 300 feet of the No. 1 Shaft Station. The fourth and fifth victims were found about 1,400 feet and 1,800 feet, respectively, from the No. 1 Shaft Station. All victims were recovered by mine rescue teams within 41 hours after the explosion. The rescue effort involved 73 dedicated mine rescue team members who assembled from local mines and from around the Nation and involved a total of 14 team entries into the mine in that period of time.

From a position of hindsight, there were a number of significant events which in combination should have established the forewarning of the potential disaster. However, when the events were considered one at a time, on a mine-by-mine basis, the overall significance was overlooked or lost. The multiple indicators of significant gas problems explained hereinafter in this report in the Belle Isle Mine were not adequately correlated by either MSHA or Cargill management.

MSHA'S INITIAL RESPONSE

Charles von Dreusche, Mine Manager, notified Wayne D. Kanack, District Manager, South Central District, Mine Safety and Health Administration (MSHA), Dallas, Texas, at 0030 hours on June 9, 1979, that an explosion had occurred at the Belle Isle Mine. Mr. Kanack was contacted moments before by James Hebert, Belle Isle Office Manager, who was at the Calumet Landing. Jay Durfee, Metal and Nonmetal Supervisory Mining Engineer, Baton Rouge, Louisiana, was informed of the explosion by Kanack at 0045 hours June 9, 1979. Mr. Kanack made contact with Roy Bernard, Deputy Administrator, Metal and Nonmetal Mine Safety and Health, MSHA, Arlington, Virginia, at 0145 hours on June 9, 1979, and he requested the assistance of the National Mine Rescue Team and the Mine Emergency Operations (MEO) Team for the disaster at Belle Isle (See Appendix S). Mr. Kanack then ordered the members of the MSHA Mine Rescue Team, Rolla, Missouri, to proceed to Belle Isle. Mr. Bernard immediately contacted Thomas Shepich, Administrator, John Waxvik, Acting Chief, Division of Safety, and J. D. Pitts, Safety Specialist, and the four of them arrived at MSHA's Headquarters Office by 0230 hours. They notified MSHA headquarters personnel who were on the Disaster Notification List. Mr. Waxvik and J. D. Pitts proceeded to notify the twenty-one National Mine Rescue Team members and ordered them to proceed to the Belle Isle Mine by the fastest available means (See Appendix R).

Jay Durfee and Jerry Millard, Metal and Nonmetal Mine Inspector, Baton Rouge, Louisiana, arrived at the mine office, Calumet Landing, Louisiana at 0315 hours on June 9, 1979. To control the mine recovery, a 103(k) order was issued to Roy Granger, Mine Foreman, by Jay Durfee at 0320 hours on June 9, 1979. Jay Durfee, Jerry Millard and a mine rescue team from International Salt Company arrived at the mine at 0430 hours on June 9, 1979, after being transported by helicopter from Calumet Landing. At that time, seventeen persons had been safety evacuated from the mine and sent to a hospital for treatment and observation. Five men were still underground, three of whom were known to be fatalities. At 0445 hours on June 9, 1979, Jerry Millard monitored the mine exhaust air at the collar of No. 1 Shaft and reported 0.8 percent methane and 700 ppm carbon monoxide.

MSHA's MEO Team, Pittsburgh Technical Support Center (PTSC) and Denver Technical Support Center (DTSC) were placed on alert by Donald P. Schlick, Director, Technical Support, for possible support of rescue efforts at the Belle Isle Mine about 0330 hours Saturday, June 9, 1979. At 0400 hours Jeff Kravits, Chief, MEO, directed deployment of the Communication/Control (C/C) van with two members of the Mine Emergency Operations Team and requested airlift service for MSHA personnel. The C/C van driven by John Hartman, Westinghouse, departed the staging facility, Pittsburgh, Pennsylvania, about 0515 hours on June 9, 1979, and arrived in the vicinity of the mine about 0800 hours on June 10, 1979.

Five chartered air flights were obtained on June 9, 1979, to airlift MSHA personnel and equipment from Pittsburgh, Pennsylvania and Denver, Colorado to the Patterson, Louisiana Airport which is located near the mine site.

On June 9, a plane left Pittsburgh at 0732 hours with Jeff Kravitz, MEO. James Banfield and Edward Miller, PTSC, aboard. J. D. Pitts boarded the plane en route, which arrived at the Patterson, Louisiana airport at 1050 hours. The personnel were transported to the mine by helicopter. MSHA personnel started installation of equipment for monitoring the exhaust air from the No. 1 Shaft.

A plane left Denver, Colorado, at 0830 on June 9, carrying Richard Kline and Ralph Foster, DTSC, plus self-contained breathing apparatus, 6 spare oxygen cylinders and gas detection equipment. The plane arrived at Patterson, Louisiana at 1410 hours and the passengers and equipment were transported by helicopter along with members of a rescue team to the mine site. The last flight arrived at Patterson at 0035 hours on June 10, 1979.

MEO activities on June 10 were directed toward setting up a base of operation at Cargill's Calumet Landing and in establishing radio communication between the mine site and the landing. MSHA's mine recovery efforts continued through July 19, when the C/C van and MEO support personnel were released. The C/C van returned to the staging facility on July 22, 1979.

GENERAL INFORMATION

The Belle Isle Mine is located along the Gulf Coast in St. Mary Parish, 19 miles southeast of Franklin, Louisiana. Belle Isle is one of a group of 5 underground salt mines located in similar domes in the area, each of which is operated by a separate company. The domes are known as Jefferson Island, Avery Island, Weeks Island, Cote Blanche Island, and Belle Isle. Although the surface elevation of the domes is not high, they came to be known as the Five Islands because they are mound-shaped and rise abruptly above the flat marsh lands. The locations are shown in Appendix A.

The land-side base of the Belle Isle Mine is known as Calumet Landing, which is located along U.S. Highway 90 on Wax Lake Outlet about 13 miles due north of the mine. Personnel and supplies were transported to the mine by boat. Salt shipments from Belle Isle were handled by an affiliated barge line.

The mine, which went into production late in 1962, was owned and operated by Cargill, Inc. The principal officers associated with Cargill, Inc., were headquartered in Minneapolis, Minnesota (See Appendix E).

Total employment was 89 persons, 75 of whom worked underground. The mine was operated 2 shifts a day, 5 days a week.

Access into the mine was through the No. 1 and 2 Shafts, which were 1,253 feet and 1,225 feet deep, respectively. These shafts were located near the north boundary of the mine.

The last regular Federal inspection of the mine was completed on April 12, 1979. A subsequent compliance follow-up inspection was completed on May 31, 1979. The mine was not classed gassy at the time of the explosion.

GAS OUTBURST PHENOMENOM IN LOUISIANA SALT MINES

Outbursts of high-pressure gases with salt out of pressure pockets in Louisiana salt mines have been documented for many years. The phenomenon has been documented in every conventionally mined Louisiana salt dome except Avery Island. The mine in the Avery Island dome has been mined at more shallow depths than the other domes until recently. It has been postulated that outbursts, at least down to the deepest depths now being mined, are more likely to be experienced with increased depth. In the Louisiana salt domes, outbursts of noteworthy size occur when salt with high-pressure gases entrained in the rock structure is penetrated by mine openings. The gas-stressed salt is oriented vertically and can extend several hundred feet in elevation. These gaseous entrainments are commonly referred to as "pressure pockets". The rather smooth-walled symmetrical shaft-like opening left in the back by outbursts are often referred to in Louisiana as "blowouts". One blowout cavity at another mine has been measured to be about 80 feet across and 280 feet high into the back. Mine blowout cavities which cannot be safely approached for detailed examination may exceed 280 feet in height. Of the five conventionally-mined domes in Louisiana today, the Belle Isle Salt Dome probably has released the greatest number of outbursts that have produced blowout cavities of noteworthy size. In Louisiana, reliably documented outbursts have always been triggered by blasting.

The salt and gases during an outburst can release with explosive force. It has been reported1/ that 15,000 tons of salt was expelled from a blowout by entrained gas pressures estimated at 80 atmospheres in the Belle Isle Mine. The gas was thought to have expanded to more than 1 million cubic feet in the mine. Ten outbursts that produced blowout cavities of significant size have occurred in Belle Isle. The blowout locations are shown in Appendix F. Six outbursts in Belle Isle, including the one on June 8, 1979, have occurred in an East-West zone that parallels the 8 Main Entry East.

1/ MSHA Storage Task Force. "Fact Finding Investigation of Southern Louisiana Salt Domes", p. 27, Golder Associates, "Geotechnical Study of Cote Blanche Island Salt Mine", Consultant Geotechnical Engineers, Vancouver, B.C., Canada, October, 1977.

The latest outburst, which fueled the mine explosion, occurred in the east face heading of 8 Main Entry East, inby Room 13.

INTENSIVE SAMPLING PROGRAM

On June 18, 1979, as one result of the disaster at Belle Isle, an intensive sampling program began at the other salt dome mines along the Louisiana coast to establish with certainty the exact presence of flammable gas in each mine. This intensive sampling program confirmed that three of the other four mines had similar flammable gas problems, and they were classed as gassy. One mine, Avery Island, was not found to have a concentration of flammable gas over 0.25 percent. (See Standard 57.21-1, see below).

The explosion has obviously affected that part of the underground salt mining industry which is now required to comply with the gassy mine standards, and in some instances, petitions for modification have been filed under Section 101 (c) of the Act. Some companies have alleged that certain standards are inappropriate for salt mining. In the event a mine operator desires a modification from the application of any safety standard, Section 101 (c) of the Act provides a special procedure for obtaining a modification from the specific requirements of a safety standard where the modification would provide at least as safe conditions as compliance with the standard.

GASSY MINES

Based on the information available at the time this report was written, MSHA's (formerly the Bureau of Mines and MESA) National policy for classifying mines gassy prior to and on June 8, 1979, was based on the four criteria contained in standard 30 CFR 57.21-1. Standard 57.21-1 states that:

> 57.21-1 Mandatory. A mine shall be deemed gassy, and thereafter operated as a gassy mine, if:
>
> (a) The State in which the mine is located classifies the mine as gassy; or
>
> (b) Flammable gas emanating from the ore-body or the strata surrounding the ore-body has been ignited in the mine; or
>
> (c) A concentration of 0.25 percent or more, by air analysis, of flammable gas emanating only from the ore-body or the strata surrounding the ore-body has been detected not less than 12 inches from the back, face, or ribs in any open workings; or
>
> (d) The mine is connected to a gassy mine.

This mandatory standard was derived from recommendations made by an Underground Advisory Committee (UAC) to the Secretary of the Interior. The recommendations were based on criteria used in the Federal coal mine safety program for classification of coal mines. The standard was promulgated on July 31, 1969 (34 FR 12526) after being published as a proposed rule on January 16, 1969 (34 FR 691).

In response to a request for comments on the proposed rule, The American Mining Congress indicated by a letter of April 30, 1969 that the UAC:

> ". . . recognized that a gassy metal or nonmetal mine was distinctly different from a gassy coal mine. This difference was in two basic characteristics: (1) The potential emanation rate of methane in a gassy metal or nonmetallic mine may be much lower than in most gassy coal mines; and (2) The product being mined is noncombustible in most metal and nonmetallic mines. Safety standards of gassy metal and nonmetal mines need not be the same as those applicable to gassy coal mines."

The Salt Institute also commented in a letter of April 28, 1969, that:

> "Another major item of concern involves the Paragraph 57.22-1 (renumbered 57.21-1), which outlines criteria for deeming a mine 'gassy'. Salt mines have not been considered 'gassy' nor should they be. However, mines are considered gassy according to sub-paragraph (b) if: 'Flammable gas emanating from the ore-body or the strata surrounding the ore-body has been ignited in the mine'."
>
> "Rarely is gas encountered in rock salt deposits and then only in minute amounts. The quantity of gas has never approached explosive proportions, nor is it at all likely to. The large volumes of air in salt mines preclude this. To classify salt mines as 'gassy' would unduly penalize the salt industry, and we respectfully request clarification of the definition, or a ruling that salt mines are not considered 'gassy'."

After considering these comments and others, the Secretary of the Interior issued the standard without change in the proposed wording.

Generally, the reason for classifying a mine as "gassy" is to warn everyone in the mine, e.g., the mine operators, workers, and inspectors that a dangerous condition may arise if certain precautionary measures are not followed. Gassy mines must be operated in accordance with all the mandatory standards issued in Part 57 including the 63 standards in Section 57.21 which apply specifically to such mines. Section 57.21 has a classification standard and 5 categories of mandatory safety standards which are fire prevention and control, ventilation, equipment, illumination and explosives.

Among the added safeguards are: a prohibition against smoking or carrying smoking materials, matches, or lighters underground; main fans must be installed on the surface; daily inspections of main fans and keeping logs of these inspections and of fan maintenance; main intake and return air currents in mines must be in separate shafts; slopes, or drifts except during shaft or slope development when a curtain wall or partition must be used; withdrawal of persons and power de-energized in affected active workings when there is a failure of mine ventilation; volume and velocity of the current of air coursed through all active areas must be sufficient to dilute, render hanmless, and carry away methane, smoke, fumes, and dust; the quantity of air coursed through the last open crosscut in pairs or sets of entries, or through other ventilation openings nearest the face must be at least 6,000 cubic feet per minute, or 9,000 cubic feet per minute in longwall and continuous miner sections; withdrawal of persons if 1.5 percent or higher concentration of methane is present in air returning from an underground working place or places, or is present in air not less than 12 inches from the back, face, or rib of an underground working place; only permissible equipment maintained in permissible condition must be used beyond the last open crosscut, or in places where dangerous quantities of flammable gases are present or may enter the air current; and, only permissible explosives, as designated permissible by the Bureau of Mines or MSHA, may be used in any gassy underground mines, except that non-permissible explosives may be used only when MSHA and the State Inspector of Mines have given their written approval for each non-permissible explosive to be used.

It should also be noted that Congressional concern regarding excessive liberations of methane or other explosive gases was reflected in the Federal Mine Safety and Health Amendment Act of 1977 (Public Law 95-164) in modifications of Section 103(i) of the Federal Coal Mine Health and Safety Act of 1969 (Public Law 91-173). 2/

2/ Section 103(i) of the Act requires:

Whenever the Secretary finds that a coal or other mine liberates excessive quantities of methane or other explosive gases during its operations, or that a methane or other gas ignition or explosion has occurred in such mine which resulted in death or serious injury at any time during the previous five years, or that there exists in such mine some other especially hazardous condition, he shall provide a minimum of one spot inspection by his authorized representative of all or part of such mine during every five working days at irregular intervals. For purposes of this subsection, "liberation of excessive quantities of methane or other explosive gases" shall mean liberation of more than one million cubic feet of methane or other explosive gases during a 24 hour period. When the Secretary finds that a coal or other mine liberates more than five hundred thousand cubic feet of methane or other explosive gases during a

Standard 57.21-1 generally was adhered to and resulted in several metal and nonmetal mine gassy classifications after the standard was promulgated. However, it should be noted that prior to June 8, 1979, all salt mines had been operated as non-gassy mines. The various MSHA District Offices generally were permitted to apply the gassy classification standard according to their own interpretation in relation to specific situations.

There did not appear to be any problem in the South Central District with the interpretation of sub-paragraphs (a) or (d) of the standard. However, there were apparently problems with the interpretation of key words in sub-paragraphs (b) and (c) by MSHA personnel, particularly the words "emanating", and "ignited", and what constituted an "ore-body or the strata surrounding the ore-body". For example, the word "emanating" seemed to imply a degree of constant liberation as opposed to rapid, short-term release of entrapped gases. It also was felt the word indicated an ability to flow or migrate freely throughout the ore-body or strata instead of being entrapped in isolated pressurized pockets. There also were questions about the application of the terms "back", "face", "rib", "air analysis", and "flammable gases" as they relate to gas sampling. The Dallas District and subdistrict office felt that in relation to salt mines the language of standard 57.21-1 was subject to challenge and would be difficult to defend. South Central District policy prior to June 8, 1979, for classifying salt dome mines gassy, was strongly influenced by the personal opinions of some management individuals. These opinions were partially based on concern for the economic impact of the gassy classification on the salt dome mines and on individual desires to avoid legal challenge to classification.

Within South Central management there was widespread feeling that with occasional government pressure the Belle Isle Mine had taken adequate steps to control concentrations of flammable gas by ventilation. There was some knowledge of the major gas outbursts and resultant excessive concentrations but they were considered to be unusual occurrences and not related to the intent of the gassy mine standards.

2/ Continued.

24-hour period, he shall provide a minimum of one spot inspection by his authorized representative of all or part of such mine every 10 working days at irregular intervals. When the Secretary finds that a coal or other mine liberates more than two hundred thousand cubic feet of methane or other explosive gases during a 24-hour period, he shall provide a minimum of one spot inspection by his authroized representative of all or part of such mine every 15 working days at irregular intervals.

HISTORICAL BACKGROUND

Belle Isle

Belle Isle is the easternmost of Louisiana's historic five islands which have served as prominent landmarks along the coastal lowlands throughout modern history. In early times the Isle remained remote and isolated except for occasional visits by explorers, pirates, plantation owners, miners, and industrialists. Belle Isle covers approximately 240 acres rising to a height of 80 feet above sea level.

Early settlers recognized that Belle Isle's shape conformed to that of a salt dome long before this fact was confirmed through geologic exploration. Accepted theory is that Belle Isle and the adjacent islands were formed through vertical movement of the salt dome into overlaying sediments because of differences in specific gravities. Although salt at the surface is heavier than surrounding newly-deposited sediments, at great depth compacted sediments become heavier than non-compactable salt causing the salt to rise buoyantly through the sediments. Belle Isle reflects surface displacement by a rising dome (See Appendix B).

The first modern effort to tap Belle Isle's mineral resources was in 1869 when an exploratory well was drilled to locate and describe the contour of the salt mass and to test for oil and gas deposits. Later wells sought commercial quantities of sulphur. By 1898 a total of 17 wells had been put down, primarily to determine the extent of salt deposits.

Around 1900 two unsuccessful attempts were made to sink shafts for rock salt mining. One, at a depth of about 390 feet was flooded in 1899 when the underground workings penetrated the dome flank. Another was abandoned due to difficulty in controlling water saturated sand at approximately 210 feet, just short of the salt deposit. Explosive petroleum gases were reportedly encountered during sinking of one of these shafts. An evaporation project was begun about 1903 in an attempt to recover salt dissolved by water forced into the dome through an encased shaft. The operation was abandoned when traces of oil in the brine resulted in an inferior salt product. A brick smoke stack and stone building from this effort still stand near the present mine surface facilities.

Later explorations included three oil test holes drilled in 1907-1908, six sulphur probes in 1916-1917, ten sulphur and oil tests in 1921-1925, and seven sulphur attempts in 1929-1930. Throughout this early drilling, high-pressure gas pockets were logged from depths of about 335 feet down, although not all holes encountered gas. Sun Oil Company began successful oil drilling operations in the 1930's which resulted in that firm's present Belle Isle refinery.

The Mine

Cargill Inc. (Cargill) began surveys and test drillings in 1960 and the present No. 1 Shaft into the salt dome was started the following year.

To avoid flooding and cave-in during the shaft sinking process the surrounding ground was artifically frozen. The process of freezing, sinking, and shaft concreting continued to a depth of 350 feet until well inside the salt dome where a concrete sealing collar was constructed. Below this level the shaft was timbered to its maximum depth of 1,253 feet.

Commercial operations began in 1963 with projected production of 400,000 tons annually which increased rapidly as sales rose. In 1967, the mine crushing and screening plant was moved underground for greater efficiency and improved warehousing. By early 1968, capacity had roughly quadrupled to about 1,600,000 tons annually and Cargill had become one of the Nation's leading rock salt producers.

1968 Fire Disaster

A major mine fire disaster occurred on Tuesday, March 5, 1968, about 2330 hours in the Belle Isle Salt Mine, while 21 men were working underground. There were no survivors; 20 died of carbon monoxide poisoning, and one as the result of a massive skull fracture. Although every piece of available evidence was examined in detail during an investigation which lasted nearly six months, neither the cause of the fire nor the point of its origin could be definitely established. Apparently the fire originated in the lower part of the shaft, at or below, the mining level. The cause could have been an electrical fault, or the use of an oxyacetylene torch, or frictional ignition of a belt conveyor, but the evidence did not clearly favor any one of the three possibilities. Direct property damage was confined to the mine shaft and its equipment. The Bureau of Mines Report on this disaster, which included a ventilation and gas section, reflected that examinations for methane were not made during normal mine operation. Prior to 1968, gas ignitions had occasionally occurred in the kerf while undercutting in areas where a shale streak appeared in the salt. From the characteristic odor and instrument tests, the flammable gas had been taken to be hydrogen sulfide. However, it is probable that the principal constituent of the ignited gas was methane, because a flammable concentration of hydrogen sulfide is a highly lethal mixture and mine workers had not experienced even slight symptoms of hydrogen-sulfide poisoning. Methane and hydrogen sulfide have been found in association in salt mines in the vicinity of shale occurrences. Analysis of samples collected during the shaft fire recovery operations, in the absence of positive ventilation, indicated the presence of 0.09 percent methane (4 separate bottle samples taken on March 13, 1968). Methane was dispelled as a factor in the cause of the fire. However, the present investigation has revealed that methane at this concentration could be associated with gas outbursts. A map included in the Bureau of Mines Report showed that face advancement had progressed to 2 Main Entry South, 4 Main Entry West on March 5, 1968. When the map is compared with Appendix F, it is apparent that at some point in time a pressure pocket was intersected at this location.

No. 2 Shaft

Preparations for sinking the No. 2 Shaft at Belle Isle Salt Mine began in 1969. The No. 2 Shaft is located 380 feet southwest of the No. 1 Shaft. The total depth of the No. 2 Shaft is 1,225 feet. Shaft sinking was accomplished by conventional methods and was completed in December, 1970. The shaft was lined and turned over to Cargill on April 1, 1971. The shaft was used to handle large equipment, as the intake (downcast) airway, and as an emergency exit.

On February 27, 1973, an unusual amount of water was noted at the shaft bottom. During a shaft inspection, a stream of water was noted on the northwest side of the shaft at the bottom of the concrete liner. An attempt to stop the inflow of water by grouting was unsuccessful. The water in the shaft was continually monitored and numerous attempts were made to save the shaft. On March 8, 1973, at approximately 1100 hours, the first surface subsidence occurred. Ground tremors were felt, and a crater developed about 40 feet south-southeast of the No. 2 Shaft near the shop building. Some ground movement continued throughout the day. It was thought from the sounds heard at the collar that a large amount of water was running into the mine. However, underground inspections conducted after the accident revealed that the expected large amount of water had not entered the mine.

On March 9, 1973, at approximately 1100 hours, a second subsidence began which resulted in the collapse of the shaft and formation of a surface crater about 200 feet in diameter and 50-60 feet deep. The first evidence of the total shaft collapse was that the rope guides tightened and broke. Within the next 10 to 15 minutes the following structures and equipment disappeared from the surface:

- The 30- by 90-foot shop building including its foundation and concrete floor.
- The eight-foot Axivane, 220,000-cfm fan.
- Thirty feet of air duct extending from the fanhouse to the shaft.
- The fanhouse.

- The cage and counterweight.

- Concrete shaft collar.

- The 65-foot headframe with backlegs and concrete backleg footings.

- Twenty-seven freeze pipes -- 266 feet long.

- Approximately 40 pilings from 40 to 60 feet long.

In addition, the No. 2 Shaft hoist house and adjoining transformer installation slid several feet toward the crater and were damaged extensively. The No. 1 hoist house also was displaced on its foundation, by approximately eight inches, and use of the hoist was condemned by MESA until September 29, 1973, when it again became fully operational.

Belle Isle was evacuated March 9, 1973 by Cargill at approximately 1115 hours. The situation was continuously monitored by Cargill over the next few days. Plans were made to backfill the crater with sand and make some exploratory trips underground. By March 15, 1973, conveyors had been set up and barge loads of sand were being delivered to the mine. On March 17, 1973, a small diesel-powered hoist was installed at the No. 1 Shaft to be used for recovery work in the mine. This hoist was used to transport men and materials into the mine. The temporary diesel-powered hoist was used between March 17 and September 29, 1973. Also, on March 17, 1973, the Bureau of Mines collected three bottle air samples at separate locations in the mine. All three samples indicated a presence of 0.03 percent methane. From the results of the Bureau's inspection conducted on March 19, 1973, calculations were made of the cubic yards of material and gallons of water in the mine. These calculations indicated that approximately 38,000 cubic yards of material and 1,500,000 gallons of water had entered the mine.

The company made general plans to recover the No. 2 Shaft. This was to be accomplished by filling and stabilizing the surface, then freezing both the top sediments and the material presently in the shaft, and sinking the shaft again through the frozen ground.

On July 20, 1973, at 1730 hours, an accident occurred involving the small diesel-powered hoist. Four men were on the cage at the time of the accident. The cage dropped approximately 50 feet. Three men received injuries that included a broken ankle, sprained ankle, and slight bruises to the face. The fourth man was uninjured. The cause of the accident was failure to have the jaw-clutch locked in when the brakes were released.

A leak also developed in the No. 1 Shaft shortly after the collapse of the No. 2 Shaft. The leak was sealed by pumping grout into holes drilled through the shaft lining. Over 1,000 bags of cement and 1,500 gallons of AM-9 chemical grout were injected at pressures below 100 psi.

1974 MESA Ventilation Survey

Following the collapse of the No. 2 Shaft in March, 1973, the mine ventilation system was modified by partitioning the single remaining shaft into exhaust and intake compartments. Dependent on the location underground, the ventilation was marginal or inadequate for dilution of diesel emissions from production equipment. Mining Enforcement and Safety Administration (MESA) inspectors began to record high concentrations of oxides of nitrogen and carbon monoxide. By early 1974 such readings occurred frequently enough that the MESA Subdistrict Manager, Dallas, Texas, requested a Belle Isle Mine ventilation evaluation by MESA's DTSC. The survey was conducted July 22-25, 1974, and resulted in 16 recommendations for ventilation improvement. The survey was requested in response to diesel emissions and was not directly related to strata or ore-body gas occurrences. A single vacuum sample obtained on the 1,160 foot shaft station revealed a trace amount of methane (0.01 percent), that was not considered to be of concern.

1975 Electrocution

On May 28, 1975, a mine electrician was electrocuted while working in the resistance gridroom in the No. 1 Shaft hoist house. The investigation revealed that the circuit the electrician was working on was not locked out.

Cargill Long Hole Probes and Gas Analysis

Sometime after July 1975, Cargill subcontracted the drilling of seven core holes which were to be drilled in different sections of the mine. Six of the holes ranged in lengths from 800 to 1,200 feet, and one hole was about 400 feet. Reportedly, the purpose for core drilling was to explore for:

1. the dome flank and the mining boundary;
2. water (including quantity and pressure);
3. salt grade levels; and
4. high-pressure methane gas.

If methane was encountered, the concept was to use the core holes to bleed off gas pressure. High-pressure gas was in fact encountered during the drilling of some of the holes. On one occasion between shifts several hundred feet of drill steel reportedly blew out of one of the holes and was wrapped in spaghetti-like fashion along the drift. The holes were drilled through a 21-foot schedule 80 stand pipe that was pressure grouted into the face. When the drilling was completed the stand pipes were capped and pressure gages were installed on some of the holes. The pipes were capped to control the bleeding of methane gas into the workings. Cargill officials did not want dangerous accumulations of methane in the working faces. The maximum gas pressure measured from the drill holes was approximately 1,200 to 1,250 psi. The subcontracted core drillers monitored for methane gas with hand-held methanometers during the drilling of the holes; however, no vacuum samples were taken at that time. Concentrations of methane gas were in sufficient amounts for the Cargill mining engineer to consider using the methane gas commercially to heat oyster shells to make a soda ash by-product. This idea was never presented to Cargill management by the mining engineer and consequently it was not developed.

Cargill eventually purchased a Sprague and Henwood Model 142 C.L. core drilling machine to continue the above drilling program. The purpose of continuing the program was strictly to gain knowledge about gas and, if it was encountered to bleed the gas through the core holes into the mine atmosphere. Three holes, 450 to 500-feet in length, were drilled at the south end of the 1 Main Entry South. The holes were drilled through a stuffing box. The water and drill cutting returns were diverted from the end of the stand pipe through an elbow in the stuffing box, and the return line extended out behind the drillers. During drilling of the first hole, high-pressure gas was encountered which caused the return line to start whipping around the drift trapping both drillers inby the face. To prevent any future occurrences, the return line was anchored through H-beams which weighed about 60 pounds. During the drilling of the holes the drillers monitored only for methane gas using hand-held methanometers; no vacuum samples were taken at this time. On occasion the methane concentrations were sufficient to peg the scale on the methanometer (in excess of five percent methane) according to Cargill officials. It should be noted that the readings were taken directly in front of the drill holes. No formal records were kept of the methanometer readings.

Reportedly, a bottle sample was drawn from a stand pipe and the analysis revealed concentrations of about 95 percent flammable gases. A vacuum sample was analyzed on May 31, 1976 for Cargill by Southern Petroleum Laboratories, Inc., Lafayette, Louisiana. (Certificate of analysis No. 63970,

Appendix JJ). This sample is believed to have come from within one of the high-pressure stand pipes previously mentioned. The gas spectrometer analysis indicated the following concentrations of flammable gases:

	Wt. %	Mol. %
Methane	84.15	92.47
Ethane	.32	.19
Propane	.05	.02

The core drilling program was discontinued after approximately two months. Information available showed there was disagreement as to why the program was discontinued. Some people indicated there was a shortage of production personnel and that the trained core drill operators bid on other jobs. Others indicated the program was discontinued because too much methane was encountered. Cargill still had the core drilling machine on June 8, 1979.

October 1975 Gas Outburst

According to Cargill representatives, a large gas outburst occurred in 7 Main Entry West adjacent to Room 4, October 1, 1975. This outburst released an estimated 800,000 to 1.2 million cubic feet of methane and resulted in 35 to 40 thousand tons of broken salt. This information appears to correspond to statements provided to the MSHA underground task force in March of 1978. (See footnote 1 in the section entitled, "Gas Outburst Phenomenon in Louisiana Salt Mines").

Sufficient quantities of methane were measured at 7 Main Entry West by Cargill representatives with hand-held instruments to shut down the area until October 6, 1975.

MESA inspection reports show that an inspection was conducted at the Belle Isle Mine on October 20-24, 1975. One of four air samples sent for analysis reported the presence of 0.04 percent methane in 1 Main Entry South. Two samples were not analyzed because they arrived with the caps off. The fourth sample indicated zero percent methane in the intake air at the No. 1 Shaft.

January 1976 MESA Ground Control Evaluation

In November, 1975, the MESA Dallas Subdistrict Manager requested a DTSC evaluation of salt mine pillar slab conditions characteristic of the Louisiana mines. The study was conducted January 20-21, 1976, and produced recommendations and criteria for evaluation and removal of the slabs. Mine atmosphere sampling was not within the scope of the assignment and the study was not related to gas outbursts, emissions or ignitions.

February 1976 Gas Outburst

On February 19, 1976, a production face blast was initiated in 6 Main Entry West adjacent to Room 5. The blast triggered a gas outburst that released an estimated 25 to 35 thousand tons of broken salt and liberated sufficient quantities of methane to cause Cargill to shut down the mine for approximately six days.

On the following day, February 20, 1976, methane concentrations were measured in excess of four percent at the shaft collar by mine management. The readings were obtained from total mine exhaust air with a hand-held methanometer.

According to Cargill officials, the outburst, methane readings, and shutdown of the mine were reported to MESA on Friday, February 20, 1976.

On Monday, February 23, 1976, a MESA Baton Rouge Field Office Inspector was sent to the property by the Dallas Subdistrict Office. The inspector was under the impression that his instructions from Dallas were to do what was necessary, but that a gassy classification of the mines was not wanted.

The mine remained closed for three additional days after the inspector arrived. During this time sampling was confined to exhaust air monitoring at the surface. MESA readings consisted solely of hand-held methanometer readings reportedly below the 0.25 percent "legal" limit. No written record was made of the MESA surface sampling. On Tuesday, February 24, 1976, a Cargill official accidentally damaged the MESA methanometer and the inspector temporarily left the site to obtain another instrument.

Re-entry into the mine was made on Thursday, February 26, 1976, at which time, the MESA inspector obtained both methanometer and vacuum samples. No analysis exceeded 0.20 percent methane.

March 1976 MESA Methane Memorandum

On March 23, 1976, a memorandum was issued by the MESA Dallas Subdistrict Manager to all subdistrict personnel concerning methane in underground salt and potash mines. (See Appendix KK). The memorandum confirmed that inspection personnel consistently encountered methane gas in salt and potash mines and after setting forth standard 57.21-1, all personnel were instructed to call this standard to the attention of mine officials. The memorandum further "emphasized that any deterioration of mine ventilation systems could easily set up a condition wherein the concentration of methane--12 inches from the back, face, or ribs--at some place in the mine could exceed 0.25 percent (subsection (c) of the standard). Additionally, if strata gas is ever ignited in the mine--no matter what the source of ignition--subsection (b) of the standard would apply". The personnel were instructed to maintain a constant vigilance for the presence of methane gas in the mine atmosphere, to make direct-reading (methanometer) tests for methane and other gases in addition to vacuum samples taken in the return (exhaust) air, poorly ventilated areas, and any other area where the methanometer indicated the presence of methane, and to keep accurate records. The penultimate paragraph stated:

> "We do not want to classify any mine gassy; but neither do we want to remove 'bodies' from a mine. Witness the recent disaster in Kentucky."

Notwithstanding this memorandum, the Belle Isle Mine was not classified as a "gassy" mine until after the explosion. During this investigation it was evident that the paragraph was interpreted by some inspectors to mean that methane concentrations found in these mines were to be controlled by mine ventilation systems, without a gassy classification.

The investigation revealed that the memorandum was not all inclusive and there was a great deal of confusion among the South Central district, subdistrict, field office supervisors and inspectors as to what constituted location of the face, ribs, and roof in different mining configurations. Examples of these misconceptions are:

1. The toe of the slope of broken salt from a blasted face was construed as the face and samples could not be taken on top of a blasted muck (salt) pile.

2. A brow in a face established the imaginary plane of the face and the sample had to be taken more than 12 inches from that plane. The lowest point along the roof established a plane and the roof sample had to be taken more than 12 inches from this imaginary plane.

3. Companion samples (two or more) were required in the same location.

4. A "legal" sample could not be taken when a ventilation fan was located in the work area and was not running.

May 1976 MESA/Industry Meeting

On May 27, 1976, a meeting between the five salt dome mine operators and MESA's Dallas, Texas, Subdistrict staff was held at a restaurant in New Iberia, Louisiana. The meeting was called after the subdistrict had compiled data from methane samples taken at the properties between January 1974 and May 1976. A review of the data alarmed the subdistrict manager who arranged the meeting to advise the companies of his concern.

Of the 140 methane samples contained in the compilation only two actually exceeded 0.25 percent although 108 others indicated presence of methane. The two samples in excess of the limit, while not at the Belle Isle Mine, had both been marked "not legal" at the subdistrict level. The subdistrict manager and Dallas field office supervisor ruled that the samples were "not legal" following detailed questioning of the inspectors regarding their sampling procedure. The inspectors maintained that the samples were taken in a legally supportable manner.

June 1976 Wyoming Trip

In June 1976, the MESA Baton Rouge field office supervisor was sent by his district manager to Green River, Wyoming. He accompanied local MESA inspectors while they inspected a gassy trona mine in Wyoming. The purpose of this trip was to observe procedures for inspecting gassy mines in accordance with the gassy mine standards.

July 1976 MESA Ventilation Survey

A ventilation survey was requested by the MESA South Central District Manager. The ventilation survey was conducted at Belle Isle Mine by two DTSC ventilation engineers during July 13-15, 1976. The purpose of the study was to evaluate the existing ventilation system and to offer assistance and recommendations to the mine management for improvements in the system. The two DTSC engineers were accompanied by four of MESA's Baton Rouge inspection personnel and a mining engineer employed by Cargill.

The general mining method and ventilation system as described in the ventilation survey dated July 22-25, 1974, were found to be essentially unchanged during the July 1976 survey. However, since the 1974 ventilation survey, the mine layout had been altered to provide larger supporting pillars. The surface fan had been replaced by another fan, and the blade setting of the booster fan located at the base of the mine shaft had apparently been changed. The resinking of the No. 2 Shaft (following the subsidence) had progressed to about 600 feet below the surface at the time of this ventilation study. The shaft sinking contractor projected that this shaft and other related underground development work would be completed within six months. Ventilation would then be accomplished by drawing fresh air down the new shaft by means of a new Joy Model H-84-50-DS fan located underground. After distributing air to the working areas, it would exhaust through the existing shaft. The new fan was underground during this visit, but had not been assembled.

The 1976 study concluded that only recommendation number 3 from the 1974 report could be considered as having been heeded or acted upon. There were a total of 16 recommendations made in the 1974 report. The number 3 recommendation reads as follows: "Sinking of the second shaft should be conducted aggressively and completed as expeditiously as possible." It should be noted that the No. 2 Shaft sinking had been completed on April 1, 1971, and had been in continuous use since that time up to the shaft subsidence on March 8, 1973. It was decided by Cargill shortly after the shaft subsidence to resink the No. 2 Shaft. This was several months prior to the July 1974 ventilation survey.

During the survey, the DTSC ventilation engineers were shown "stand pipes" in the 2 Main Entry South face by the Cargill Mining Engineer and were told that the pipes went into high-pressure zones of gas. The pipe valves were located in the 2 Main Entry South face according to the DTSC Engineers. One of the pipes had a valve on it and the MESA Baton Rouge, Louisiana Field Office Supervisor participating in the survey asked what would happen if the valve was opened. The Cargill mining engineer stated that methane would come out of it. The MESA supervisor asked him to open the valve, and when the Cargill mining engineer opened it, a strong force of water spray came out. The Cargill engineer stated that the valve should be shut off before all the water drained off or 100 percent methane would come out. The valve was shut off.

The DTSC ventilation engineer stated that the methane reading was zero before the valve was opened and he could not remember if any methane measurements were taken afterwards. The Cargill mining engineer stated that his idea was to pipe this gas to the surface to be used as fuel for a soda ash process. The DTSC ventilation engineers were shown three large gas blowouts and the Cargill engineer stated that the most recent one had filled the mine with methane to a point that the reading at the collar was above one percent which kept the workers out of the mine for more than one day. Five bottle samples were taken during the July 1976 ventilation survey, methane concentrations ranged from zero to 0.06 percent. Prior to leaving for Louisiana, the DTSC ventilation engineers were advised by their supervisor that the Dallas Subdistrict Manager stated only MESA inspectors were responsible for taking gas samples, and that they were not to take samples.

<u>October and November 1976 DTSC Staff Memorandum</u>

On October 22, 1976, a memorandum was prepared by the ventilation engineers who conducted the aforementioned ventilation survey. The subject concerned the classification of Cote Blanche, Belle Isle, and Weeks Island Salt Mines. The memorandum was sent to the Acting Chief, Ventilation Branch, DTSC. It was the considered opinion of the engineers that the gas-filled cavities within these mines represented potentially imminent dangers, and special precautions should be initiated by MESA and the mine operators to minimize the possibility of fire and explosion in these mines. The engineers recommended that each mine should be considered individually, and if positive evidence existed that placed any operation "repeatedly" within the gassy mine classification standard 57.21-1, the law should be enforced.

On November 3, 1976, a cover memorandum was attached to the above memorandum by the Chief, Division of Health Technology DTSC. The memorandum was sent to the District Manager, South Central District. It was noted that the ideas of the engineers did not necessarily reflect a DTSC opinion. In an interview obtained during the present investigation from the man who was District Manager at the time the memos were issued, he stated that he had reviewed both memorandums shortly after they were issued. He stated that he agreed with everything in the October memorandum with the exception of item 5, which reads as follows: "It is questionable whether the compiled evidence of hazardous conditions within these mines relating to flammable gas had been considered seriously." He then contacted the Chief, Division of Health Technology, and requested an explanation. He was told that, as stated in the November 1976 memorandum, item 5 was the opinion of these engineers and it did not necessarily reflect a DTSC opinion.

January 1977 MESA Ground Control Survey

On January 4, 1977, a ground control investigation was conducted by a member of the DTSC Ground Control Group. This investigation was conducted at the request of the Dallas Subdistrict Office because of a major roof fall in the Belle Isle Mine at 9 Main Entry East Room 8. The intent was to have a geologist specializing in ground control observe the fall and other problem areas to make recommendations to both MESA and Cargill for the establishment of safe ground conditions.

The original report of this investigation stated that observed irregular roof line was a result of blasting overbreak caused by ignition of natural gas entrapped within the rock mass. A further clarification statement indicated occasional natural gas pockets ignited concurrently with routine blasting which resulted in an overcharge effect. The DTSC geologist prepared his comments based on personal observations and conversations with mine management rather than air samples, or other data to substantiate his opinion.

Prior to distribution, the report was forwarded to MESA's Dallas Subdistrict Office for approval. The Subdistrict Manager objected to the inclusion of a reference to flammable gas ignition because it was founded upon an apparent supposition instead of supportable facts. The report was amended to delete the gas ignition statement and was distributed in this revised form.

The geologist did not strongly oppose the revision although he believed the report was weakened by evading a significant issue. His acceptance of the deletion was based on lack of supportive evidence of actual gas presence or ignition. A contributing factor was a feeling among some Technical Support employees that utilization of their services was often dependent on not opposing or offending MESA enforcement personnel. The technical group operated in a support role in response to requests from enforcement management.

Underground Storage Task Force

Beginning in January 1977, MESA formed an Underground Storage Task Force to study the impact that creation of a Strategic Petroleum Reserve (SPR) in two of the salt mines in Louisiana would have on further mining in the same salt domes. From the beginning of the study, there was a problem in obtaining specific information concerning blowout size and particulars about gases released. By late 1977, it was evident that the task force would have to take an inventory of the blowout cavities present in the salt dome mines by conducting fact finding surveys.

In March 1978, the entire MSHA task force examined four mines of the Five Islands Group with known blowout cavities. The main objective of this work was to determine how much salt should separate a SPR from a mine in the same salt dome. The blowouts were mapped and measured with the aid of helium-filled balloons and this data was included in a report.3/

From the task force survey of blowouts in the separate mines, it became apparent that large volumes of gases were released into the working area when these outbursts occurred. When queried concerning the gases released during outbursts, officials at one mine contended that although some methane was likely released, carbon dioxide was the predominant gas from blowouts. It should be pointed out that the officials at the Belle Isle Mine were candid about the volume of gases they estimated to be released from the largest blowout in the mine.

3/ Ibid, Footnote 1.

A memorandum of understanding between MSHA and DOE became effective on June 21, 1979. This memorandum of understanding defines MSHA jurisdiction and responsibility for safety in underground workings controlled by DOE or mines being affected by DOE operations.

March 1977 Imminent Danger Order

From March 15-17, 1977, an inspection was conducted at the Belle Isle Mine by MESA. During this inspection an examination was made in respect to methane in the production areas. On March 15, 1977, at 1040 hours, Imminent Danger Order No. 195 was issued. The order stated that "methane was detected in 7 Main East 13 and ventilation was not adjusted to remove gas, area of mine affected: "7 Main East 13". A vacuum-type sample was taken at this location and an analysis showed 0.10 percent methane (See Appendix LL). The order was abated the following day after ventilation fans were installed and the gas was diluted. In conjunction with the above order, two other imminent danger orders were issued for high concentrations of nitrogen dioxide.

On March 15-16, 1977, eight vacuum-type samples were taken in the production areas in the east side of the mine and were sent to DTSC Lab., Denver, Colorado, for analysis. The eight samples indicated concentrations of 0.09, 0.22, 0.23, 0.10, 0.16, 0.23, 0.15 and 0.30 percent methane. At 1500 hours on March 24, 1977, the Dallas MESA Office was informed of the 0.30 percent analysis (which was taken at 6 Main Entry East Room 15).

From the information available to the investigators, the eight air samples were taken in accordance with 30 CFR 57.21-1c. However, the Dallas MESA management contended that the 0.30 percent sample was "not legal" because there were not two companion samples above 0.25 percent and the documentation was inadequate.

It was their belief that an inspector must have companion samples with very accurate records that were initialed, if possible, by the company official present with the inspector.

According to the inspector, he was criticized by his supervisor and subdistrict manager for writing the order. The inspector then voiced his concern to the district manager about methane in the Belle Isle Mine. He was told to put all of his information in a memorandum to the district manager. However, according to the inspector, he was then told by his supervisor and subdistrict manager not to complete the memorandum which he was writing and, thus, the memorandum was never completed.

The inspection report sent to Cargill included "Table 1 - Analyses of Air Samples Collected" (See Appendix LL). An asterisk was added by the Dallas Office next to the 0.30 percent methane concentration, sample no. 12065, which indicated this to be an inconclusive sample due to the district policy.

March 1977 MESA/Cargill Meeting

On the evening of March 29, 1977, a meeting was held at a restaurant in Morgan City, Louisiana, between Cargill officials and the Dallas Subdistrict Manager. The primary purpose of this meeting was to discuss ventilation modifications at the Belle Isle Mine to improve the quality of the mine air and to reduce methane concentrations. It was agreed that low-roof face advancement would cease until major ventilation improvements were made.

On April 1, 1977, an assistant Cargill vice-president wrote a letter to the Dallas Subdistrict Manager confirming the discussion of March 29, 1977. (See Appendix MM). This letter specified the following improvements related to ventilation:

"1) Effective 3/29/77, Cargill will only mine the benches. We estimate 1½ years production if only benches are mined. We will not continue normal face advancement at the upper and lower levels until such time as our ventilation plan has been completed and air can be properly coursed to all operating faces.

2) The nine (9) barges that were at the mine on 3/29/77 will be loaded. All production will then be discontinued until 4/11/77. We will then resume production.

3) Cementation will continue working in the number 1 shaft from midnight Thursday to midnight Sunday of each week. The ventilation fan will be turned off at midnight on Thursdays and turned back on at Sunday noon.

4) Major below-ground emphasis will be placed on ventilation. We will add a crew of nine (9) to our labor group to build the stoppings required. If nine are not available from the outside labor force, this crew will be made up from our production crew. Priority will be (1) complete the stoppings; and (2) produce salt as miners become available.

* * * * * * *

5) Kingston Construction is building the air lock doors at the lower level off the Main air entry. This project will be completed by 4/15/77."

The letter also addressed other MESA/Cargill issues including timely compliance with safety citations and orders, and established time tables for completion of the items discussed.

January 1979 Tunnel Fire

An underground fire occurred at the mine on January 9, 1979. The fire was discovered about 0735 hours when the day shift employees saw smoke emitting from the No. 1 Shaft as they approached the mine landing on the crew boat. No one was underground at the time of the fire discovery.

MSHA inspectors, having conducted an inspection from January 3-9, 1979, were holding an inspection close-out conference with mine officials at the Calumet Landing at the time the fire was discovered. They were notified at 0740 hours, and, thereafter, advised MSHA's Baton Rouge field office and the Dallas subdistrict office. A 103(k) order was issued directing "all work to cease until the fire is extinguished and the mine air is determined safe". Upon request of Cargill officials, DTSC and Pittsburgh Mine Emergency Operation personnel responded to this emergency arriving on January 10, 1979. After examining the fire situation, Cargill and MSHA field personnel were advised on procedures for extinguishment, monitoring and ventilation control.

The fire consumed the wooden supports and conveyor belts in the material transfer tunnels underneath the storage bins, along the incline and in the entry between 1 Main Entry East and the discharge point opposite the No. 1 Shaft Station.

Belle Isle had installed three high expansion foam systems to protect the conveyor belts against a fire. Despite the inspection of these systems shortly before the fire by a fire specialty company, two of the three systems failed to activate. One system failed because of a salt corroded valve. The second system failed because a pressure gage on a compressed gas tank was stuck showing the tank to be full when it actually was empty or nearly empty.

An investigation conducted by MSHA, Cargill and International Chemical Workers representatives failed to determine the cause of the fire. Based on indirect evidence, the fire apparently resulted from a salt buildup on the conveyor belt that caused the head pulley to slip and ignite the conveyor belt.

On January 19, 1979, the 103(k) order was modified to allow work to proceed underground provided that regular carbon monoxide monitoring continued in the fire area and was recorded. As a result of the fire and related damage to the equipment, the screening plant was out of operation for 22 days.

Analysis of samples taken in the fire area during and after the fire showed the highest reading to be 0.071 percent methane. Because of this concentration and other factors, methane was not considered to have been a factor in this fire.

February 1979 Skip Station Fire

A small fire occurred in the Belle Isle Mine at 1928 hours on February 2, 1979. All persons were evacuated from underground by approximately 2000 hours. The MSHA Baton Rouge office was notified of the fire at 2030 hours on February 3, 1979. Citation No. 157269 was issued to Cargill for failure to make immediate notification about the fire to MSHA. The fire destroyed a wooden head pulley frame, motor, gearbox, belting and electrical components of the transfer conveyor at the No. 1 Shaft. The conveyor was located in a 7-by 7-foot, 40 feet long tunnel, 20 feet below the No. 1 Shaft Station and transferred salt from a storage transfer conveyor dump point along the north wall of the No. 1 Room to the No. 1 Shaft skiploading pockets.

The investigation revealed the most probable ignition source of the fire to be the No. 3 panel box which was found to have a relay with a carbon buildup and fused wires across the phases. The fire was believed to have progressed along the electrical wiring from the box to the conveyor motor and head pulley assembly. The fire was extinguished between 2015 to 2055 hours by using water from a 1,200 gallon tank near the No. 1 Shaft Station. The tank had been installed after the fire of January 9, 1979. The investigation also disclosed that some diesel fuel oil, that was piped down the No. 1 Shaft for filling a tank near that shaft station, may have seeped into the loading area where the fire occurred. This fuel oil leakage may have been involved in the fire. A citation was written to extend the piping a safe distance from the No. 1 Shaft area. A sample taken during the investigation on February 5, 1979, showed a trace of methane (0.005 percent). There was no indication that flammable gas was involved in the fire.

March 1979 Resumption of Low-Roof Mining

In early March 1979, the MSHA Baton Rouge Field Office Supervisor was contacted by the Dallas Subdistrict office and told to check the ventilation in low-roof areas of the Belle Isle Mine in order to permit the resumption of face advance mining. (See Appendix MM). Although he was not familiar with the ventilation discussion between MESA and Cargill on March 29, 1977, his assignment was to confirm that conditions established at that meeting had been met. The methanometer readings taken in 8 Main Entry East Rooms 8 and 10, and 5 Main Entry East Room 15X, and a vacuum sample taken in 5 Main Entry East Room 15X, all in low-roof areas, revealed no significant amounts of flammable gas. As a result of these readings and the sample, the limitations were ended.

May 30, 1979, Gas Encounter

On May 30, 1979, 10 days before the explosion, methane was detected in 7 Main Entry East Room 15 during the undercutting phase of the mining cycle. The equipment operator refused to continue the job and activities were suspended in the immediate area for about 4 days until the gas was diluted.

Summary of Inspections, Investigations and Surveys

Ninety-three inspections, investigations and surveys were conducted at Belle Isle Mine by Federal mine inspectors between April 1971, and May 1979. There were 42 regular inspections, 41 spot inspections, 6 investigations (3 of which were for underground fires), and 4 surveys. A total of 1,111 Notices, 49 Citations and 222 Orders (Imminent Danger and Noncompliance) were issued during these inspections, investigations and surveys. The number of violations are listed by Section and Category in Appendix G.

The last regular inspection was conducted at the Belle Isle Mine on April 10-12, 1979, and a follow-up or spot inspection was made on May 31, 1979. Four detector tube samples also were taken during the regular inspection and they showed 0.0 percent methane. As a result of the regular inspection one (1) electrical violation was cited and abated during the inspection. Between April 1971 and June 1979, Federal mine inspectors issued a total of 15 orders related to electrical hazards and 192 notices or citations for violations of mandatory electrical safety standards at the Belle Isle Mine. Electrical violations documented during this period addresses equipment grounding, electrical lock-out safety procedures, open or bare energized electrical equipment, labeling of electrical circuits, and cable splices.

After the gas explosion on June 8, 1979, an MSHA electrical specialist was sent to the Belle Isle Mine. The electrical violations cited by the specialist were in the East side mining area. Regular inspection personnel could be expected to observe approximately 50 percent of the electrical violations found after the explosion and described later in this report. Only a specialized electrical inspector could be expected to observe the remainder.

MINING METHODS, CONDITIONS AND EQUIPMENT

Mining Method

Mining was done utilizing the room-and-pillar method (See Appendixes H, I and N). In the southeast area of the mine, where mining has been progressing for some time, pillar dimensions were approximately 160 feet by 75 feet at the base. Distance between pillars throughout the mine was 63 feet except for two air tunnels and four permanent access entries. Room-and-pillar height in the mine was 22 or 82 feet.

The mine operated and functioned from two levels 40 feet apart. These levels were established from 2 main parallel entries on each level that were aligned vertically with those on the lower level and separated by a 40-foot-thick sill. On the lower level, these two entries were called tunnels. Mining was done by first driving development headings 63 feet wide and 22 feet high in advance for several pillar lines on the upper level, and then retreating the bench. Thus, most mined-out areas yielded rooms 82 feet high. Roof bolts were installed in the back (roof) from the upper level, particularly above rooms or entries expected to be utilized as haulageways after benches were retreated. Rock bolts were not utilized in the ribs.

Explosives

Blasting was done at the Belle Isle Mine by use of 60 percent ammonia gel dynamite and ammonium-nitrate fuel oil (AN-FO) premix. Face rounds for advancing headings on the upper level consisted of blastholes containing 6 to 7 cartridges of 16-by 1-1/2-inch dynamite, with blastholes tamped but not stemmed. Generally, 12 feet of salt was blasted from 12 feet of blasthole depth. The faces were 63 feet wide and 22 feet high and were undercut by an 8-inch kerf 12 feet deep. Side cuts were not used. Four rows of breast-holes were used in the face rounds spaced in 8 equidistant rows across the width of the faces. Closely spaced trimmers were used to maintain smooth ribs and back. Electric detonators were used in each blasthole, and the primer was the second cartridge from the rear of the blasthole. Millisecond delay electric caps were used to sequence the round and break the salt toward the kerf (See Appendix J).

Blasting of benches was done with AN-FO premix. Twelve feet of bench was pulled with each round. Benches were undercut with an 8-inch kerf, 12 feet deep. The round consisted of three rows of downholes 60 feet deep and 4 feet apart. Starting from the edge and 4 feet back, holes in the first row were 8.8 feet apart, in the second row 7.5 feet apart, and in the back row 6.6 feet apart. Thus, the blastholes made essentially a staggered pattern. The first row for the succeeding round was drilled prior to charging the round to eliminate drilling close to a dropoff. The distance between rib holes and bench holes was 5 feet in each row (See Appendix K).

Blastholes in the benches were loaded with explosives in two ways. Out in the bench, a stick of dynamite was placed at the bottom of the blastholes to fill the kerf. These blastholes were then filled to with 20 feet of the top with AN-FO. The primer with electric detonator was placed at the 20 foot elevation and the remainder of the hole filled with AN-FO. Downholes were not stemmed. Downholes in the benches were loaded with sensitized ammonium nitrate from an explosives loading Jumbo. Two of these Jumbos were in the mine. The rib holes were cushion-loaded with dynamite separated by spaces of fine salt. Each stick was tied to detonating cord, and initiation for these rib holes came from a single detonator. Millisecond-delay electric caps were used to sequence the round and break the salt toward the center.

Large slabs were taken off pillars with explosives. An electric cap and detonating cord was used to detonate the explosives.

Equipment

For the upper level development headings, three face drill Jumbos were available to drill blastholes in the face. Two hydraulically operated drag bit drills were mounted on each of these Jumbos. Three floor drills were used on the upper level to drill benches. These floor drills were hydraulically operated drag-bit drills. Power for all these drill units was furnished by the mine electrical system from portable load center transformers.

Artificial ground support was installed by use of two self-propelled roof bolters and one truck-mounted roof bolter, all of which were diesel-powered. Two Gradall scaling units and two high-roof scaling units were also diesel-powered.

Generally, in the lower level production areas, electrically powered cutter machines were the only pieces of equipment used other than loading and hauling units. There were four cutting machines available to undercut benches and faces in the mine.

Diesel-powered loaders and trucks were used to load and move broken salt to the primary crusher dump points. Seven diesel-powered articulated-type trucks hauled the broken salt. Three had 22-ton capacity each, one 35-ton capacity, and three had 40-ton capacity each. Six front-end loaders were available for loading. One had 3½-cubic-yard capacity, another 5½-cubic-yard capacity, and four had 10-cubic-yard capacity each.

As explained, the access to the mine was by two parallel entries that proceeded south, one on the east side and one on the west side of the shafts, on both levels. The east side entries were aligned vertically on the upper and lower levels and were called 1 Main Entry South and 1 Main Tunnel South, respectively. On the west side, these entries were aligned vertically on the upper and lower levels and were called 2 Main Entry South and 2 Main Tunnel South, respectively. The crushing equipment, conveyor transport, and salt storage were located in the 1 Main Tunnel South. Generally, on the upper level, shops were located in center crosscuts and in the 2 Main Entry South. The 1 Main Entry South was used for heavy equipment parking and the screening plant. Processing of salt proceeded from the primary roll crusher north to the primary screen, also on the lower level. Oversize went to the secondary roll crusher. Crushed salt was sized by the screening plant on the upper level in 1 Main Entry South. The salt processing required belt conveyors virtually the length of the 1 Main Tunnel South on the lower level. Final storage of sized products was at the north end of the 1 Main Tunnel South. Fine waste salt was conveyed from the screens to mined-out rooms in the east portions of the mine. Crushing equipment consisted of a 1,500-ton per hour primary roll crusher and a 600-ton per hour secondary crusher.

The maintenance and electrical shops consisted of the usual tools and shop equipment to maintain heavy vehicles and mining equipment and systems. Assigned shop vehicles included a 7 1/2-ton crane and a 15-ton crane, a heavy-duty service truck, a heavy-duty forklift, several light service trucks, and several electric carts for personnel transport. Additionally, there were several small diesel-powered personnel carriers and jeep-type vehicles. Supervisory and professional personnel were also assigned these types of small vehicles, both electric carts and diesel units, to conduct their business.

Travelways

The parallel entries from the two shafts going south served all active areas of the mine. Access to the development and production areas was by east-west entries off the two main south entries on both levels. These east-west entries were the haulage routes and the accessways for mining equipment to reach benches, headings, and blasted salt.

The major development of the mine was east of the main south entries and tunnels from the shafts. In the present state of development of the mine east of 1 Main Entry South; 7, 8 and 9 Main Entries East were the only east entries that were not benched out and accessible from 1 Main Entry South on the upper level. Because all drilling of benches and development headings was done on the upper level, nearly all of the mining equipment was located on the upper level. These unbenched east entries were the only accessways to the mining activities. Access into the benched out east main entries was from 1 Main Tunnel South on the lower level. Since bench rounds yielded the major portion of the salt production, these benched out east entries were the major haulage routes for broken salt. Broken salt from development headings on the upper level was hauled via 7 Main Entry East and 8 Main Entry East to a dump point in 1 Main Entry South just north of 6 Main Entry East. There was no break-through between the 6 Main Entry East and the 7X Entry benched out areas on the lower level, so that the 1 Main Tunnel South was the only access into these two areas.

Equipment was moved between levels via a ramp between 2 Main Entry South and 2 Main Tunnel South just west of the shafts at the north end of the mine. Besides using this ramp, personnel could use a belt elevator manlift between levels in the 2 Main East cutout just west of the 1 Main Tunnel South.

Mine Shafts

The No. 1 Shaft was driven through approximately 200 feet of alluvial material above the salt dome to a total depth of 1,253 feet. The floor of the mining level was 1,163 feet below the surface, and the shaft was lined with concrete to a depth of 620 feet. Skip pockets were located in the shaft below the mine floor. Finished diameter of the shaft was 16 feet. The shaft was equipped with steel guides for conveyances used for hoisting both men and salt. The shaft also served as the return airway.

No. 1 Shaft was served by a Vulcan double-drum mine hoist. The east drum of the hoist was provided with a jaw-type clutch and the brake engines were hydraulically released and gravity weight applied. The mine hoist was powered by two 1,000 h.p., a.c. electric-drive motors, at 4,000 volts, through single-motion gear reduction. Hoist ropes were 1-7/8 inches in diameter. A skip was attached to the east hoist rope and a cage-over-skip combination was attached to the west hoist rope. Man hoisting speed was 600 feet per minute.

The No. 2 Shaft was circular, 16 feet in diameter, and concrete-lined to a depth of 1,225 feet. The shaft was equipped with four guide ropes suspended from the headframe and anchored in the shaft bottom. Guide rope anchors in the headframe were provided with hydraulic loading devices to tension the guide ropes. The west pair of guide ropes served as guides for the hoist counterweight and the east pair of guide ropes served as guides for the conveyance. The shaft was used for fresh air intake, material raising and lowering, and for an emergency escapeway.

No. 2 Shaft was served by a single-drum electric hoist. The mine hoist was equipped with a single brake only and this was hydraulically released and gravity weight applied. The mine hoist was powered by a 900 h.p., a.c., electric-drive motor, at 2,300 volts, through single-motion gear reduction. Hoist ropes were 1-3/16 inches in diameter. The overlay rope on the north (left) side of the drum was attached to the material conveyance and the underlay rope on the south (right) side of the drum was attached to the counterweight. Each hoist rope was reeved through an idler sheave attached to the load and was dead-ended at the top of the headframe. Normal hoisting speed of the conveyance was 390 feet per minute.

Ventilation and Gas Monitoring

Based upon information from Cargill and MSHA computation, two hundred eighty-five thousand cubic feet per minute (cfm) of intake air was coursed down the No. 2 Shaft to the 1221 (lower level) air entry tunnel. A schematic isometric of the ventilation system is shown in Appendix L. Air flowed past the Room 5 crosscut which connected the 2 Main Tunnel South and the air entry tunnel, and this crosscut contained large 20- by 20-foot airlock doors which opened mechanically upward in guides mounted on the side of the drift and along the back. An estimated 20,000 cfm of return air recirculated around the doors from the 2 Main Entry Tunnel into the intake Air Tunnel.

The main fan, which was a Joy Manufacturing Company Model H-84-50-DS, was located in the air tunnel just south of the airlock doors. The fan was directly driven by a 500-horsepower, 870 rpm electric motor. This fan was electrically connected so that it could be restarted from the surface after a mine power outage.

The air was coursed south in the Air Tunnel from the fan to an incline which connected the 1221 (lower) level at the 3 Main Tunnel Entry to the 1163 (upper) level at the 5 Main Entry.

Except for 2 and 3 Main Entries East and West, the Air Entry was separated from 1 and 2 Main Entries South by stoppings consisting of salt piled to within 4 to 6 feet of the roof. The remaining space was filled by bags of salt, flattened barrels or, more recently, with salt put in place by a new "flinger" machine. In 2 Main Entry off the old air Entry (upper level), steel bulkheads with doors had been installed.

The air coursed south in the Air Entry to 8 Main Entry where the air was split. Two free-standing fans, one a direct motor-driven Joy H56 and one V-belt driven Jeffrey 8H72, were located in 8 Main Entry East between 1 Main South Entry and the Air Entry. One fan blew air to the east and one served as a standby. A third free-standing fan, a Joy M56 blowing north, was located in 2 Main Entry South between the 7 Main Entry West and the 7X Entry. This fan was operated intermittently depending on the need for air to the shop in 2 Main Entry South, and the air requirement to the production area in the southeast section of the mine.

From the two fans in 8 Main Entry East, air was coursed to the east in that entry, which was separated from the rooms by brattices hung from cables along the roof between pillars east to Room 7.

A free-standing Joy Manufacturing Company 38-26½-1750 fan was located near the south rib of 8 Main Entry East opposite Room 9 and was blowing east. A 4-foot-diameter Hartzell fan was blowing south into Room 14X off 7X Entry East. A free-standing 38-26½-1750 two-stage Joy fan was located at 7 Main Entry East and Room 14 blowing to the north. The air from this area was free-flowing back to the No. 1 Shaft and exhausted to the surface.

The free-standing axial-flow fans depended on the high velocity of the fan discharge to carry air from ~~the fan along the entries~~. The amount of air recirculated depended on the location of the fan in relation to other fans in the system and the configuration of the mine.

Numerous 4- and 6-foot diameter, free-standing Hartzell propeller fans were located in 1 Main Entry South, the 1 Main Entry South Tunnel and 2 Main Entry South. These free-standing propeller fans produced large quantities of air at limited velocity. As a result, they were used primarily to prevent stratification by mixing the air in the large rooms and entries.

Mine atmosphere sampling was done by using a Draeger multi-gas sampler. Nitrogen dioxide and carbon monoxide were the principal gases sampled. Prior to the explosion the principal contaminant given off by the diesel-powered engines that resulted in gas concentrations over the Threshold Limit Value (TLV) was nitrogen dioxide, and a log was kept of the monitored concentrations of this gas. Diesel engines were shut down and personnel in the affected area were moved to other working places when the nitrogen dioxide concentrations reached the TLV and ceiling value of 5 ppm, or when the carbon monoxide concentrations reached 50 ppm.

Monitoring for methane was done using a Mine Safety Appliance (MSA) methanometer Model M-502. A methanometer was available for mine foremen, engineers, and the union president, but it only was used on the day shift. Preshift examinations or tests for flammable gas were not required. This methanometer was locked in a box on the engineering cart at the time of the explosion. It was subsequently tested and found to be in calibration (See Appendix GG). Records of methane readings were not kept; however, Cargill officials indicated that when readings over 0.25 percent were obtained, personnel were withdrawn from the affected areas and ventilation was adjusted and mining in such areas was delayed until the methane levels return to below 0.25 percent.

Escape and Evacuation

Notification for evacuation of the mine was done by a combination telephone and messenger system. The procedure was to notify the surface and instructions were given by the person in charge on the surface to evacuate the mine. Underground telephones were located at the No. 1 Shaft, skip-loading conveyor, reclaim tunnel, electrical shop, maintenance shop, screening plant, bottom of the manlift and the primary crusher. Since there were no telephone communications with the production areas on either the upper or lower levels, a messenger was dispatched to notify the workers to evacuate.

In the event of fire, the No. 2 intake shaft served as the primary escape route (See Appendix M). The shaft could be reached from the upper level by means of a 60-foot manlift, which was an electrically-driven vertical belt with foot platforms and hand-holds located along the belt's length. The belt and a ladderway were installed in a bored hole between the two levels. The belt escapeway was located 10 feet east of the west rib of 1 Main Entry South in 2 Main Entry East.

Escape from the bottom of the manlift, lower level production area, and from the primary or secondary crusher area of the 1 Main Tunnel South was through an 8-foot-diameter culvert with a mandoor installed in the salt bulkhead separating the 1 Main Tunnel South and the air tunnel. From the culverts in 2 Main Entry, escape was north in the airway tunnel to the No. 2 intake shaft and then out.

Escape from the lower level production area on the east end of the 7X Entry East area could also be made through a tunnel connecting 1 and 2 Main Tunnels South at the 5 Main Entry and then south on 2 Main Tunnel South to the culvert at the 3 Main Entry West or the airlock doors.

Escape from the upper level at the screen area in 1 Main Entry South could be accomplished by proceeding past the No. 1 Shaft to the west, down the equipment ramp in 2 Main Entry South to the airlocks and out the No. 2 Shaft.

The shop area was located in 2 Main Entry South between 1 Main Entry West and 2 Main Entry West. The escape route from the shop area was east in 2 Main Entry West to the manlift or west from 2 Main Entry South into 1 Main Entry West to Room A, and north in Room A to Room 1. From the Room 2 and Room 1 intersection, the escape route was east in Room 1 to the equipment ramp, down the ramp to the airlock doors and out the No. 2 Shaft.

The No. 1 Shaft, which was on return air, was the secondary escapeway. Signs which read "Intake Escapeway" with directional arrows were mounted on the walls in various parts of the mine. Escapeway maps were also located in the mine at the shop area, the No. 1 and No. 2 Shafts, and at the manlift. An escapeway map was located on the surface at the lamp house. A fire procedure was written and posted with the maps. Evacuation procedures and routes were covered during the indoctrination for new employees. Retraining was to have been done periodically. Self-rescuer training by a certified instructor was to be included in the indoctrination for new persons and the safety refresher training.

A mine rescue station was maintained at the mine. Twenty-one persons were trained in mine rescue procedures and 12 Draeger self-contained oxygen breathing apparatus were maintained.

Electrical Distribution

High-voltage power was supplied by the Central Louisiana Electric Company to the utility-owned substation at the mine site. Electrical power was delivered into the mine at 4160 volts a.c. to the main mine substation which was located near the No. 1 Shaft on the 1163 level. High-voltage power was then distributed through metal-clad switchgear and power cables to various substations and load centers on both the upper and lower levels. The 4160-volt power was transformed down to 480/240 volts at these substations and load centers for utilization. There also was a standby diesel-powered generator available on the surface.

Illumination

Individual cap lamps were provided for mine personnel. Shaft stations, electrical substations, workshop areas and main entries were provided illumination by incandescent lamps. Incandescent lighting had been replaced by self-ballast mercury vapor lamps in some areas of the main entries. Illumination was also provided at Mine Portable Load Center No. 2 at 7 Main Entry East Room 13 in the active mining area, by means of a 400-watt 220-volt incandescent lamp. Area illumination was provided by lights mounted on 10-foot high standards located on floor drills.

Smoking

The use of smoking materials was permitted in the mine workings except in designated "no smoking" areas. "No smoking" areas designated by the Company, included mine shafts and stations; mine explosives and cap magazines; oil, gas, diesel or grease storage areas, and at product conveyors over storage bins; reclaim belts in tunnels; conveyor belt gantry from headframe to loading dock; load dock building; mine storeroom; on or near powder jumbos; screen plant structure; within 50 feet of explosives that are being handled; on any conveyance being used to transport explosives or caps; in any other areas designated by any supervisor.

EVENTS BEFORE AND AFTER THE EXPLOSION

During the day shift of June 7, 1979, the face in Room 14 south of 7X Entry East was drilled in preparation for blasting. During the investigation MSHA investigators were informed by Cargill employees that methane had been released from these blastholes. The face was charged and blasted at the end of the evening shift. A methanometer was not available underground for use by the evening shift.

Two miners were assigned to pick up blasting lines in Room 14 at the beginning of the day shift on June 8. Upon arriving at Room 14, they heard an audible gas emission and observed characteristic cone-shaped blown-out pockets in the right side and upper left-hand corner of the face. The audible emission was coming from the center of the left blown-out pocket and was described as sounding like air coming out of an inner tube. The sound could be heard above the noise created by a nearby ventilation fan. A short time later, John McFarlain, the individual assigned to monitor gas emissions, arrived and obtained methane readings sufficiently high to warrant withdrawal of employees. The heading was placed off limits, smoking and open flame restrictions were established, and ventilation adjustments were made in an attempt to dilute the methane in the face.

The face of 8 Main Entry East to the east of Room 13 was drilled. The drilling was toward the projected intersection of 8 Main Entry East and Room 14, where the gas was emitting. Approximately 48 feet of salt separated the two advancing faces.

Shortly before the end of the day shift an electrical fire occurred in an auxiliary fan motor and cable located south of the shop area in 2 Main Entry South. A mine evacuation was underway when it was determined that the fire was minor and brought under control. Employees in the vicinity of the fire had evacuated to the No. 2 Shaft station. Some employees assigned to remote sections of the mine failed to receive notifications and remained in their work areas.

Elray Granger, General Mine Foreman, and A. J. Boutte, Shift Foreman, assigned to the evening shift, met with day shift management at approximately 1530 hours on June 8, 1979. This meeting concerned normal production activities and it was reported by the participants that there was no mention of the methane gas emissions, as noted above, in the east area. Despite the presence of flammable gases in this area, mine personnel did not monitor for concentrations of these gases. Methane detection equipment was not available in the mine during the evening shift. Normally, shift personnel did not sample for methane or other flammable gases during the evening shifts, but relied solely on sampling done during the day.

Employees of the evening shift were assigned their regular duties of hauling salt from lower level production areas to the crusher, drilling, undercutting and charging blastholes in the faces and floors in the upper level East area. Sometime after lunch, diesel emission accumulations from the haulage equipment caused the production crew to leave the lower level and begin hauling salt from headings on the upper level. The crew hauled salt from Room 14 south off 7X Entry East where the gas emission had occurred during the day shift. Another crew drilled floors in Room 14 south of 6 Main Entry East and Room 11 north of 8 Main Entry East, and undercut the face in 8 Main Entry East at Room 13. After the drilling and undercutting was completed, the three rounds were charged by the undercutter and drill operators with assistance from haulage personnel and Shift Foreman Boutte.

At approximately 2250 hours, eleven employees assembled at the bottom of the lower level manlift, off 1 Main Tunnel South, for a scheduled meeting. Two additional employees, Adam Sampay and Amedee Olivier (victims), returned to detonate the three charged rounds from the blasting board at 7 Main Entry East, Room 13. Eight other employees, including victims Zimmerman, Collins and Mayon, were on the upper level preparing to leave their work areas at the end of the shift.

As A. J. Boutte stepped out of the underground operations office on his way to conduct the meeting, he heard one of the scheduled blasts and assumed it was the floor round in Room 14 off 6 Main Entry East. A. J. Boutte proceeded to the manlift area and conducted the meeting for approximately seven minutes. Just as he finished the meeting about 2308 hours, a larger explosion was heard followed almost immediately by extreme concussion and strong winds, which rapidly rose to destructive levels. The explosion forces and winds destroyed or damaged equipment and fixtures throughout the mine and caused injuries to some of the 11 miners at the meeting.

At the time of the explosion, A. J. Boutte was kneeling on the front seat of his production truck with his back to the steering wheel talking to the men. Ten employees were seated on benches in the bed of the production truck. Alton Oppenheimer was standing along-side the passenger side of the production truck, which was a 3/4-ton open cab military-type Jeep. Some of the men were knocked down by the forces of the explosion.

It was extremely dusty and visibility was zero due to the hurricane-like winds. A. J. Boutte became separated from the 11 employees.

A. J. Boutte took the escape route south on 1 Main Tunnel South and through the first set of corrugated culverts to the Airway Tunnel, which led to the No. 2 Shaft. At the Airway Tunnel, A. J. Boutte was blown approximately 30 feet down the tunnel toward the No. 2 Shaft by an increase in wind velocity. Due to the extreme heat and high wind in the Airway Tunnel, A. J. Boutte decided to crawl back to the corrugated culverts and cross over 2 Main Tunnel South. At this time visibility was zero in 2 Main Tunnel South, but the wind was not blowing as hard as in the Airway Tunnel and the extreme heat was not present. A. J. Boutte was disoriented and confused while going up the equipment ramp. He fell down, stumbled, weaved from side to side and bumped into various objects in the travelway. A. J. Boutte was confused and thought he was lost until he heard Peggy Blaney screaming. As he walked toward the screaming sounds and made contact with Peter Boutte and Perry Thompson, who were enroute to the No. 2 Shaft. A. J. Boutte advised them about the extreme wind and heat in the Airway Tunnel to the No. 2 Shaft and stated that the intake air appeared to be coming down the No. 1 Shaft at this time, rather than the No. 2 Shaft. The three men started toward the No. 1 Shaft. A. J. Boutte found Peggy Blaney, who kept screaming that she was burning and on fire. Blaney was dragged part way and eventually crawled the rest of the way to the No. 1 Shaft.

Floyd Linton had followed A. J. Boutte to the corrugated culvert but then returned to the other ten employees at the manlift. Linton, who was trained in mine rescue. suggested that all the miners join hands and try to make their way through the escape route to the No. 2 Shaft (See Appendix O). Hurricane-like wind made the travelway extremely dusty and visibility was zero. The miners had trouble breathing and the dust caused them to choke and cough. The temperature increased considerably. The 11 miners moved slowly south through 1 Main Tunnel South to the corrugated culverts and proceeded north in the Airway Tunnel toward the No. 2 Shaft. The miners were subjected to intense heat but there was no evidence of fire in the Airway Tunnel. The air movement at the No. 2 Shaft appeared to have reversed from intake to exhaust because the main fan which was located underground was destroyed by the explosion. The miners again had trouble breathing. All of the miners were carrying self-rescuers but no one used them.

Floyd Linton climbed on top of a salt stopping by the fan located in the Airway Tunnel and advised the others that the air was better at that location. The other miners climbed up and joined him. A cloud of smoke came toward them and they decided to move toward the No. 2 Shaft. The 11 miners arrived at the No. 2 Shaft at approximately midnight. Several of the men sat on boxes of explosives which were stacked on pallets approximately 50 feet from the No. 2 Shaft. There were an estimated 350 fifty-pound boxes of explosives at this location. One of the miners began hitting the No. 2 Shaft station gate with a short piece of pipe in an attempt to let the people on the surface know that they were alive. The mine phones and the cords used to signal between the mine level and the surface were blown out. Audio and visual communications eventually were made with the surface by shouting and use of cap lamps.

Immediately after the outburst, shot-firers Sampay and Olivier (victims) abandoned their vehicle near the blasting board at 7 Main Entry East Room 13, and moved on foot toward the shaft. Sampay was found approximately 3,300 feet from the vehicle in 2 Main Entry West at Section 1. Olivier had traveled about 2,600 feet and was found in 1 Main Entry South, adjacent to Section 4 (See Appendix P).

Five of the remaining eight employees on the upper level were enroute to the No. 1 Shaft to be hoisted to the surface at the end of the shift. Herman Zimmerman (victim) was riding in a jeep-type vehicle in 1 Main Entry South when the explosion forces knocked the vehicle out of control. The vehicle came to rest with the rear half hanging over the edge of the P-39 conveyor decline and Zimmerman fell about 30 feet to the floor of the decline on the east side of the conveyor. Jason Mayon, the driver, remained behind the wheel during the explosion but as he got out of the vehicle he also fell onto the conveyor and received back injuries.

Perry Thompson and Peter Boutte were riding on a small tractor-like "boss buggy" some distance behind Zimmerman and Mayon, and although one of them was blown off the vehicle, neither man received a significant injury. These two men made voice contact with Jason Mayon and the three men walked the short distance to the No. 1 Shaft Station. Eldridge Roman, the tunnel conveyor operator, who was working alone in the 1 Main Tunnel South area, also arrived at the No. 1 Shaft slightly injured.

The telephone by No. 1 Shaft Station was broken, so Mayon and Roman went to the tunnel to use the telephone, but it was also out of order. Parts from this phone were used to repair the phone at the No. 1 Shaft Station. A. J. Boutte then phoned Elray Granger who was on the surface and related the location of the six employees at the No. 1 Shaft Station.

Prior to the explosion, three employees were sitting in a vehicle adjacent to the No. 1 Shaft Station while waiting for the end of the shift. This vehicle was blown from the shaft area into 2 Main Entry South. Donald Mayon and Richard Collins died from the explosion forces and Peggy Blaney was injured seriously.

General Mine Foreman Elray Granger had been underground throughout the shift but had returned to the surface around 2300 hours via the No. 1 Shaft. Granger proceeded to the mine office which was adjacent to the No. 1 Shaft collar. About 10 minutes later, Granger heard the underground explosion and ran outside the mine office. He stated that the sound of the explosion first started faintly and then grew louder and louder until it reached a peak and held for several minutes. Granger stated that the sound was like five freight trains and was coming out of both the No. 1 and No. 2 Shafts along with dust, smoke and debris. Granger ran back into the mine office and phoned Charles von Dreusche, Mine Manager, at home to report the explosion. Granger then went to the No. 1 Shaft collar with Terry Hebert, Topside Foreman, where they found the mancage a few feet above the collar and a great deal of debris and loose power cables around the collar area.

Granger and Hebert decided to clean up the area and to send the cage down to the mine level with a communications radio aboard. While they were doing this, the mine phone at the headframe rang. Granger answered and talked to A. J. Boutte who was at the upper level shaft station with five other people. Boutte reported that Zimmerman, Donald Mayon and Collins were dead and that he thought the rest of the employees also were dead. A. J. Boutte called again asking the surface to hurry because he could see "the bad air coming". About five minutes later, or approximately 2340 hours, the No. 1 Shaft collar was cleared. The cage was lowered, and the upper level survivors -- A. J. Boutte, Eldridge Roman, Peter Boutte, Perry Thompson, Jason Mayon and Peggy Blaney -- were hoisted to the surface. The empty cage was then returned to the mine level with a radio on board in case other survivors reached the Shaft Station.

At the time of the explosion, the No. 2 Shaft conveyance also was at the collar. The explosion forces lifted the cage to the top of the headframe where the safety dogs engaged because of the slack rope. The cage was lodged in the upper part of the headframe. Clyde McKay, No. 2 Shaft Hoistman, heard pounding signals and other noises from the bottom of the No. 2 Shaft at approximately 0045 hours, June 9, 1979. Efforts were then concentrated on clearing the No. 2 Shaft conveyance to effect the rescue of the miners at the lower level Shaft Station.

The cage was lowered, but it became "hung up" at 500 feet and also at 700 feet below the shaft collar on steel plumb lines left from the shaft-sinking operations which were entangled with all four guide ropes (See Appendix NN). The cage was raised and dropped several times until the obstruction was cleared, and then the cage was lowered to the 11 men -- Al Thompson

Alton Oppenheimer, Floyd Linton, Charles Verdun, Joseph W. Boutte, Girault Frilot, Joseph Buttler, Brian McFarlain, Prentis Shaw, Esau Mitchell and Lenneth Hill -- who were at the lower level Shaft Station.

These miners reached the surface at approximately 0245 hours on June 9, 1979. All 17 survivors were transported by helicopter to the Franklin Foundation Hospital in Franklin, Louisiana. At the time, five miners were still underground, one had been determined to be a fatality and the location of two other miners was known and it was believed that they were fatalities. The location and condition of the remaining two miners were not known.

RECOVERY AND RE-ENTRY PROCEDURES

At 0030 June 9, 1979, Mr. James A. Hebert (who was at the Calumet Landing), notified Mr. Wayne D. Kanack, District Manager, Dallas, Texas, that there had been a violent explosion in the Belle Isle Mine. Mr. Charles von Dreusche, Mine Manager, contacted Mr. Kanack shortly thereafter once he had arrived at the mine site. Mr. von Dreusche requested advice and assistance. He informed Mr. Kanack that men were trapped in the mine and that Cargill's Mine Rescue Team was organizing. Mr. Kanack agreed with Mr. von Dreusche that the cage should be lowered to the mine bottom but that mine rescue team activities should wait until a back-up team was available. They agreed to communicate with each other at 0130 hours. Mr. Kanack immediately contacted Mr. Jay Durfee, Supervisory Mining Engineer, Baton Rouge, Louisiana, who departed with Mr. Jerry Millard, Mine Inspector for the Calumet Landing, by 0115 hours. Mr. Kanack arrived at the Dallas MSHA office with Mr. H. P. Richardson, Acting Dallas Subdistrict Manager, shortly before 0130 hours. Upon arriving Mr. Kanack telephoned Mr. von Dreusche to obtain additional information and learned that the mine was being evacuated and that there had been at least one fatality. Mr. Kanack made contact with Mr. Roy Bernard, Deputy Administrator, Metal and Nonmetal Mine Safety and Health, at 0145 hours and as described previously the Arlington staff proceeded to activate the Mine Emergency Procedure.

As indicated earlier, five chartered air flights were obtained through the Dallas and Headquarters MSHA offices to airlift personnel and equipment from around the Nation. MSHA's first personnel arrived at the mine landing by 0315 hours and were helicoptered to the mine site along with the first back-up Mine Rescue Team from International Salt Company at 0430 hours (See Appendix Q).

At 0440 hours, Mr. Kanack and Mr. Richardson left Love Airport in Dallas via a chartered flight and arrived at Patterson Airport at about 0540 hours. They immediately boarded a helicopter provided by Cargill and arrived at the mine site at 0620 hours.

The No. 1 mine rescue team from Cargill entered the mine at 0555 hours on June 9, 1979, via the No. 2 Shaft (fresh air) and returned to the surface at 0630 hours. The team reported a methane concentration of 1.0 percent 180 feet from No. 1 Shaft Station and visibility of about 15 feet. The Cargill No. 1 mine rescue team re-entered the mine at 0815 hours on June 9, 1979, and returned to the surface at 0936 hours. The bodies of three victims were located. Two International Salt Company Mine rescue teams, each with a Cargill mine rescue team member, entered the mine for the third trip at 1100 hours. The teams returned to the surface at

1250 hours and reported that Amedee Olivier, the fourth victim, had been located. The mine rescue team from the MSHA Rolla Subdistrict office arrived at the mine at 1200 hours on June 9, 1979. Two mine rescue teams composed of personnel from Cargill and MSHA entered the mine at 1440 hours on June 9, 1979, and returned to the surface at 1600 hours. Additional MSHA mine rescue personnel arrived at the mine at 1500 hours. At 1700 hours three teams composed of personnel from Diamond Crystal Salt Company, Cargill, and MSHA entered the mine and returned to the surface at 1830 hours. Two of these mine rescue teams recovered the bodies of the four victims and transported them to the surface through the No. 1 Shaft. The third mine rescue team continued the search for Adam Sampay who was still missing. A sixth trip underground was accomplished by MSHA's mine rescue team which entered the mine at 2030 hours on June 9, 1979. The team returned to the surface at 2115 hours without locating Sampay.

A volume of 40,000 cfm of air flowed down the No. 2 Shaft and exhausted to the outside air from the No. 1 Shaft by natural means during the first six trips made by the mine rescue teams. The underground main fan, doors and stoppings were demolished by the explosion.

A conference was held on the morning of June 10, 1979, to assess progress and outline additional procedures to locate the fifth missing person. The arrival of additional mine rescue teams now permitted a Cargill mine rescue team member to accompany each of the other teams as a guide. In addition, a 75 h.p. fan, borrowed from the Department of Energy, had been installed at the collar of the No. 2 Shaft and was operated blowing down the No. 2 Shaft. The volume of exhaust air from the No. 1 Shaft was increased from 40,000 cfm to 155,000 cfm.

A mine rescue team from the Diamond Crystal Salt Company entered the mine at 0930 hours on June 10, 1979, at No. 1 Shaft, and returned to the surface at 1120 hours without any new information. An MSHA mine rescue team entered the mine through the No. 2 Shaft at 0935 hours on June 10, 1979, and explored the main tunnel south to 5 Main Entry East. The team returned to the surface at 1120 hours and reported that the main fan and conveyor belt were destroyed. A concentration of 2 percent methane was recorded on top of a salt pile 12 feet above the floor of one of the entries. An MSHA mine rescue team entered the mine at 1203 hours on June 10, 1979, and explored the 7 Main Entry East area. The mine rescue team recorded a maximum concentration of 700 ppm carbon monoxide and methane concentrations ranging from 0.7 to 2.1 percent. The team returned to the surface at 1400 hours without locating Sampay. The tenth trip was performed by the International Salt Company Team which entered the mine through the No. 2 Shaft at 1340 hours on June 10, 1979. At 1500 hours, the team reported to the surface that the fifth victim had been located at the tire storage area of the shop in the upper level. The body was hoisted to the surface through the No. 1 Shaft. The mine rescue team returned to the surface at 1517 hours on June 10, 1979. At this time, entry into the mine was suspended by MSHA so that the Agency could make a close inspection of the hoists and shaft systems.

Throughout the re-entry of the mine by the rescue teams, field test instruments were used for testing the mine atmosphere for methane and carbon monoxide. Methane concentrations ranged from a trace near the bottom of the No. 2 Shaft (intake air) to a high of 2.8 percent at the primary crusher (dump point) in 1 Main Entry South. Carbon monoxide concentrations ranged from a trace to 1700 ppm, as recorded on the mine rescue team reports.

Gas monitors were used at the collar of the No. 1 Shaft ~~and the~~ concentrations of methane and carbon monoxide from June 9 to June 13, 1979, inclusive, were recorded. The graphs are shown in Appendixes U and V.

Anemometer readings were taken at the collar of the No. 1 Shaft every 15 minutes when mine rescue teams were underground to confirm that the volume and direction of air flow had not changed.

Re-entry and Recovery of the Mine

After the last victim was recovered on June 10, 1979, the mine was closed for extensive rehabilitation which first had to be accomplished on the surface. A conference between Cargill and MSHA representatives on June 11, 1979, resulted in a procedure for re-entry of the Belle Isle Mine and the formal investigation of the explosion disaster. The hoists and shafts required a considerable amount of repair to make them safe for use during re-entry for the mine recovery. The re-entry procedure was comprehensive and required the submission of written plans for approvals, by the District Manager, for each step in the re-entry process.

MSHA held daily meetings with the Company and Union, to evaluate the daily progress and to discuss projected activity.

The explosion had blown out almost all stoppings and doors in the crosscuts off the 1 and 2 Main Entries South and the air was short-circuited from No. 2 Shaft to No. 1 Shaft. With the fan and other ventilation controls destroyed, there was the ever present risk of another explosion. In order to eliminate this risk to the greatest extent possible, coordinated re-entry procedures were formulated. Re-entry and initial exploration of the mine was done in a methodical and progressive process. Certain workers, with breathing apparatus in case a noxious atmosphere was encountered, examined the underground areas. No power was allowed in the mine in case an explosive atmosphere developed.

During this same period the investigation committee itemized the expected location of equipment in order to locate all potential ignition sources (See Appendix W). The investigators conducted numerous initial interviews of Cargill employees and mine rescue team members. This investigation committee began its underground investigation on July 17, 1979, after the mine had been determined safe by the District Manager, South Central District, MSHA, for the committee's entry.

INVESTIGATION OF CAUSE OF THE EXPLOSION

Investigation Committee

Thomas J. Shepich, Administrator, Metal and Nonmetal Mine Safety and Health, Mine Safety and Health Administration, appointed an investigation committee composed of MSHA enforcement and technical support personnel including three special investigators who were assigned to conduct interviews, take statements and assist in the investigation. The investigation Committee was composed of the following persons:

H. G. Plimpton	Subdistrict Manager (Chairman) Salt Lake City Subdistrict Rocky Mountain District
Ralph K. Foster	Mining Engineer (Deputy Chairman) Denver Technical Support Center
John S. Risbeck	Supervisory Mining Engineer Rolla, Missouri Subdistrict South Central District
Roy P. Rutherford	Mine Technical Specialist (Electrical) Rocky Mountain District Denver, Colorado
Richard F. King	Supervisory Mine Specialist Rocky Mountain District Denver, Colorado
Gary L. Buffington	Mine Specialist Southeastern District Birmingham, Alabama
Warren C. Traweek	Mine Specialist Western District Tucson, Arizona

The following persons participated in the investigation or were present during investigation conferences:

Cargill, Inc.

Charles von Dreusche	Mine Manager
Thomas F. Fudge, Jr.	Mine Engineer
Elray Granger	General Mine Foreman

Steve Dismuke	Mine Engineer
Everett McBride	Electrician
Daryl Sisk	Electrician
C. Frederick Quest, Ph.D.	Consultant, Cargill, Inc.
Frank Neuner	Attorney, Cargill, Inc.

International Chemical Workers, Local Union 869

John D. McFarlain	President

Mine Safety and Health Administration

Edward M. Kawenski	Chief, Industrial Safety Branch Division of Safety Technology Pittsburgh Technical Support
George C. Price	Senior Mining Engineer Division of Safety Technology Pittsburgh Technical Support
Earl F. Mazzeo	Audio Visual Production Specialist Division of Audio Visual Services Pittsburgh, Pennsylvania

The investigating committee made a detailed examination of all accessible underground areas. An estimated 800 photographs were taken to confirm the observations made by the committee of the outburst and subsequent explosion. Approximately 50 items were obtained relating to the explosion.

Description of the Outburst

The investigation committee obtained the assistance of Edward M. Kawenski and George C. Price, Industrial Safety Branch, PTSC, MSHA, to determine the sequence of events that caused the explosion. Because of the necessary delays in restoring the mine ventilation system, they entered the mine on July 20, 1979, accompanied by Cargill officials and MSHA representatives to begin their investigation. This subsection and the following subsections entitled "The Explosion and Flame" and "Explosion Forces" are based upon their investigative report. 4/

Shortly past 2200 hours on June 8, 1979, the face of 8 Main Entry East had been undercut, drilled, loaded with explosives and was ready to be blasted. The blast was initiated by two shot-firers positioned in 7 Main Entry East between Rooms 12 and 13. A massive outburst was triggered by the blast. An examination of the blowout region and a plot of the flame extent from the subsequent gas explosion indicated an affected area of approximately 500 feet in radius from the point of blowout (See Appendix X). This affected area encompassed a volume of about 4 million cubic feet. Calculations of the blowout salt mass, made from extrapolations from mine measurements, indicate that a volume of 350,000 cubic feet of broken salt was expelled, or about 15,750 tons (not including the volume in the blowout cavity). Because of the massive volume of salt dispersed, overpressures were developed by air movement from salt displacement and from high-pressure methane liberated during the disturbance. It should be kept in mind that the 4 million cubic-foot volume affected by the flame from the gas explosion must reasonably coincide with the gas zone created by the outburst. Also, it should be kept in mind that the locations of shot-firers' bodies indicated approximately a 10-minute delay between the outburst and the explosion. The shot-firers were undoubtedly shaken up by the outburst, but were still able to travel about one-half mile during the 10-minute interval preceding the explosion. Researchers 5/ that conduct tests on the physiological effects of blast pressures have shown that peak overpressures of 1 psi will knock a person down; 5 psi will rupture eardrums; and 15 psi will cause lung damage. Data on blast-wave studies in tunnels 6/ point out that transmitted shock overpressures, or static pressures,

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4/ Kawenski, Edward M., and Price, Georce C., "Explosion, Belle Isle Salt Mine," Investigative Report, Pittsburgh Technical Support Center, Mine Safety and Health Administration, Pittsburgh, Pa., December 1979.

5/ The Atomic Energy Commission, "Characteristics of the Blast Wave in Air," reprinted from "The Effects of Nuclear Weapons."

6/ Taylor, William J. "Blast Wave Behavior in Confined Regions," Annuals of the New York Academy of Sciences, Vol. 152, Art. 1, pp 339-356 are non-directional and exist at right angles to the directional incident shock overpressure or dynamic pressure. The dynamic pressure from a blast wave normally averages about twice the static pressure value. The instantaneous dynamic pressure build-up from the outburst within the confinement of the upper mine openings probably had sufficient energy to overturn the flat-bed shop truck used by the shot-firers, but it did not exert a static pressure that seriously injured the two men. It is significant that air starvation from heavy methane or salt concentration in the mine atmosphere could have caused the internal combustion engine of the shop truck to stall. This phenomenon was reported to have occurred in the mine in the past when a previous outburst occurred and a diesel powered jeep type vehicle lost power as it was driven toward the blowout cavity. The phenomenon has also been said to have occurred in another salt mine in the area. Utilizing the law of expanding gases within the 4 million cubic-foot volume, the combined effect of the air volume displaced by salt was 0.35 million cubic feet and by methane was about 0.6 million cubic feet. The transmitted shock overpressure would be 3.6 psi (See Appendix Z).

The assumption has been made that the calculated 3.6 psi transmitted overpressure would not seriously handicap the shot-firers. From the relationship between air speed and static pressure 7/ it has been found that an air speed of 186 feet per second, or 127 mph, is produced by a static pressure of 3.6 psig. The corresponding incident over-pressure of twice the transmitted value, 7.2 psi, would provide ample energy to overturn the shop truck near the shot-firers. Blasting was initiated from a blasting board in the 7 Main Entry East, next to the south pillar. It has been logically assumed that both shot-firers were at this approximate position with the shop truck positioned in the intersection with Room 13.

The assumed 0.6 million cubic-foot volume of gas has been rationalized to provide a methane concentration ranging from above the upper explosion limit inby the blowout cavity to values below the lower explosion limit along the outer edges of the 500-foot radius perimeter from the blowout location. For the purposes of calculations, rationalized imput must be used to obtain values that will serve to explain in an empirical way how conditions experienced during the moments after the gas explosion would reasonably occur. Though for purposes of calculations 0.6 million cubic feet of gas volume will be used, a far greater volume may have been released by the outburst that might not have subjected the shot-firers to damaging pressurers. For instance, there was evidence that methane was

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7/ Richmond, J.K. and I. Liebman, "A Physical Description of Coal Mine explosions, Fifteenth International Symposium on Combustion." The Combustion Institute, Pittsburgh, Pa., 1979.

in the cut-off portion of 9 Main Entry East at Room 10 and the western-most portions of this entry. When the outburst was initiated, the gas would have proceeded westward down 8 Main Entry East past Room 13. When this avenue of relief became jammed with salt, the gas would have turned 90 degrees and blown into Room 13. The outburst filled the 8 Main Entry East heading virtually to the back almost to Room 12, and Room 13 virtually to the back about halfway to the 7X entry. If gas from the outburst blew south out of 8 Main Entry East into 9 Main Entry East virtually along the total length of the entry, then even more gas would have blown north into the benched-out high back portions of the 7X Entry. The more conservative 500-foot radius of critical area will be specifically selected for the calculations in this report, with the other facts and possibilities reserved to explain any discontinuities in the development.

The gas within the 4 million cubic-foot critical area was under the initial 3.6 psi overpressure, and rapidly expanded to a state of equilibrium at atmospheric pressure. A retonation wave or inrush of air to overcome the vacuum in the blowout cavity caused the gas/air mix to expand to a volume approaching 5 million cubic feet. At this stage of the development leading up to the gas explosion, most areas in the original critical zone of 4 million cubic feet now should have contained methane above the 5 percent lower explosive limit. Lean methane/air mixtures should have existed at the outer extremities of the zone which became progressively fuel-rich towards the blowout cavity.

It is well known that methane/air mixtures are readily ignited by low-energy electric sparks, electrical arcs, heated surfaces, or open flames. Evidence, discussed later on in this report, indicates that electrical arcing or open flames begun by arcing initiated the explosion.

Based on observations, the discussions and the available evidence, the conditions that prevailed just prior to the explosion within the critical 4 million cubic-foot area adjacent to the outburst have been formulated. In review, a gas zone was established by a large outburst that may have been further enlarged by one or more releases out of the same blowout cavity. The released gases encompassed a volume of about 4 million cubic feet within 500 feet of the blowout cavity. The affected volume was under a short-lived instantaneous transmitted over-pressure of 3.6 psi, and a directional incident overpressure of 7.2 psi. The outer edges of the gas-affected zone expanded to about 5 million cubic feet when the zone returned to mine atmospheric pressure. The expansion permitted the outer fringes of the former volume to attain a methane/air mixture within the lean explosive range. The explosion occurred when the expansion process caused explosive methane/air mixtures to develop in areas containing ignition sources.

The Explosion and Flame

Accompanied with rapid increases in temperature, the explosion propagated toward the blowout cavity into fuel-rich mixtures above the upper explosive limits for methane. Researchers have shown that with elevated temperatures, the upper explosive limit for methane is raised above 15 percent, and the lower explosive limit is decreased below 5 percent. Because flames propagated toward the zone interior, the flame extent may have been somewhat limited and confined to the zone within the initial 4 million cubic-foot expansion. Flame extension outside the area of critical gas mixture also may have been inhibited by fine salt particulate, suspended because of the pressure wave that would have preceded the explosion flame. Salt particulate, when in suspension, is an effective inerting material for arresting flame during gas explosions. The general rule that flame extension beyond an explosion zone is proportional to the volume and length of the gas zone should not be applicable, generally, along the upper level headings. This inhibiting effect of suspended salt particulate could have been particularly effective in the upper level headings. The flame-extension rule may have applied, however, for that part of the gas zone in or over the benched-out portions of the 7X Entry and its benched-out room intersections. When the critical gas-laden area exploded, the expanding volume and the hot gases put severe forces and temperatures through the adjacent portions of the mine.

Explosion Forces

Just prior to the explosion, the assumed critical volume should have expanded from 4 million cubic feet to about 5 million cubic feet and contained 0.6 million cubic feet of methane. When methane gas explodes with air, the increase in temperature causes the gases to expand over seven times their original volume. For the Belle Isle explosion, a five-fold expansion of gases will be assumed because of the relatively large and partially confined volume. Using the assumed parameters and assuming 2000°F temperature, the expanded mass of 20 million cubic feet would initially create a static pressure in excess of 50 psig that would dissipate rapidly with expansion. It will be assumed that 20 percent of the expanded mass was lost through the upper-level crosscuts in 6 Main Entry East and the other mined-out areas. The remainder of the pressure wave traveled out by the Main Entries East and then in the Main Entries South toward the No. 2 Shaft bottom. The affected mine volume, including both the upper and lower levels of Nos. 6, 7, 8 and 9 Main Entries East contains approximately 56.3 million cubic feet. Applying the law of expanding gases within a constant volume, the 20 million cubic feet of heated gases added to the original 56.3 million cubic feet would create a critical transmitted overpressure of 5.3 psig (See Appendix Z).

This transmitted overpressure would exert a force of 763 pounds on each square foot of surface in the shaft area. The leading edge of the incident shock wave may have subjected the shot-firer victims to dynamic overpressures in excess of 10 psig, if they were in the direct path of the wave. This overpressure would have been equivalent to maximum wind velocities of over 300 miles per hour. Although the dynamic overpressures would decrease with increasing distance from the explosion center, it was evident from the autopsies on the bodies of the five fatalities that they had been exposed to such high overpressures. It was further evident that the dynamic overpressures on the bottom level in the Main Entry South tunnels were much less severe and accompanied by cooler gases because nobody on this level received lung damage or burns. Mining equipment and facilities in the path of the dynamic overpressure wave were heavily damaged or completely demolished in most cases; but in some places damage was fairly light when a location was in the same path of the wave, but located between areas of heavy damage. For example, the virtually undamaged screening plant located in 1 Main Entry South between areas of heavy damage.

The two vertical shafts were the sole points of pressure release to the outside atmosphere. Both shafts were in a direct path of the dynamic overpressure wave from the explosion. The bodies of three of the five fatalities were located in parallel entries on either side and adjacent to the No. 1 Shaft location. At the time of the explosion, the cage was positioned at the collar of the No. 2 Shaft, which has one shaft station at the north end of the air tunnel on the lower level. The forces on the No. 2 Shaft drove this cage 55 feet upward in the shaft headframe. The base of the 1.5-ton cage occupied about 54 square feet of area in the shaft. It is assumed that after decay of explosion pressures in the 1225-foot shaft, the cage bottom was subjected to an overpressure of at least 4.0 psig (See Appendix AA).

Heat and Heat Dissipation

The portion of the mine encompassed by the assumed 4 million cubic-foot critical area was subjected to very high temperatures. The only exceptions were the small gas-free pockets at the very east end of the 7X Entry and the end of Room 14 toward the South. A Gradall scaler was left virtually undamaged at the very end of the 7X Entry. Electric power distribution cable and all other mining equipment in the upper level headings and rooms within 500 feet of the blowout cavity sustained heavy heat damage. Power cable insulation was deeply charred or burned away unless covered by salt (See Appendix HH). Hydraulic hoses, plastic materials, and tires were badly deteriorated from heat exposure unless shielded by framework. Temperatures in excess of 2000°F may be attained in a methane/air explosion at specific locations, and combustible solid materials exhibit flash ignition at such temperatures. With the exception of the two small pockets mentioned within the 4 million cubic-foot explosion zone being considered, the presence of flame was evident at all locations in the upper level headings.

Outside of the critical 4 million cubic-foot area being considered, there was evidence of flame in the western part of 8 Main Entry East where charred wood planks from the chassis of a powder wagon were scattered from the intersection with Room 3 to the intersection with Room 2. The force of an explosion in 9 Main Entry East blew out the salt stopping between the 9 Main Entry East and 8 Main Entry East at Room 4. A core drill at the Room 2 cutout in 9 Main Entry East was completely demolished by this blast even to the structure of its chassis. Flame from the explosion in 9 Main Entry East may have charred the powder-wagon planks in 8 Main Entry East. Nine Main Entry East is an isolated, confined entry that opens out into 1 Main Entry South and into the Air Entry. The east-most cutoff portion of 9 Main Entry East was heavily blackened by gas-rich fire following the explosion. There was evidence that high-speed smoke-laden gases entered the high back portions of the 7X Entry out of 8 Main Entry East. The evidence indicates that small particles of carbon and debris out of the gases impinged on the salt as the gases turned west down the 7X Entry from the south. From the intersection of Rooms 10 to 6 with the 7X Entry, the north ribs of the entry were perceptibly gray. The south ribs of the Entry,west to Room 6,were not discernibly darker. There was evidence that the eastern-most parts of 6 Main Entry East and intersecting Rooms 13 and 14 to the 5X Entry were subjected to very high temperatures and some overpressure. The tires, paint and solid combustibles on a new Joy undercutter were heavily scorched in Room 13 between 6 Main Entry East and 5X, and electrical cable throughout the area was badly scorched.

When an analysis is made of the rise in air temperatures because of heat of compression caused by the explosion, the calculations fall short of yielding temperatures that were present in the South Main entries on the upper level and the lower level air tunnel. All fatalities suffered in this disaster occurred in or just off the Main Entries South on the upper level. Three of these five fatalities suffered second or third degree flash burns generally where skin was not shielded by clothing. One other person, Peggy Blaney, on the upper level received severe burns on exposed skin. Clothes of burned persons did not ignite. According to the autopsy reports for the victims that received burns, the burns were classified as "flash burns." In the lower level Main Entry South tunnels where nobody was killed, the survivors experienced a high wind accompanied by uncomfortable temperature, but the temperature on the lower level did not burn exposed skin. Clearly, personnel on the upper level Main Entries South were subjected to higher temperature than those on the lower level.

Peggy Blaney and one of the victims who were located just west of the No. 1 Shaft were flash-burned with second and third degree burns. High temperature explosion gases and hot air from the vicinity of the explosion traveled with the dynamic pressure wave to the area just west of the No. 1 Shaft. In the 1 Main Entry South a victim was burned at the 3X crosscut. It was significant that survivors and one victim who were on the upper level in 1 Main Entry South and north of the 2 Main Entry East crosscut were not burned. It was apparent that most of the hot air and explosion gases on the upper level traveled north to the No. 1 Shaft area via the Air Entry and the 2 Main Entry South. The momentum of the hot expanding gases and air out of 9 Main Entry East carried across 1 Main Entry South and into the Air Entry. Momentum of the hot gases and air out of 8 Main Entry East carried them across to 2 Main Entry South. The explosion forces and momentum of the hot gases and air out of the open stopes to the east carried across the 1 Main Entry South and through at least to 2 Main Entry South. The hot gases and air traveled north via the Air Entry and 2 Main Entry South to the No. 1 Shaft area. A part of the dynamic overpressure wave, and the hot air in the Air Entry, traveled through the Air Tunnel on the lower level to the No. 2 Shaft.

Heat to raise the mine atmosphere temperature during this disaster could have come from three sources, or their combination. The three sources are: (1) Heat from compression of the mine atmosphere; (2) Flame heated air; and (3) Gases comprising the explosion. It will be assumed that the heat from compression, because of the expanded gases, would be about the same on both levels. Utilizing the law of expanding gases within a given volume, it was seen that 20 million cubic feet of hot expanded gas in the affected mine volume of approximately 56.3 million cubic feet yielded a static transmitted overpressure of 5.3 psig. This 5.3 psig of overpressure would raise the mine atmosphere temperature, but not enough to cause burns on bare skin. According to medical authorities contacted by the investigators, a temperature of approximately 900°F would be required to cause second or third degree flash burns, dependent on exposure time.

The evidence indicates that, except for the Air Tunnel, a little temperature rise occurred in the tunnels on the lower level. The evidence also indicates that no reasonable static overpressure could yield the temperatures required to produce second and third degree flash burns on victims in the upper level. It is apparent from the known evidence and from application of the nominally selected parameters in the blast simulation calculations that chemical energy from the reactions in the explosion was transferred to ambient mine air that was caused to move at high velocity through the upper level entries, mainly the Air Entry and 2 Main Entry South, to the No. 1 Shaft Station. The heated mine air and gases expanded out behind the incident shock wave through the upper level Air Entry and 2 Main Entry South past the

No. 1 Shaft. Cooler ambient mine air, not flame heated by the explosion in the upper entries, moved through the lower level Main Entry Tunnels and was heated somewhat by the compression on the lower level. Only a small amount of the hot products of combustion escaped from the Main Entries East into the 1 Main Tunnel South because most of the hot products of combustion exited on the upper level. The hot gases and air carried very little carbon monoxide and, consequently, there only was one death that may have been caused by carbon monoxide. The pressure and temperature throughout the explosion affected areas of the mine quickly built to a maximum. With the passing of the shock wave, they held for a short period and, thereafter, rapidly dissipated as air and explosion gases went up the shafts.

Explosives

The investigators do not believe burning explosives out of either the face round in 8 Main Entry East or the bench round in Room 11 just off this entry initiated the gas explosion. There was no evidence of burned explosives out of the rounds, but any unexploded dynamite from the face round would have been covered by the preponderance of salt from the outburst, which to date has not been moved. The rapid expulsion of methane from the outburst resulted in a concentration of methane far above the explosive limits at the area of the face blast in 8 Main Entry East. The investigators believe that for a 10-minute period from the outburst until the ignition occurred the concentration of methane was always too great to permit an ignition. The investigators also believe unexploded dynamite from the bench probably would have remained in the confines of Room 11 and would have been covered by the broken salt yield. A search on and around the muck piles did not identify explosives that came from the rounds.

Detonating cord used in the bench round in Room 11 may have burned briefly following blasting. The investigators believe that the requirement for the detonating cord to have burned for about 10 minutes makes this source for gas ignition very remote.

Fourteen sticks of burned dynamite and two sticks of unburned dynamite were found in Room 12 approximately 20 feet north of the 8 Main Entry East intersection. These burned sticks were lying on the floor next to the east rib of Room 12 between the explosives loading jumbo and the rib. A number of the sticks were beyond the rear of the jumbo. The situation indicated that these burned explosives had been left by the powdermen who charged the blast holes in the rounds. Almost certainly, the dynamite was ignited from the heat of the burning gas of the explosion and continued to burn.

Underground Electrical Equipment

After the explosion, electrical equipment for power distribution remained undamaged in 1 Main Entry South at the screening plant general area. Load Center No. 3, which had consisted of a 500 Kva, 4160/480- volt transformer and its auxiliary equipment, was completely demolished as a result of the explosive forces. This load center had been located at the shop area in the upper mining level.

Electrical Equipment at or Near the Active Mining Area on the Upper Mine Level

A load center, designated as Mine Portable Load Center No. 2, was located on the upper level at 7 Main Entry East Room 13, the active area of the mine at the time of the explosion in the mine. Mining machines, lighting equipment, ventilation fans and the blasting board were furnished 480/240 volts from this load center. Because the mine was not classed gassy, permissible electrical equipment was neither required nor used in the active mining area where the explosion occurred.

Mine Portable Load Center No. 2 received high voltage power at 4160 volts from the main mine substation switchgear. Power was delivered by means of three conductor size 1/0 electrical cable. The cable was supported from the mine roof approximately 20 feet high and was routed from the substation along the east side of 1 Main Entry South and then into 7 Main Entry East along the north side to Mine Portable Load Center No. 2. Fused cutouts were installed in this feeder circuit in 1 Main Entry South near the 6 Main Entry East intersection and were located near the roof. The outer jacket of the cable was scorched or charred for some distance west from Room 13 in 7 Main Entry East. The cable had been torn loose from the roof bolt supports and was lying on the mine floor in the 7 Main Entry East Room 12 area. The cable was lying on a salt pile in 12 Crosscut off 7 Main Entry East and a hole was observed in the cable at this location. The hole appeared to have been caused when the cable tore away from a roof bolt directly above.

Mine Portable Load Center No. 2 consisted of a 600 Kva 4160/480-volt transformer protected by oil-immersed primary fuses. Transformer connections were delta/wye.

Ground fault current on the secondary circuit was limited to 15 amperes by means of a current-limiting resistance. There were two 240-volt single-phase 70-ampere circuits and four 480-volt three-phase 600-ampere circuits provided for distribution. Ground fault tripping also was provided. Power outlets were interlocked for undervoltage tripping of the circuit-breakers. The blasting board branch circuit consisted of size 12 conductors. This circuit was fed from "A" circuit-breaker, 600 amperes, to an external 50-ampere safety switch mounted on the upper left side of the power center.

The cover for the load center had been blown off and was found 10 feet to the north. Rubber grommets at the push-button stations on the load center were melted and burned. The remains of small wiring, possibly for lighting circuits leading vertically from the load center were charred and burned away. Power outlet undervoltage tripping interlocks were bypassed by means of wire jumpers in the cases of Circuits "B" and "C", and by corroded or rusted linkage in the case of Circuit "A". Ground fault trip relays were situated on the east end of the load center. The relays had each been provided with transparent covers. The cover was missing from one of the relays. Effectiveness of the ground fault trip protection could not be verified at the time of the investigation because the mine power had not yet been restored.

As far as could be determined, three of the four 480-volt 600-ampere power outlets were in use at the time of the explosion. The circuit-breakers, power outlets and cable connectors (nips) were not labeled to show which units they controlled. Connected loads consisted of either mobile or portable equipment. Equipment in use was located at various distances ranging up to 1,000 feet from this load center. Excess portable cable or trailing cable was looped on the mine floor. The portable cables and trailing cables had been buried by rock falls at a number of locations and some also had been severed at certain locations. A number of cable splices also had been torn apart. These conditions were attributed to wind velocities resulting from a gas outburst in 8 Main Entry East heading, or the violent forces resulting from the explosion that followed, or both.

Distribution Boxes

A distribution box was at 7X Entry in Room 12. The distribution box was upside down and had been subjected to physical damage. This distribution box received 480-volt power from Mine Portable Load Center No. 2. The undercutter machine M-7 and the face drill M-11 received power from this distribution box. The casing of the left-hand 600-ampere molded case circuit-breaker was cracked. The crack in the circuit-breaker casing was in the vicinity of the main moving contact arc chutes.

A second distribution box was located in Room 14 just north of 7 Main Entry East. This distribution box had been subjected to physical damage and was lying on its back. The distribution box received 480-volt power from Mine Portable Load Center No. 2 and delivered power to the floor drill located at 7 Main Entry East and Room 14, as far as could be determined.

A third distribution junction box, which was homemade, was located at 8 Main Entry East at the north rib line near Room 11. This junction box received power at 480 volts from Mine Portable Load Center No. 2. The floor drill M-14 was located at 8 Main Entry East Room 11 and was connected to this junction box.

Equipment

Joy Fan

The Joy fan was at 8 Main Entry East Room 9. The jacket of the 480-volt branch feeder cable from the junction box was charred and baked from heat and had burned away near the fan. Rubber grommets were burned and charred at the push-button stations on the west side of the electrical enclosure. The 150-ampere molded case circuit-breaker was in the "On" position. Instantaneous trip settings were set on "High" (1500 amperes). Each of the three motor overload relays were rendered inoperative by means of jumper wires connected across the thermal elements. The motor leads were charred and baked from heat.

Floor Drill M-14

The floor drill M-14 was at 8 Main Entry East Room 11. The V-belts for the hydraulic pump drive were burned off. The 480-volt 70-ampere molded case circuit-breaker was found to be in the "Tripped" position. This would indicate that the machine was switched on at the time of the explosion. Area illumination was provided by electric lighting mounted at the top of a 10-foot high post. Insulation for the wiring to this light had been completely burned away. The 10-ampere cartridge fuses for the lighting circuitry had been bypassed as the lighting load wires were connected to the top or line side of the protective fuses.

Floor Drill M-12

The floor drill M-12 was at 7X Entry Room 12. The jacket of the trailing cable showed signs of a great deal of heat within 5 feet of the machine. The 125-ampere 480-volt molded case circuit-breaker was in the "On" position, indicating that the machine was switched on at the time of the explosion. The circuit-breaker instantaneous trip device was set on "High." The metal enclosure for the electrical control equipment was open because the cover was not in place. This cover plate had been left off at some time prior to the explosion. Insulation of the wiring to the 10-foot high lighting fixture was damaged by heat.

Floor Drill M-17

The floor drill M-17 was at 7 Main Entry East Room 14. The trailing cable was looped and knotted around the framework of the machine and was torn apart at a splice at this location.

Hartzell Fan M-43

This fan was at the entrance to Room 14 at 7X Entry and appeared to be in its original position. A metal enclosure adjacent to the fan in 7X Entry had been torn loose from the rib and was hanging by its cable from the roof. Both the insulation and the cable appeared to be in fair condition. The fan circuit-breaker was in the tripped position and probably was switched on at the time of the explosion. The fan was unplugged. Reportedly, the fan was running shortly before the explosion.

Joy Undercutter Machine M-7

The Joy undercutter machine was in 7X Entry Room 13 at the toe of the salt pile resulting from the outburst. One of the sealed beam lights was blown out of the light fixture and the wires were bare. The conductor entry was sealed with a type of putty.

Face Drill M-11

The face drill was in 7X Entry Room 13 and was lying on its side at the southeast corner. The machine had been blown some 50 feet east of its original parked position as evidenced by skid marks on the mine floor. An entanglement of burned shooting wire was hanging from the south side of the machine near the right rear wheel. The electrical control enclosure appeared to be clean and the molded case circuit-breaker was switched on. Insulation on lighting wiring was burned and a light fixture was blown out. Only a piece of the exposed lamp filament remained.

Joy Fan, Two-Stage M-37

The fan was at 7 Main Entry East Room 14 and was lying on its side. The skid was facing east to west, indicating the fan turned through an angle of 90° during the explosion. The fan circuit-breaker was switched on, and overload relays were not tripped. There was some deterioration of the push-button station due to heat.

Blasting Circuit for the Blasting Board in 7 Main Entry East Near Room 13

The 480-volt, three-phase, size 12 conductors for the blasting circuit originated at the load side of the circuit "A" 600-ampere circuit-breaker in Mine Portable Load Center No. 2, located at 7 Main Entry East Room 13. The instantaneous trip setting was at "High" (6000 amperes). These conductors extended to a 50-ampere circuit-breaker and safety switch in a metal enclosure. This enclosure was mounted on the west side of the load center. The blasting board branch circuit conductors did not pass through the 15/5 ampere ring-type current transformer provided. Thus, ground fault tripping was bypassed for the 480-volt blasting board circuit. The 50-ampere Westinghouse molded case circuit-breaker handle had been melted and distorted by heat and the equipment grounding conductor insulation also showed signs of excessive heat.

Blasting Board

The blasting board was fed 480-volt three phase power by a four-conductor No. 12 cable. The cable was torn apart at a splice at a distance of 20 feet east of the load center where it was buried by loose rock salt. There were a number of splices in this cable.

The blasting board had been located within 20 feet east of the load center in 7 Main Entry East. The excess of the feed cable was coiled on the mine floor. The investigators were advised that the board had consisted of a fused disconnect switch, shunt plug, three small magnetic starters and three "On-Off" control switches, all metal enclosed. These components were mounted on a 4- by 8-foot plywood board attached to a metal frame support. Remains of the blasting board were found at 7 Main Entry East Room 16, three rooms east of its original location. Blasting rounds were intitiated from the 480-volt magnetic starters by means of the manually-operated control switches. The rounds were wired to this board by two conductor, size 12 cable. Charred remains of this cable were found as far away as 5 Main Entry East Room 14 on the lower level. While 480-volt circuits from the blasting board would normally remain energized only for as long as the shot-firer held a control switch in the "On" position, it should be emphasized that the 480-volt supply to the blasting board would remain energized for an indefinite period.

Portable Blasting Board

According to company personnel, the portable blasting board had been located in 8 Main Entry East near Room 11 prior to the explosion. The portable blasting board was hanging from the south side of the explosives loading jumbo engine in Room 12 at 8 Main Entry East at the time of the investigation.

The metal enclosed circuit-breaker was mounted on a 1/16-inch steel plate. The plastic covered wiring to the line side of the switch was threaded and doubled back through a 1-1/4 inch hole in the metal plate as an anchor or strain relief. The plastic insulation had been melted.

The 480-volt circuit-breaker for the portable blasting board was in the "On" position. A short length of the portable cable feeding this circuit-breaker was still attached and the end lying on the mine floor was burned off and badly charred.

Trailing Cables

1. A round portable size 2/0 American Wire Gauge, AWG, cable was connected to Circuit "B" of the Mine Portable Load Center No. 2. This cable supplied power to the Joy Coupler located at 7X Room 12. Excess cable had been looped on the mine floor at the intersection of 7 Main Entry East Room 12, and the cable had been buried by rock falls at this location. Estimated length of the cable was 500 feet. This cable was tested with a Megger Battery Insulation Tester, Catalog No. 2182. The megger test indicated that the phase conductors were short-circuited and also ground faulted.

   Calculations of phase-to-phase fault currents in three-phase circuits is treated extensively elsewhere based on the conventional methodology used in industry. Researchers, 8/ after extensive study and analysis, have calculated maximum allowable circuit-breaker settings for short-circuit protection of trailing cables using this methodology. References from this material are presented and used here (See Tables II and III in Appendix BB and CC, respectively). For example, the minimum expected short-circuit current for 500 feet of 2/0 AWG, 480-volt, three-phase trailing cable may be expressed by the following equation using typical values not uncommon in operating mine power systems:

8/ See the paper entitled "Instantaneous Circuit Breaker Settings for the Short Circuit Protection of Three Phase 480,600 and 1040 Trailing Cables," by George Fesak, William Helfrich, William Vilcheck and David Deutsch, U. S. Department of the Interior, Mining Enforcement and Safety Administration, published in the IEEE 1977 IAS Conference Record, pages 798-807.

$$I\phi\phi = \frac{K_A E\phi\phi}{2\ Z_1}$$

$$= \frac{0.8545\ (456)}{2\ (0.0729 + j0.0601)}$$

$$= 2{,}062\ \text{A}$$

Where $I\phi\phi$ = Phase-to-phase-fault current.

K_A = Arcing fault factor = 0.8545

$E\phi\phi$ = 95% phase-to-phase voltage = 456

and Z_1 = Total positive sequence impedence = $0.0729 + j0.0601$

The circuit-breaker instantaneous magnetic trip setting must then be set at a value that is less than the minimum expected short-circuit current, in order to ensure that proper short-circuit protection is provided for the trailing cable.

The maximum allowable instantaneous circuit-breaker setting may be calculated by multiplying the minimum expected trailing cable short-circuit current by a circuit-breaker tolerance factor of 1/1.3 9/. Thus the circuit-breaker instantaneous setting for this size 2/0 AWG cable must not exceed 1600 amperes.

Circuit-breaker "B", frame No. TKM836F000, in Mine Portable Load Center No. 2 was provided with a 600-ampere adjustable instantaneous magnetic trip unit for short-circuit protection. The instantaneous magnetic setting was on "High." This setting represents a value of 10 times the current rating, 6000 amperes (See Appendix DD). The manufacturer's tolerance on any setting is ± 10 percent (See Appendix EE). The circuit-breaker instantaneous setting was 400 percent (four times) the maximum allowable setting.

9/ Ibid, p. 804

The investigation indicated that in the past arcing cable in the mine had been observed which had continued to burn until the power was shut off manually. On at least one occasion, a fall of ground from a blast had resulted in cable burning.

2. Three branch circuits originated at Circuit "C" of Mine portable Load Center No. 2. These circuits were all connected together at the cable attachment plug or nip and are described separately below.

3. Two round portable three-conductor size 6 AWG cables were connected in parallel to supply power to the fan located at 7 Main Entry East Room 14. Portions of these cables were buried by rock falls. The outer jackets were severely scorched. A megger test of each cable indicated that the conductors were not short-circuited or grounded.

   Circuit-breaker "C", frame No. TKM836F000, was provided with a 600-ampere trip unit. The trip unit instantaneous setting was on "High." Table II lists the minimum expected short-circuit current for conductor size 6 with a cable length of 0-500 feet at 480 volts as 570 amperes. Table III lists the maximum allowable circuit-breaker setting at 400 amperes. The trip unit instantaneous setting was 1650 percent (more than sixteen times) the maximum allowable setting. The "Low" setting for the instantaneous trip unit also exceeds the maximum allowable value. It also must be mentioned here that the insulation damage curve for No. 6 copper conductor lies to the left of the circuit-breaker time-current curves (See insulation damage chart, Appendixes DD and FF).

4. An additional round portable three-conductor size 2 AWG cable was connected at Circuit "C". This cable extended approximately 40 feet from the load center where it was open-circuited at a cable splice. The other end was not found during the investigation.

   Table II lists the minimum expected short-circuit current for conductor size 2 with a cable length of 0-500 feet at 480 volts as 1348 amperes. Table III lists the maximum allowable circuit-breaker setting at 1000 amperes. As stated above, circuit-breaker "C" instantaneous setting was on "High." The trip unit instantaneous setting was 660 percent (more than six times) the maximum allowable setting.

   The "Low" setting also exceeds the maximum allowable value. It must further be mentioned here that the insulation damage curve for No. 2 copper conductor lies to the left of the circuit-breaker time-current curves (See insulation damage chart, Appendix DD and FF).

5. An additional circuit was connected at Circuit "C." The phase conductors were size 2 AWG. This cable was a type service-entrance (type S.E. construction). A bare steel messenger wire was cabled with the phase-conductor assembly. The messenger wire was severed and was not bonded to the load center. A bare copper equipment-grounding conductor was concentrically applied to the assembly. The equipment-grounding conductor was broken at 7 Main Entry East Room 12 and at several other locations. The cabled assembly was not provided with an overall outer covering. This cable supplied power to the junction box for the Joy fan located at 8 Main Entry East Room 9. Reportedly, the Joy fan junction box had been located at the southeast corner of Room 10 in 8 Main Entry East, but only the branch feeder conductors remained. The cable had been buried by rock salt falls at the intersection of 7 Main Entry East and Room 12. The estimated length of the cable was 1000 feet. This cable was supported by roof bolts 20 feet above the mine floor. Conductor insulation had been completely destroyed by heat. Another type S.E. cable was spliced to this cable at 8 Main Entry East Room 11 to feed a junction box at the north rib line near Room 11. The trailing cable for the floor drill M-14, located at 8 Main Entry East Room 11, was connected to this junction box. A megger test of the type S.E. size 2 AWG cable indicated that the phase conductors were short-circuited. It also indicated that the phase conductors were ground faulted. The minimum expected short-circuit current for 1000-foot, Number 2 AWG, 480-volt three-phase cabled conductors may be expressed by the equation:

$$I_{\phi\phi} = \frac{K_A E_{\phi\phi}}{2\, Z_1}$$

$$= \frac{0.8545\ (456)}{2(0.2114 + j0.0691)}$$

$$= 876\ \text{A}$$

The maximum allowable circuit-breaker setting may be calculated by multiplying the minimum expected cable short-circuit current by a circuit-breaker tolerance factor of 1/1.3. Thus, the circuit-breaker instantaneous setting must not exceed 650 amperes for this cable.

As stated above, circuit-breaker "C" instantaneous setting was on "High." The trip unit instantaneous setting was 1000 percent (ten times) the maximum allowable setting. It must further be mentioned here that the insulation damage curve for No. 2 copper conductor lies to the left of the circuit-breaker time-current curves (See Appendixes DD and FF). Furthermore, since an overall protective cable jacket was not provided, the arc from a short-circuit fault would be exposed to the mine atmosphere.

6. A round portable size 4/0 cable was connected to Circuit "D" of Mine Portable Load Center No. 2. As far as could be determined, this cable extended approximately 220 feet from the load center where it was torn apart at a splice. This splice was located at 7 Main Entry East Room 14. The cable had been buried in places by rock salt falls and the load that had been attached to the cable was not determined. A megger test of this cable indicated that the phase conductors were short-circuited and ground faulted.

   Circuit-breaker "D", frame No. TKM836F000, in Mine Portable Load Center No. 2, was provided with a 600-ampere adjustable magnetic trip unit for short-circuit protection. The instantaneous magnetic setting was on "High." Table II lists the minimum expected short-circuit current for conductor size 4/0 with a cable length of 0-500 feet at 480 volts as 2673 amperes. Table III lists the maximum allowable circuit-breaker setting at 2050 amperes. The trip unit instantaneous setting was 300 percent (three times) the maximum allowable setting.

7. Area illumination at Mine Portable Load Center No. 2 had been provided by an overhead 240-volt 400 watt incandescent lamp supported from a rock bolt in the 20-foot high mine roof. A round portable four-conductor size 12 AWG cable was connected to the extreme right-hand cable connector at Mine Portable Load Center No. 2. This connector or circuit was not labeled to indicate the circuit or load connected to it. The cable was torn apart at a splice approximately 5 feet from the load center. This was all that remained of what was assumed to have been the lighting circuit. Circuit-breaker "F," 240-volt, 70 amperes, was still in the "On" position at the time of the investigation.

Maintenance Shop Truck M-72

The red shop truck used by the deceased shot-firers was located in 7 Main Entry East near Room 13. Reportedly, the truck was a 1-1/2 ton capacity 1974 Chevrolet with a diesel engine. At the time of the investigation, the vehicle was upside down facing to the southwest. The cab and seats were completely burned out. Salt was encrusted on the east side of the tire walls.

The radiator cooling fan and both V-belts were still intact and the tip of one of the fan blades was resting on a radiator hose. The hose had not been damaged by the fan blade. This would indicate that the engine was stationary when the truck overturned. The starter motor was removed, tested, and found to be intact.

The truck battery was on the mine floor underneath the overturned truck and directly below what had been the battery stand. Battery connector conductors were of a stranded copper extra flexible insulated motor lead wire construction. The positive lead to the starter motor was size 4/0 AWG, while the negative lead to the truck frame was 2/0 AWG. The insulated positive conductor passed between the fuel filler pipe and metal framework of the fuel tank. Conductor insulation had been torn apart at this location and the exposed conductor was impinged between the fuel filler pipe and the metal framework. The insulated negative conductor was open-circuited from the battery post because the lead alloy battery connector had broken apart. The end of the connector attached to the conductor showed melted lead. The other end, which was attached to the battery post, showed a fatigue crack through 50 percent of the broken area, and a new break over remaining area. The end remaining on the battery post showed no positive evidence of melting.

Gradall Scaler M-5

The Gradall scaler was in 8 Main Entry East near the south rib of Room 11. The machine was at its original parked position. Paint on the east side of the machine was intact. There were signs of much heat on the west side of the machine where the paint and oil residue was scorched. The battery was located on the east side of the machine where one of the battery connections was melted off as evidenced by melted lead. The free end of the battery conductor produced a spark when shorted against the frame.

PROBABLE POINT OF ORIGIN

The Mine Safety and Health Administration investigators believe that the explosion was initiated in 8 Main Entry East near Room 10.

SUMMARY OF FINDINGS

Conditions observed during the investigation, together with statements taken from company officials and employees of Cargill provided evidence as to the cause and most probable origin of the explosion. A summary of the findings by the investigators is as follows:

1. The Belle Isle Mine had experienced outbursts of significant volumes of combustible gases prior to the explosion.

2. Officials at the Belle Isle Mine terminated mining in the west areas of the mine in 1976 because of significant outbursts of flammable gases.

3. An outburst of gas occurred in 1977 at the intersection of 8 Main Entry East and Room 13 which prompted the company officials to stop advancing headings in the southeast part of the mine.

4. Advancement of headings into the area where the June 8, 1979, outburst occurred were resumed after ventilation into the area was upgraded.

5. During day shift, June 8, 1979, the company obtained methanometer readings in Room 14 south of the 7X Entry sufficiently high to warrant withdrawal of employees.

6. The present outburst as evidenced by the huge amount of salt, occurred when the face in 8 Main Entry East was blasted. The blasted face was east of Room 13 and close to the projected Room 14 intersection.

7. Salt and gas from the outburst blew into the 8 Main Entry East until the salt formed a blockage. The salt and gas turned north into Room 13 as salt out of the pressure pocket began to plug the 8 Main Entry East.

8. The outburst filled the 8 Main Entry East to the back west beyond Room 13 with salt. Room 13 was filled virtually to the back north from 8 Main Entry East halfway to the 7X Entry.

9. The diesel-powered shop truck used by the shot-firers was not utilized by the two men to exit from the area of the blasting board at 7 Main Entry East and Room 13. The outburst prevented the shot-firers from using the truck either because of air starvation or physical damage which included the possiblility that the shock from the outburst may have been sufficient to overturn the vehicle.

10. The shop truck used by the shot-firers was overturned either by the dynamic overpressure wave from the outburst or from the dynamic overpressure wave from the gas explosion.

11. The shot-firers were able to travel approximately 10 minutes on foot after the outburst occurred before the dynamic overpressure wave from the gas explosion killed them.

12. Evidence indicates that the heaviest dynamic overpressure traveled outby from the areas of the gas explosion west through the upper level parts of the mine; and that the dynamic overpressure wave crossed the 1 Main Entry South at each East Main Entry intersection and deflected north following the 2 Main Entry South and the Air Entry and the Air Tunnel towards the shafts.

13. Evidence also indicates that the momentum of the hot air and gasses out of the explosion regions in the southeast portions of the mine generally carried them outby west past the 1 Main Entry South and then north in the 2 Main Entry South and the Air Entry and the Air Tunnel. Except for the Air Tunnel, the major portion of the hot air and gasses exited the explosion area via the upper level entries.

14. The dynamic overpressure wave had sufficient magnitude to blow out nearly every steel bulkhead between the Air Entry and 1 and 2 Main Entries South on the upper level, and the steel doors between the Air Tunnel and 2 Main Tunnels South on the lower level. The main ventilation fan in the Air Tunnel was destroyed by the wave.

15. The evidence indicates that ignition of the gas explosion occurred at the periphery of the known gas-affected area within about 500 feet of the blown-out cavity.

16. Mine Portable Load Center No. 2 was energized and received high voltage power at 4160 volts from the main mine substation switchgear.

17. Power outlet undervoltage tripping interlocks were bypassed by means of wire jumpers in the cases of Circuits "B" and "C", and by corroded or rusted linkage in the case of Circuit "A". Ground fault and undervoltage trip relays were situated on the east end of the Mine Portable Load Center No. 2. Three of the four 480-volt 600-ampere power outlets were in use at the time of the explosion.

18. The distribution box in 7X Entry at Room 12 was upside down and had been subjected to physical damage. The casing of the left-hand 600-empere molded case circuit-breaker was cracked in the vicinity of the main moving contact arc chutes.

19. A distribution box in Room 14 just north of 7 Main Entry East had been subjected to physical damage and was lying on its back.

20. The Joy fan was at 8 Main Entry East Room 9. The jacket of the 480-volt branch feeder cable from the Junction box was charred and baked from heat and had burned away near the fan. Rubber grommets were burned and charred at the push-button stations on the west side of the electrical enclosure. The 150-ampere molded case circuit-breaker was in the "On" position. Instantaneous trip settings were set on "High" (1500 amperes). Each of the three motor overload relays were rendered inoperative by means of jumper wires connected across the thermal elements.

21. The floor drill M-14 was at 8 Main Entry East Room 11. The 480-volt 70-ampere molded case circuit-breaker was found to be in the "Tripped" position. Area illumination was provided by electric lighting mounted at the top of a 10-foot high post. Insulation for the wiring to this high light had been completely burned away. The 10-ampere cartridge fuses for the lighting circuitry had been bypassed because the lighting load wires were connected to the top or line side of the protective fuses.

22. The floor drill M-12 was at 7X Entry Room 12. The jacket of the trailing cable showed signs of a great deal of heat within 5 feet of the machine. The 125-ampere 480-volt molded case circuit-breaker was in the "On" position. Insulation of the wiring to the 10-foot high lighting fixture was damaged by heat.

23. The floor drill M-17 was at 7 Main Entry East Room 14. The trailing cable was looped and knotted around the framework of the machine and was torn apart at a splice at this location.

24. Hartzell Fan M-43 was at the entrance to Room 14 at 7X Entry and appeared to be in its original position. A metal enclosure adjacent to the fan in 7X Entry had been torn loose from the rib and was hanging by its power cable from the roof. The fan circuit-breaker was in the tripped position. The fan was unplugged. The fan was running shortly prior to the explosion.

25. The Joy undercutter machine was in 7X Entry Room 13 at the toe of the muck pile resulting from the outburst. One of the sealed beam lights was blown out of the light fixture and the wires were bare. The conductor entrance was sealed with a type of putty.

26. The face drill was located in 7X Entry Room 13 and was lying on its side at the east rib. The machine was blown some 50 feet east of its original parked position as evidenced by skid marks on the mine floor. The electrical control enclosure appeared to be clean and the molded case circuit-breaker was switched on. Insulation on lighting wiring was burned and a light fixture was blown out. Only a piece of the exposed lamp filament remained.

27. The 480-volt, three-phase, size 12 conductors for the blasting circuit originated at the load side of Circuit "A" 600-ampere circuit-breaker in Mine Portable Load Center No. 2. The instantaneous trip setting was at "High" (6000 amperes). These conductors extended to a 50-ampere circuit-breaker and safety switch in a metal enclosure. The blasting board branch circuit conductors did not pass through the 15/5 ampere ring-type current transformer provided. Ground fault tripping was bypassed. The 50-ampere Westinghouse molded case circuit-breaker handle had been melted and distorted by heat. The equipment grounding conductor insulation also showed signs of excessive heat.

28. The blasting board was fed 480-volt three-phase power by a four conductor size 12 cable. The cable was torn apart at a splice 20 feet east of the load center and was buried by loose rock salt. There were a number of splices in this cable.

29. The blasting board had been located 20 feet east of the load center in 7 Main Entry East at the south rib. Remains of the blasting board were found at 7 Main Entry East Room 16, or three rooms east of its original location. The rounds were wired to this board by two-conductor, size 12 cable. Charred sections of this cable were found as far away as 5 Main Entry East Room 14 on the lower level. While 480-volt circuits from the blasting board would normally remain energized only for as long as the shot-firer held a control switch in the "On" position, it should be emphasized that the 480-volt supply to the blasting board would remain energized for an indefinite period.

30. The portable blasting board had been located in 8 Main Entry East near Room 11 prior to the explosion. The portable blasting board was hanging from the south side of the explosives loading jumbo engine in Room 12 at 8 Main Entry East. The metal enclosed circuit-breaker was mounted on a 1/16-inch steel plate. The plastic covered wiring was threaded and doubled back through a 1-1/4-inch hole in the metal plate, and the insulation had been melted. The 480-volt circuit-breaker was in the "On" position. A short length of the portable cable feeding this circuit-breaker was still attached. The end lying on the mine floor was burned off and badly charred.

31. A round portable size 2/0 AWG cable was connected to Circuit "B" of Mine Portable Load Center Number 2. The cable was buried by rock falls at the intersection of 7 Main Entry East Room 12. The megger test indicated that the phase conductors

were short-circuited and also ground faulted. The circuit-breaker 600-ampere adjustable instantaneous magnetic trip unit for short-circuit protection was set at 400 percent (four times) the maximum allowable setting. The cable was not protected for overcurrents caused by short-circuits or overloads.

32. Two round portable three-conductor size 6 AWG cables were connected in parallel at the Circuit "C" cable connector to supply power to the fan at 7 Main Entry East Room 14. Portions of these cables were buried by rock salt falls. The outer jackets were severely scorched. A megger test of each cable indicated that the conductors were not short-circuited or ground faulted. The trip unit instantaneous setting was 1650 percent (more than sixteen times) the maximum allowable setting. The insulation damage curve for size 6 copper conductor lies to the left of the circuit-breaker time-current curves. The cables were not protected for overcurrents caused by short-circuits or overloads.

33. An additional round portable three-conductor size 2 AWG cable was connected at Circuit "C". This cable extended approximately 40 feet from the load center where the cable was open-circuited at a cable splice. The trip unit instantaneous setting was 660 percent (more than six times) the maximum allowable setting. The insulation damage curve for No. 2 copper conductor lies to the left of the circuit-breaker time-current curves. The cable was not protected for overcurrents caused by short-circuits or overloads.

34. An additional circuit was connected at Circuit "C". The phase conductors were size 2 AWG, type S.E. construction. The messenger wire was not bonded to the load center. The equipment grounding conductor was broken at 7 Main Entry East Room 12 and also at several other locations. The cabled assembly of conductors was not provided with an overall outer covering. This cable supplied power to the junction box for the Joy fan located at 8 Main Entry East Room 9. The Joy fan junction box had been located at the southeast corner of Room 10 in 8 Main Entry East. Only the branch feeder conductors remained. Conductor insulation had been completely destroyed by heat. The cable was buried by rock salt falls at the intersection of 7 Main Entry East Room 12. Another type S.E. cable was spliced to this cable at 8 Main Entry East Room 11 to feed a junction box located at the north rib line near Room 11. The trailing cable for the floor drill M-14, located at 8 Main Entry East Room 11, was connected to this junction box. A megger test of the cable showed that the phase conductors were short-circuited and also ground faulted. The circuit-breaker trip unit instantaneous setting was 1000 percent

(ten times) the maximum allowable setting. The insulation damage curve for size 2 copper conductor lies to the left of the circuit-breaker time-current curves. The cable was not protected for overcurrents caused by short-circuits or overloads. Furthermore, since an overall protective cable jacket was not provided, the arc from a short-circuit fault would be exposed to the mine atmosphere. In addition, since both the steel messenger wire and also the concentric equipment grounding conductor were not continuous, an effective grounding path was not provide to facilitate the operation of the ground-fault protective device of the circuit.

35. A round portable size 4/0 AWG cable was connected to Circuit "D" of Mine Portable Load Center No. 2. As far as could be determined, this cable extended approximately 220 feet from the load center where it was torn apart at a splice at 7 Main Entry East Room 14. The cable had been buried in places by rock salt falls. A megger test of this cable indicated that the phase conductors were short-circuited and also ground faulted. The circuit-breaker trip unit instantaneous setting was 300 percent (three times) the maximum allowable setting. The cable was not protected for overcurrents cause by short-circuits or overloads.

36. In the past, arcing cable had been observed which had continued to burn until the power was shut off manually. On at least one occasion, a fall of ground from a blast had resulted in a cable burning.

37. Area illumination at Mine Portable Load Center No. 2 had been provided by an overhead 240-volt 400-watt incandescent lamp supported near the 20-foot high mine roof. A round portable four-conductor size 12 AWG cable was connected to the extreme right-hand cable connector at Mine Portable Load Center No. 2. The cable was torn apart at a splice approximately 5 feet from the load center. Circuit-breaker "F", 240-volt, 70 amperes, was still in the "On" position.

38. The red shop truck used by the deceased shot-firers was located in 7 Main Entry East between Rooms 12 and 13. The vehicle was upside down facing southwest. The cab and seats were completely burned out. Salt was encrusted on the east side of the tire walls. The engine was stationary when the truck overturned. The starter motor was intact. The truck battery insulated positive conductor was installed between the fuel filler pipe and metal framework of the fuel tank. Conductor insulation had been torn apart and the exposed conductor was impinged between the fuel filler pipe and the metal framework. The insulated negative conductor was open-circuited from the battery post because the lead alloy battery connector had broken apart and could have arced or sparked when it broke.

39. The Gradall scaler was located in 8 Main Entry East near the south rib at Room 11 at its original parked position. Paint on the east side of the machine and engine was intact. There were signs of intense heat on the west side of the machine where the paint and oil residue was scorched. The battery was located on the east side of the machine where one of the battery connections were melted off, as evidenced by melted lead. The free end of the battery conductor produced a spark when shorted against the frame.

40. Force vectors plotted on the isometric drawing (Appendix Y) show that forces within the critical gas-affected area traveled north and east. This plot was based on the direction that equipment moved in this critical area. It must be kept in mind that the gas concentration at the periphery of the critical gas-affected area would be prone to dilute down to the explosive range for methane before the inner portions of the area.

    a. The portable blasting board was blown from the Room 11 intersection with the 8 Main Entry East to just inside Room 12 off this entry. The face drill in the 7X Entry at Room 13 was moved approximately 50 feet east. The blasting board at the intersection of 7 Main Entry East and Room 13 was blown east to Room 16. The hood of the shot-firers' truck was blown from between Room 12 and 13 in 7 Main Entry East to Room 16.

    b. The ribs in the high back stope of the 7X Entry were perceptibly stained gray along the north side only from Room 10 to Room 6.

    c. Equipment in the 8 Main Entry East near the periphery of the critical gas-affected area was not violently disturbed by the gas explosion forces. Heat damage to this same equipment was somewhat directional. For instance, the Gradall scaler in the 8 Main Entry East between Room 11 and 12 had the paint burned off on its west side, but paint was not burned at all on its east side.

    d. Electric power cables in the 8 Main Entry East were located where they received the full impact of the dynamic overpressure wave from the outburst. The electric power cable to the junction box for the axial vane fan at the Room 9 intersection with 8 Main Entry East did not have an overall outer protective jacket around the three conductors. The fan junction box was blown away, thus leaving the energized three-conductor power cable leads free.

CAUSE OF THE EXPLOSION

Based on the vector forces, other factors and the summary of findings discussed in this report, the investigators believe that the explosion was caused by an ignition of methane and minute quantities of other hydrocarbons in 8 Main Entry East near Room 10 by electric arcs or sparks, or by burning electric cable insulation. The outburst of gas occurred approximately 10 minutes earlier when the face in 8 Main Entry East was blasted and triggered the outburst from the pressure pocket.

CAUSE OF THE DISASTER

The cause of the disaster was a general failure by MSHA and Cargill management to recognize the serious hazards of the blow-out phenomena with the sudden and violent release of large quantities of flammable gas into the mine atmosphere, and a failure to correlate the significant events that should have indicated the potential for a major flammable gas explosion.

ORDERS AND CITATIONS

The substance of orders and citations, with certain modifications relating to the disaster is as follows:

Orders Issued

103(k) Order Number 157273

A 103(k) Order Number 157273 was issued June 9, 1979, at 0320 hours. An explosion occurred after blasting at 2315 hours on June 8, 1979. The blasting was in the face of 8 Main East on the first level. This order is in effect for rescue of all persons underground, and until the mine has been determined safe. Area or Equipment: Total underground area.

The above order was modified on November 29, 1979, at 1530 hours. This modification permitted loading, hauling, and hoisting of approximately 10,000 tons of broken salt that was lying on the mine floor. All the equipment used in this operation had been inspected and found to be equipped with calibrated and correctly functioning methane monitors. Primary blasting was not permitted, however, blasting of large slabs was permitted to facilitate haulage.

This order was further modified on April 15, 1980, at 1530 hours to maintain continuity of the 103(k) Order Number 157273. Following the December 20, 1979 letters to Cargill from MSHA that approved Operating Plan #1 and #2, the mine blasting circuits, tag boards and methane monitoring systems were inspected and found to be acceptable. Accordingly, limited salt production from benches and development of the new 1600 foot level mine is permitted as of December 20, 1979.

103(j) Order Number 153202

103(j) Order Number 153202 was issued June 12, 1979, at 1300 hours. Appropriate procedures including but not limited to written procedures must be taken to not disturb or destroy any evidence which will assist in investigating the causes of the mine disaster which occurred at approximately 11:00 pm, June 8, 1979. All persons entering the underground mine must be made aware of the provisions of this order. Area or Equipment: Entire mine.

The above order was modified July 27, 1979, at 0800 hours. The 103(j) Order No. 153202 is modified to release all of the mine to the company, except 6 Main East lower level, 7 and 8 Main East upper level. The aforementioned area is to remain under the 103(j) Order issued on June 12, 1979.

The above order was modified October 5, 1979, at 0800 hours. Order 103(j) dated 6/12/79 is modified to remove the 6 Main East Lower Heading, 7 Main East Upper Heading and 8 Main East Upper Heading from the 103(j) Order, except Room 13X inby the South rib of the X entry of 7 Main East and 8 Main East inby the intersection of the east rib of Room 12. This modification does not preclude an employee of Belle Isle Mine, Cargill, Inc., approved by the District Manager, South Central District, from making air analysis checks with hand-held instruments to determine the quality of mine air in the mine area remaining under the 103(j) Order.

Citations Issued

104(a) Citation Number 0566608

On October 2, 1979, at 1350 hours the Joy undercutter situated on the lower level 6 Main East Room 13 and No. 3 Mine Portable Load Center situated on lower level at 5X East and Room 12 had been removed from their locations in the mine in violation of Modification No. 1 of 103(j) Order issued June 12, 1979.

57.6-1 104(a) Citation Number 0566568

On July 3, 1979, at 1445 hours, there were approximately 350 50-pound boxes of dynamite stored in the drift at a distance of 65 feet from the bottom of No. 2 Shaft. The explosives magazine was located near the No. 1 Shaft. No. 2 Shaft was designated as the emergency escapeway. Thus, explosives were not stored in the storage magazine and had been stacked in transit from the surface. Persons using the escape route were exposed to the dynamite. Area or Equipment: No. 2 Shaft.

57.12-30 104(a) Citation Number 0566594

On July 24, 1979, at 1100 hours, power outlet interlocks were bypassed by means of wire jumpers in two cases, circuits "B" and "C", and by corroded or rusted linkage in one case, circuit "A". These conditions rendered the interlocks to be inoperative. These were 3-phase, 480-volt circuits. The circuits had been energized and were also in use after the interlocks were bypassed. Area or Equipment: Mine Portable Load Center No. 2.

57.12-1 104(a) Citation Number 0566595

On July 24, 1979, at 1200 hours, each of the three motor overload relays were rendered inoperative by means of jumper wires connected across the thermal elements in the motor starter. Thus, mandatory protection against excessive overload of the fan motor circuit was eliminated. Area or Equipment: Joy Fan, 8 Main East Room 9.

57.12-3 104(a) Citation Number 0566596

On July 26, 1979, at 1000 hours, a round portable size 2/0 cable was connected to circuit "B" Mine Portable Load Center No. 2. Instantaneous setting of the circuit breaker was High, 6600 amperes. This value was 400% of the maximum allowable setting shown in 30 CFR Part 18, Table 8. Table 310-16, N.E.C., shows ampacity of 2/0 cable to be 175 amperes. The circuit breaker was rated 600 amperes. Therefore, the cable was not protected against overcurrents caused by short-circuits or overloads. Area or Equipment: Mine Portable Load Center No. 2 at 7 Main East Room 13 for the trailing cables of mobile equipment.

57.12-3 104(a) Citation Number 0566597

On July 26, 1979, at 1015 hours, three branch circuits originated at circuit "C" of Mine Portable Load Center No. 2. Conductor sizes were No. 2 AWG, No. 2 AWG, No. 6 AWG, No. 6 AWG. These 480-volt circuits were all spliced together and connected to a cable connector, or nip. Thus, overload or short-circuit protection was not provided for the individual trailing cables of mobile equipment. Area or Equipment: Mine Portable Load Center No. 2, 7 Main East Room 13, for the trailing cables of mobile equipment.

57.12-3 104(a) Citation Number 0566598

On July 26, 1979, at 1030 hours, two round portable 3-conductor size 6 cables were connected in parallel to circuit breaker "C" in Mine Portable Load Center No. 2. The instantaneous setting of the circuit breaker was High, 6600 amperes. This value was 2200% of the maximum allowable setting shown in 30 CFR Part 18, Table 8. Table 310-16 N.E.C., shows ampacity of size 6 cable to be 65 amperes. The circuit breaker was rated at 600 amperes. Therefore, the cables were not protected against overcurrents caused by short-circuits or overloads. Area or Equipment: Mine Portable Load Center No. 2, 7 Main East Room 13, for the trailing cables of mobile equipment.

57.12-3 104(a) Citation Number 0566599

On July 26, 1979, at 1045 hours, a round portable 3-conductor size 2 AWG 480-volt cable was connected to circuit "C", Mine Portable Load Center No. 2. The instantaneous setting of the circuit breaker was at High, 6600 amperes. This value was 825% of the maximum allowable setting shown in 30 CFR Part 18, Table 8. Table 310-16 N.E.C., shows ampacity of size 2 cable to be 115 amperes. The circuit breaker was rated at 600 amperes. Therefore, the cable was not protected against overcurrents caused by short-circuits or overloads. Area or Equipment: Mine Portable Load Center No. 2, 7 Main East Room 13, for the trailing cables of mobile equipment.

57.12-3 104(a) Citation Number 0566600

On July 26, 1979, at 1130 hours, round portable size 4/0 cable was connected to circuit "D". The circuit breaker instantaneous trip device was set on High 6600 amperes. This value was 260% of the maximum allowable setting shown in 30 CFR Part 18, Table 8. Table 310-16, N.E.C., shows ampacity of size 4/0 cable to be 230 amperes. The circuit breaker was rated at 600 amperes. Therefore, the cable was not protected against overcurrents caused by short circuits or overloads. Area or Equipment: Mine Portable Load Center No. 2, 7 Main East Room 13, for the trailing cables of mobile equipment.

57.12-18 104(a) Citation Number 0566601

On July 24, 1979, at 1115 hours, circuits A, B, C, D, circuit breakers, cables, cable nips (connectors) were not labeled to show which circuits they supplied. These were 480-volt 600-ampere circuits. Since this load center provided power to trailing cables of mobile equipment and also to portable cables of portable equipment, identification could not be readily made by location. Area or Equipment: Mine Portable Load Center No. 2.

57.12-1 104(a) Citation Number 0566603

On July 24, 1979, at 1215 hours, the 10-ampere cartridge fuses for the lighting circuit had been bypassed as the lighting load wires were connected to the top, line, side of the protective fuses. Insulation for the wiring to the high light was completely burned away. Area or Equipment: Floor Drill M-14, 8 Main East Room 11.

57.12-32 104(a) Citation Number 0566604

On July 24, 1979, at 1230 hours, the cover plate had been left open, on the metal enclosure for the electrical control equipment. One of the cover plate fixing bolts was still in place in the enclosure. The enclosure contained 480-volt equipment. Thus, employees had been exposed to electrical hazards. Area or Equipment: Floor drill M-12, 7X Room 12.

57.12-3 104(a) Citation Number 0566605

On July 26, 1979, at 1100 hours, a type S.E. cable, size 2 AWG, 3-conductor 480-volts, was connected to circuit "C" of Mine Portable Load Center No. 2. The circuit breaker instantaneous setting was on High, 6600 amperes. This value was 825% of the maximum allowable instantaneous setting shown in 30 CFR Part 18, Table 8. Table 310-16, N.E.C., shows ampacity of size 2 cable to be 115 amperes. The circuit breaker was rated at 600 amperes. Therefore, the cable was not protected against overcurrents caused by short circuits or overloads. Area or Equipment: Mine Portable Load Center 2, 7 Main East Room 13, for the trailing cables of mobile equipment.

57.12-30 104(a) Citation Number 0566606

On July 24, 1979, at 1245 hours, the blasting board branch circuit conductors did not pass through the 15/5 ampere ring-type current transformer provided. Ground fault tripping was bypassed for the 480-volt blasting board. Thus, a potentially dangerous condition had been created and the circuit had been in service. Area or Equipment: Mine Portable Load Center No. 2, 7 Main East Room 13.

57.12-8 104(a) Citation Number 0566607

On July 24, 1979, at 1300 hours, the plastic covered wiring to the "line" side of the 480-volt switch passed through a 1-1/4-inch hole in the 1/16-inch steel plate on which the switch was mounted. The wires were double looped through this hole as a form of strain relief. The hole was not provided with a substantial insulated bushing, or any bushing. The insulation was completely burned. Area or Equipment: Portable blasting board on the loading buggy at 8 Main East Room 12.

57.12-30 104(a) Citation Number 0566609

On July 26, 1979, at 1115 hours, a type S.E. cable, size 2 AWG, 3-conductor, was connected to circuit "C" of Mine Portable Load Center No. 2 at 7 Main Entry East Room 13. The circuit-breaker instantaneous setting was on High, 6600 amperes. This value was 825% of the maximum allowable instantaneous setting shown in 30 CFR Part 18, Table 8. Table 310-16, N.E.C. shows ampacity of size 2 cable to be 115 amperes. The circuit breaker was rated at 600 amperes. Therefore, the cable was not protected against overcurrents caused by short-circuits or overloads. The cable was attached to roof bolts, to feed the Joy Fan at 8 Main Entry East Room 9 and also a junction box at 8 Main Entry East near

Room 11, and was not provided with an overall outer protective jacket. Thus, the arcing from a short-circuit fault would be exposed to the mine atmosphere. In addition, the cable was approximately 1000 feet in length. This length exceeds the maximum permitted length shown in 30 CFR Part 18, Table 9. Furthermore, the messenger wire was not bonded to the load center and the equipment grounding conductor was broken at 7 Main Entry East Room 12 and also at several other locations. Therefore, an effective grounding path was not provided to facilitate the operation of the ground fault protective device of the circuit. Thus, a potentially dangerous condition existed with equipment and wiring energized. A methane ignition occurred on June 8, 1979.

57.20-31 104(a) Citation Number 082226

On June 8, 1979, at approximately 11:08 p.m., an ignition of flammable gas occurred underground in the vicinity of 8 Main East Room 13 at Belle Isle Mine. Prior to this ignition on numerous occasions dangerous accumulations of flammable gas had been encountered throughout the mine. On June 8, 1979, prior to the ignition, twenty-two men were not removed to safe place before blasting, which resulted in five fatalities and several injuries.

57.5-2 104(a) Citation Number 0565746

On June 8, 1979, at approximately 11:08 p.m., an ignition of flammable gas occurred underground in the vicinity of 8 Main East Room 13, following a production blast. Flammable gas emissions had been detected in the adjacent 7 Main East Room 14X at approximately 8:30 a.m. of the same day. Between 8:30 a.m. and the time of ignition, gas surveys had not been conducted as frequently as necessary to determine adequacy of control measures.

57.21-1(b) 104(a) Citation Number 0565748

On June 8, 1979, at approximately 11:08 p.m., an ignition of flammable gas emanating from the ore-body or the strata surrounding the ore-body occurred underground in the Belle Isle Mine. Prior to the ignition, the mine had not been classified nor operated as a gassy mine.

RECOMMENDATIONS

The following recommendations are those of the investigative committee. Some of these recommendations are covered by citations issued.

1. The mine should be operated as a gassy mine. The mine was classified gassy by the South Central District on June 12, 1979 (See Appendix II and Citation Number 0565748)

2. Rounds in benches and faces should be blasted from the surface with no person underground or in the shaft or conveyance.

   Under Standard 57.20-31 which is applicable to gassy and other mines, company, union and MSHA agreed that the surface is the safe location. (See Citation Number 0565748).

3. The sudden release of a large volume of high-pressure gas associated with outbursts tends to neutralize the effectiveness of the normal mine ventilation in preventing an explosive atmosphere from being created. In the normal gassy mine with the gradual liberation of gas from the strata above or below, or from the ore, the intake air outby the last open crosscut is not materially affected by gas emitted during or after a blast. Conversely, with the high over-pressure and gas velocity resulting from outbursts, the flammable gas can travel against the normal ventilation causing an explosive atmosphere in the intake air courses. Consequently, special provisions to prevent a flammable gas explosion in mines prone to outbursts should be considered in addition to the normal mine ventilation and control of ignition sources in the face and return required in gassy mines.

4. All electric power circuits into the mine, other than the blasting circuits, should be turned off before blasting of benches and faces is done. Power should not be restored in the mine after benches and faces have been blasted until the areas near the blasts have been examined and checked for flammable gases.

5. Power to the blasting circuits going from the surface to benches and faces in the mine should be automatically de-energized after initiation of each round.

6. When two or more portable cables or trailing cables junction to the same distribution center, means should be provided to assure against connecting a cable to the wrong size circuit-breaker.

7. Mobile and portable electric motor-driven mine equipment should be provided with an MSHA approved continuously monitored fail-safe grounding system that will maintain the frames of the equipment and the frames of all accessory equipment at ground potential.

8. The fuse ratings or instantaneous settings of circuit-breakers for short-circuit protection of portable cables and cords, as shown in 30 CFR Part 18, Table 8, should not be exceeded.

9. A short-circuit and coordination analysis of the Belle Isle Mine power system should be conducted to ensure no sacrifice of safety.

10. At least 6 exploration holes 30 feet deep should be drilled ahead of face advancement in an attempt to delineate gas zones.

11. A review of 30 CFR Part 57.21 standards should be made to determine their completeness and applicability regarding the type of flammable gas emissions in metal and nonmetal mines. The review also should particularly address the situations where significant gas emissions in metal and nonmetal mines are not continuous but present a potential hazard.

12. Nongassy metal and nonmetal mines with the potential for flammable gas emissions should be required to make periodic checks for flammable gas, record all measurements and report concentrations in excess of 0.25 percent to the Mine Safety and Health Administration.

13. Electrical standards for metal and nonmetal mines should be re-evaluated for inclusion of more specific guidelines for safe settings for electrical protection, based on recommendations of National Electrical Code and other recognized authorities.

14. An analysis of the chain of events (Fault Tree Analysis) indicates that events transpired in the past which, at the time, may have appeared to be unrelated. For example, pressure pockets were encountered; flammable gas was evidenced in the mine; mine fires occurred that may have been of electrical origin. Fault tree analysis should be emphasized in future training of responsible individuals. The committee, therefore, recommends that training efforts to upgrade and develop better expertise, particularly in the electrical field, be reviewed and accelerated for authorized representatives of the Secretary.

15. Shafts, particularly those with rope guides, should be kept clear of extraneous, unsecured material.

16. In mines where stench warning through compressed air lines or ventilation systems is not possible, a positive audible or visual system that will provide an instantaneous warning for rapid evacuation for all underground employees should be used.

17. Research should be conducted to develop large permissible self-propelled mobile equipment for use in salt dome mining, or to create methods to eliminate known ignition potentials on the non-permissible self-propelled mobile equipment presently in the mines.

18. Research should be conducted to develop an effective method to outline outburst and pressure pocket anomalies in underground salt mines. Research also should be conducted to develop safe mining procedures for penetrating outburst prone areas for the improved safety of the miners.

19. It is highly important that equipment be maintained and operated within the specifications and limits developed by designers and manufacturers. When equipment specifications and limits are not observed, whether because of intent or lack of training and knowledge, serious circumstances that are detrimental to the safety of the miners will likely occur. Therefore, the committee recommends that more frequent inspections should be conducted by specialized electrical and hoisting inspection personnel.

20. When methane readings over a trace are found in any metal or nonmetal gassy mine an active sampling program should be instituted by the mining company and MSHA to determine

the potential for danger. This type of sampling program was instituted by MSHA after the June 8 explosion in the other four salt dome mines.

21. MSHA procedure for sampling and classifying a mine "gassy" should be clarified and standarized.

ACKNOWLEDGEMENT

The courtesies, cooperation and assistance extended by all individuals and organizations is appreciated.

Respectfully submitted,

H. G. Plimpton
Subdistrict Manager

Richard F. King
Supervisory Mine Specialist

Ralph K. Foster
Mining Engineer

Gary L. Buffington
Mine Specialist

John S. Risbeck
Supervisory Mining Engineer

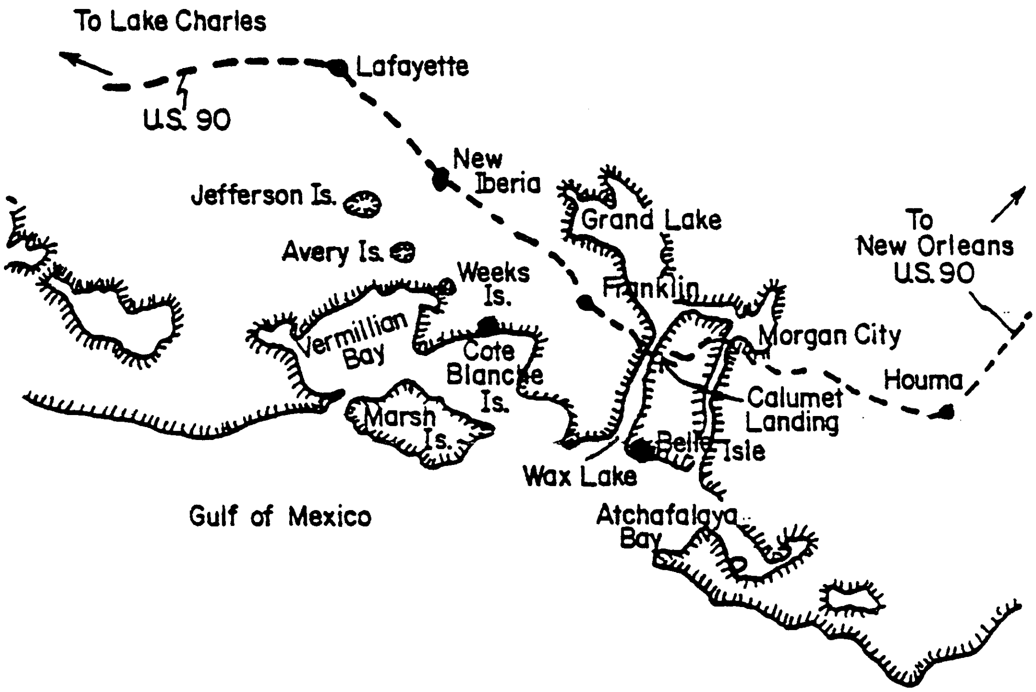
Warren Traweek
Mine Specialist

Roy P. Rutherford
Mine Technical Specialist (Electrical)

Approved by:

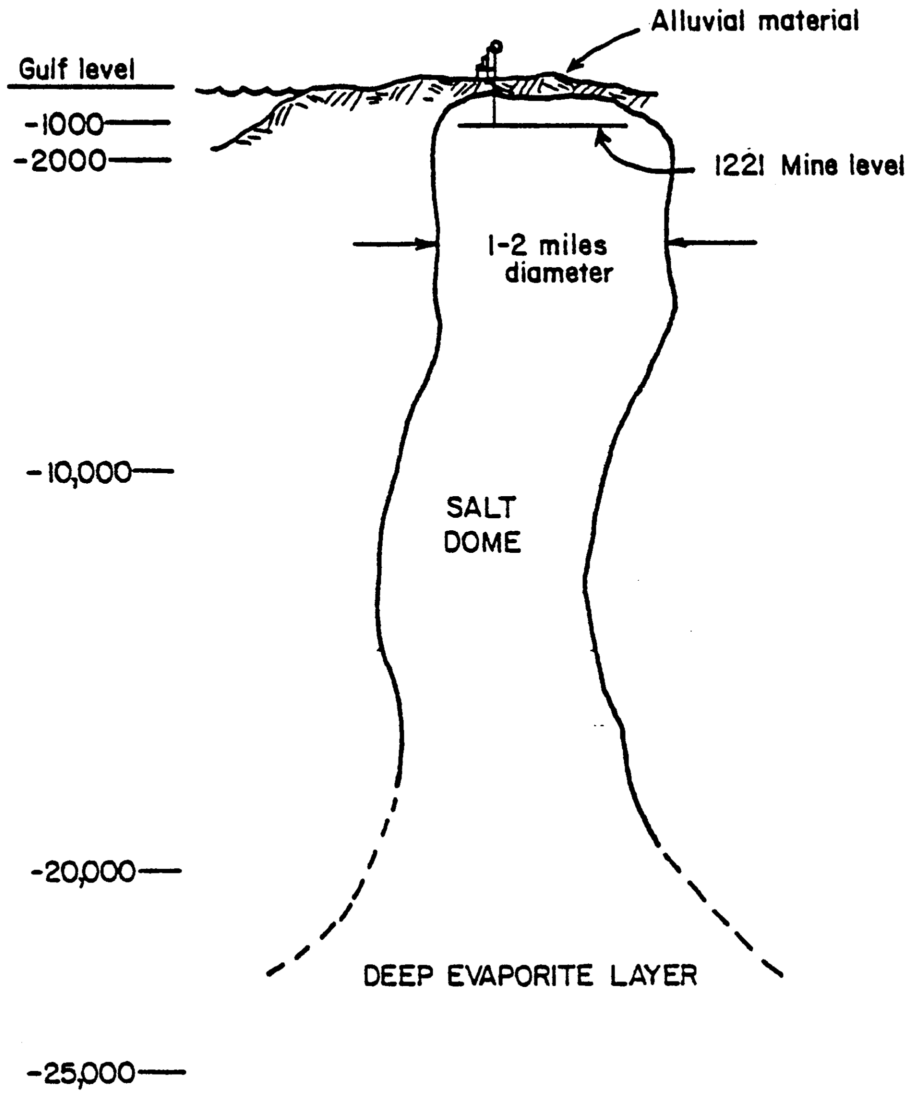
April 30, 1980

Thomas J. Shepich
Administrator for Metal and
Nonmetal Mine Safety and Health



SKETCH
LOUISIANA GULF COAST (PARTIAL)
SHOWING
"THE FIVE ISLANDS"

APPENDIX A



SKETCH
TYPICAL SECTION
BELLE ISLE SALT DOME

AFTER NICHOLAS J. NICOLA
CARGILL INCORPORATED

APPENDIX B

APPENDIX C
VICTIMS OF MINE DISASTER, BELLE ISLE MINE
CARGILL, INCORPORATED

June 8, 1979

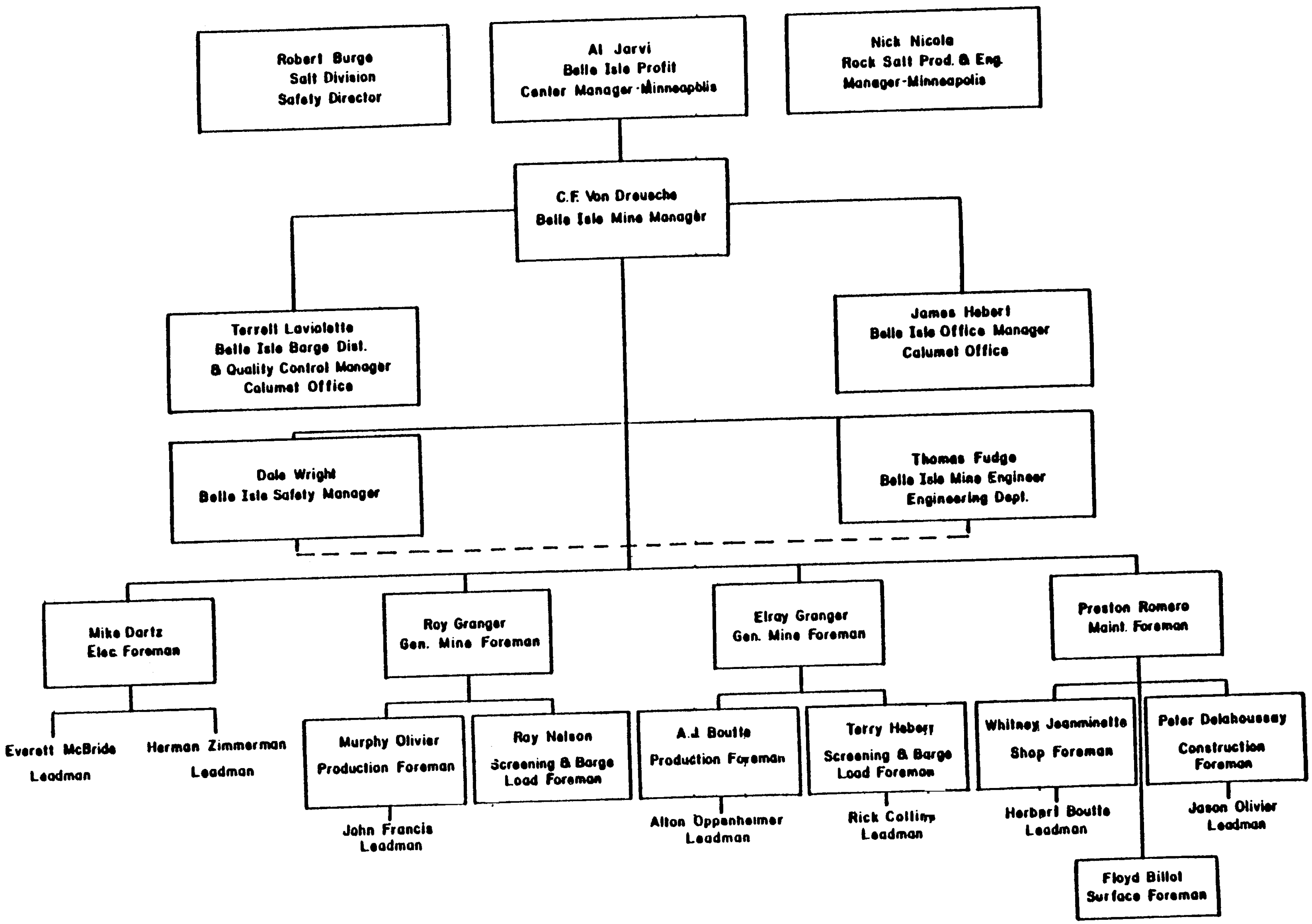
Name	Social Security Number	Age	Dependents	Occupation
Collins, Richard	437-76-8909	31	3	Preparation Miner
Mayon, Donald	433-58-6603	38	3	General Miner
Olivier, Amedee	433-96-6153	22	0	Preparation Miner
Sampay, Adam	433-94-5189	23	0	Production Miner
Zimmerman, Herman	437-38-6678	48	8	Plant Maintenance Master

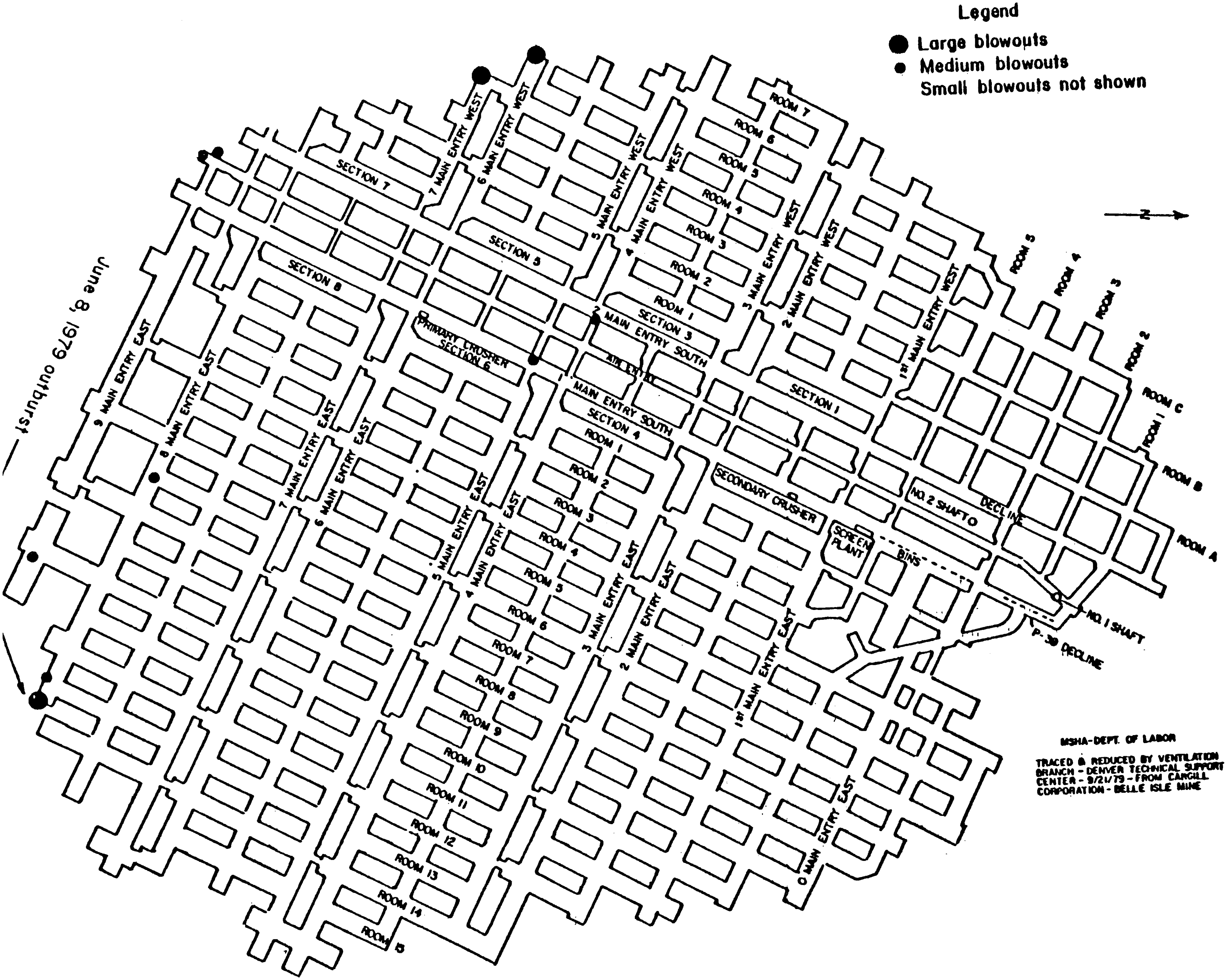
APPENDIX D

VICTIMS' CAUSE OF DEATH

NAME	AGE	CAUSE OF DEATH
Collins, Richard	31	Cause of death is attributed to axphyxiation secondary to hemorrhage into the bronchial tree from the acute pulmonary hemorrhage due to ruptured alveoli in the lungs due to the airblast in the mine explosion. Extensive (50%) third degree burns over entire dorsum of body. Membranous Glomerulonephritis.
Mayon, Donald	38	Cause of death attributed to acute pulmonary hemorrhage and aspiration with asphyxia secondary to airblast from gas explosion.
Olivier, Amedee	22	1. Acute pulmonary hemorrhage (bilateral) secondary to alveolar rupture due to airblast in mine explosion. 2. Carbon monoxide poisoning. 3. Multiple areas (30%) second degree flash burns.
Sampay, Adam	23	Cause of death attributed to acute pulmonary hemorrhage due to alveoli rupture secondary to airblast from mine explosion. Multiple second degree burns over the body.
Zimmerman, Herman	48	Immediate cause of death attributed to asphyxia and concomitant acute pulmonary hemorrhage due to ruptured alveoli secondary to airblast from gas explosion. Compound fracture left femur.

CARGILL CORPORATION
ORGANIZATION CHART




Legend
Large blowouts
Medium blowouts
Small blowouts not shown
June 8, 1979 outburst
SECTION 7
SECTION 5
SECTION 8
SECTION 3
SECTION 6
PRIMARY CRUSHER
SECTION 4
SECTION 1
SECONDARY CRUSHER
SCREEN PLANT
BINS
NO. 2 SHAFT
DECLINE
NO. 1 SHAFT
P-30 DECLINE
9 MAIN ENTRY EAST
8 MAIN ENTRY EAST
7 MAIN ENTRY EAST
6 MAIN ENTRY EAST
5 MAIN ENTRY EAST
4 MAIN ENTRY EAST
3 MAIN ENTRY EAST
2 MAIN ENTRY EAST
1st MAIN ENTRY EAST
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6 MAIN ENTRY WEST
5 MAIN ENTRY WEST
4 MAIN ENTRY WEST
3 MAIN ENTRY WEST
2 MAIN ENTRY WEST
1st MAIN ENTRY WEST
2 MAIN ENTRY SOUTH
1 MAIN ENTRY SOUTH
ROOM 1
ROOM 2
ROOM 3
ROOM 4
ROOM 5
ROOM 6
ROOM 7
ROOM 8
ROOM 9
ROOM 10
ROOM 11
ROOM 12
ROOM 13
ROOM 14
ROOM 15
ROOM A
ROOM B
ROOM C
N
MSHA-DEPT. OF LABOR
TRACED & REDUCED BY VENTILATION BRANCH - DENVER TECHNICAL SUPPORT CENTER - 9/21/79 - FROM CARGILL CORPORATION - BELLE ISLE MINE

APPENDIX E

APPENDIX G

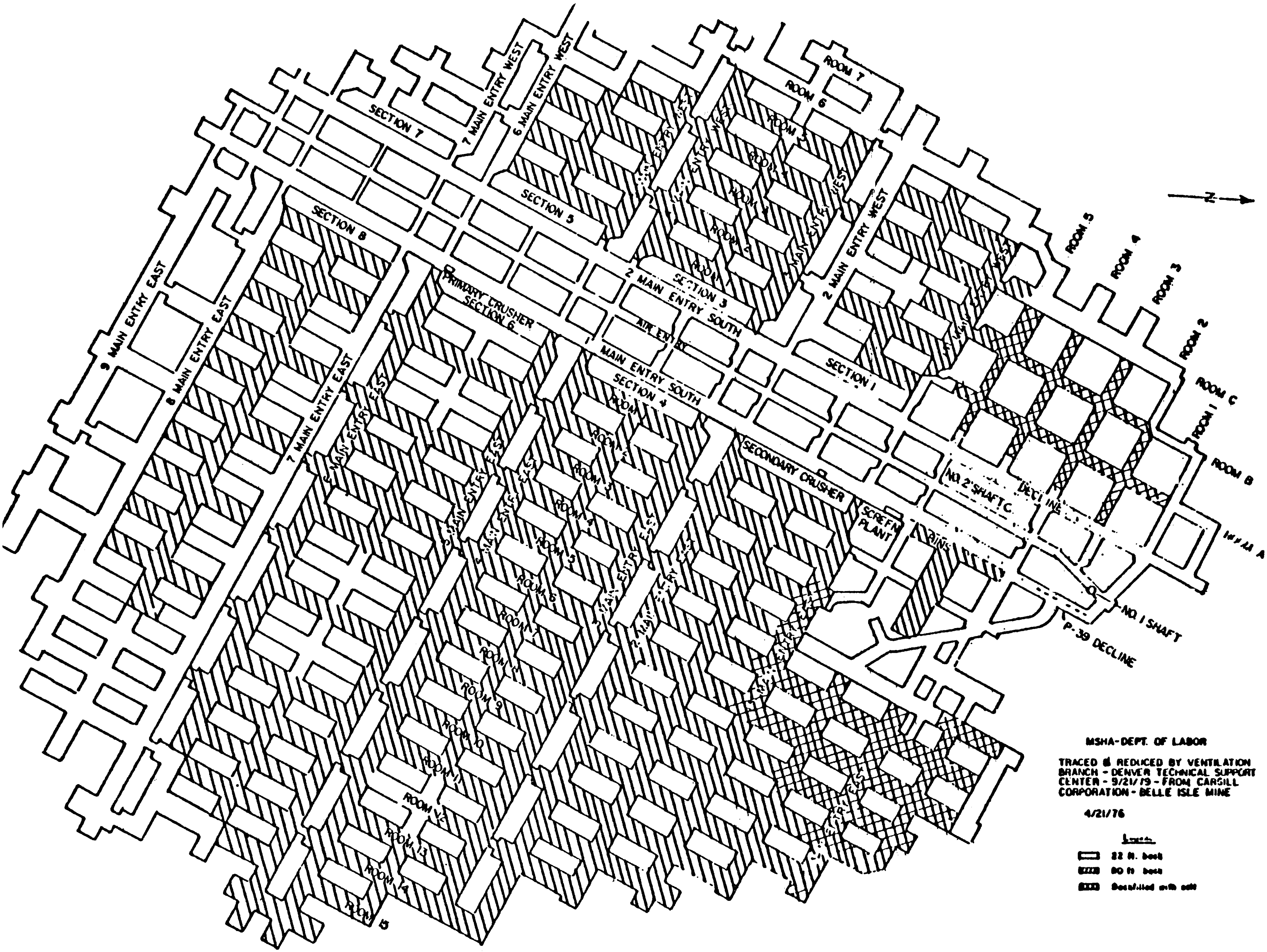
LIST OF ORDERS, CITATIONS AND NOTICES - BY SECTION
ISSUED AT BELLE ISLE MINE
APRIL 1971 - MAY 1979

Section	Title	Number of Orders*	Number of Citations**	Number of Notices***
57.3	Ground Control	105	9	37
57.4	Fire Prevention	7	4	123
57.5	Air Quality	7	5	30
57.6	Explosives	13	3	101
57.9	Load/Haul/Dump	25	1	126
57.11	Travelway	23	8	212
57.12	Electricity	15	7	185
57.13	Compressed Air			3
57.14	Guarding	10	11	184
57.15	Personal Protection	8	1	19
57.16	Material Storage	1		34
57.17	Illumination	1		10
57.18	Safety Program			3
57.19	Manhoisting	7		50
57.20	Miscellaneous			4

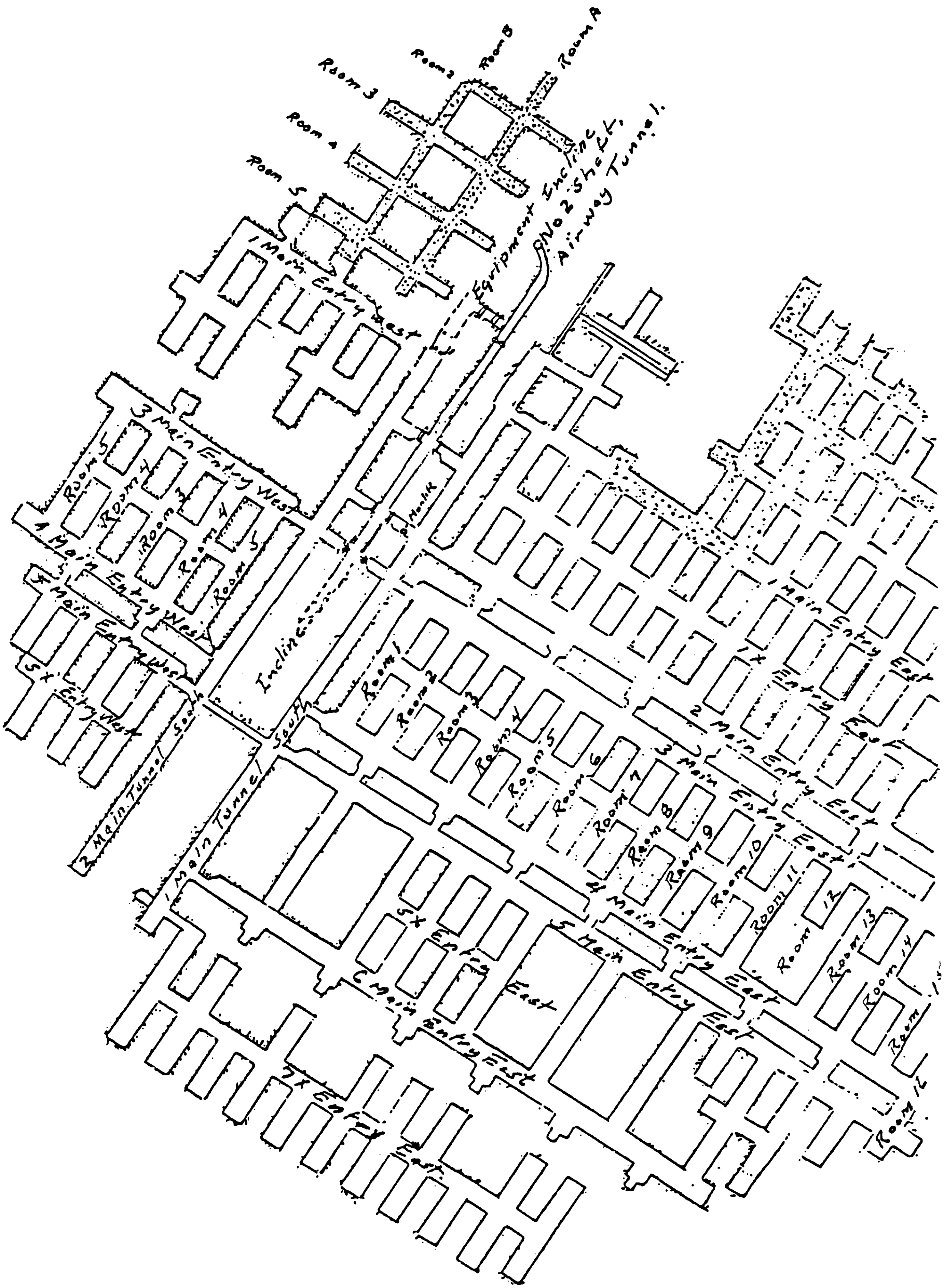
* Orders - Issued under Public Law 89-577 and Public Law 91-173 as amended by Public Law 95-164.

** Citations - Issued under Public Law 91-173 as amended by Public Law 95-164.

*** Notices - Issued under Public Law 89-577.



Plan View Belle Isle Mine



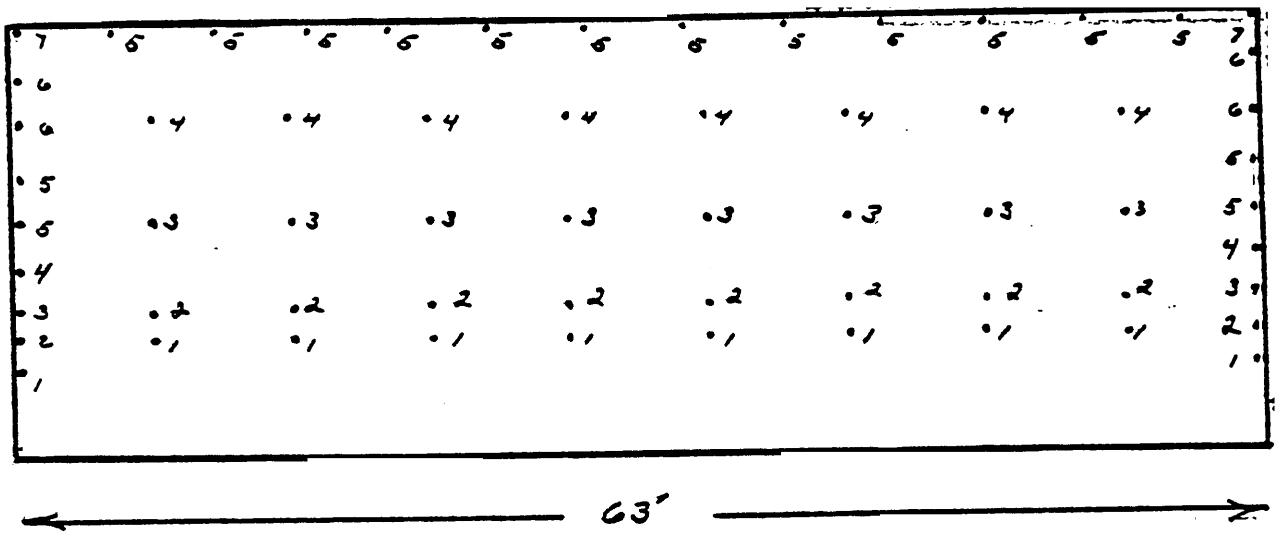
LOWER LEVEL BELLE ISLE MINE

APPENDIX J

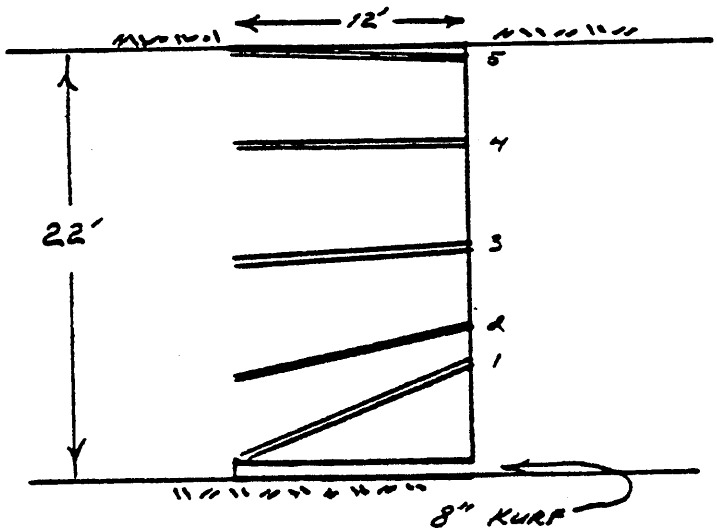
CARGILL, BELLE ISLE SALT MINE

T. Fudge 6-26-79

FACE ROUNDS



FRONT VIEW



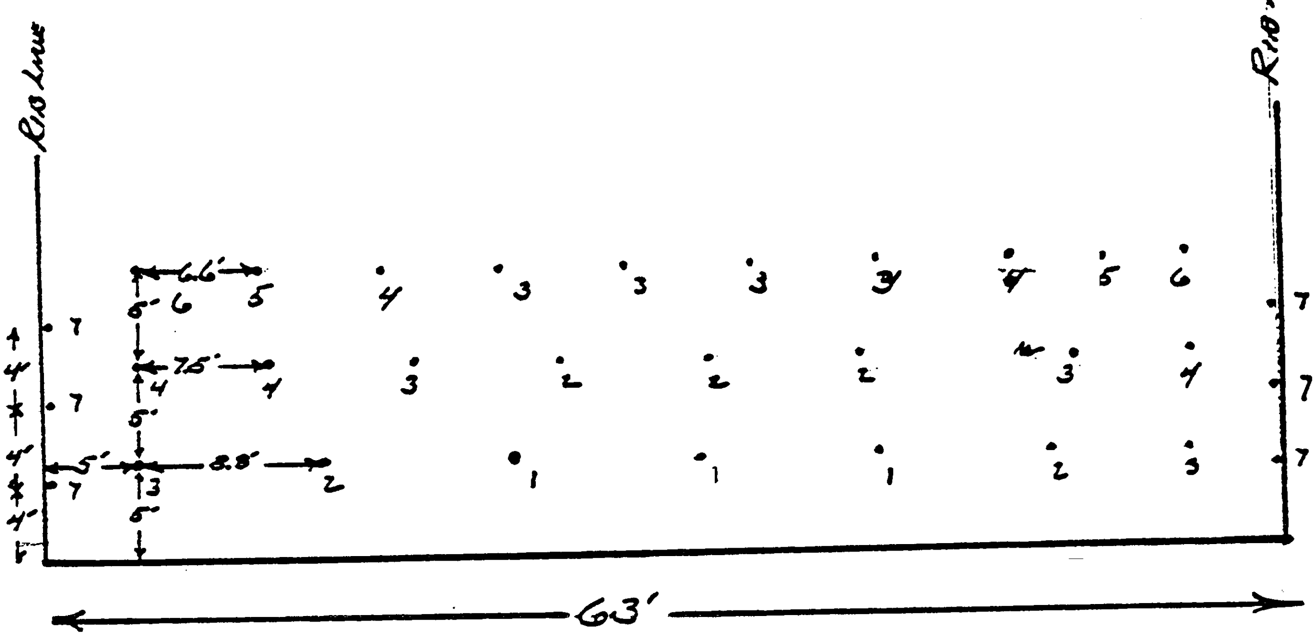
SIDE VIEW

All Holes loaded with 6 to 7 Sticks of 16" x 1½" Unigel, Detination by Electric Cap placed in second stick (ie second stick placed in hole).

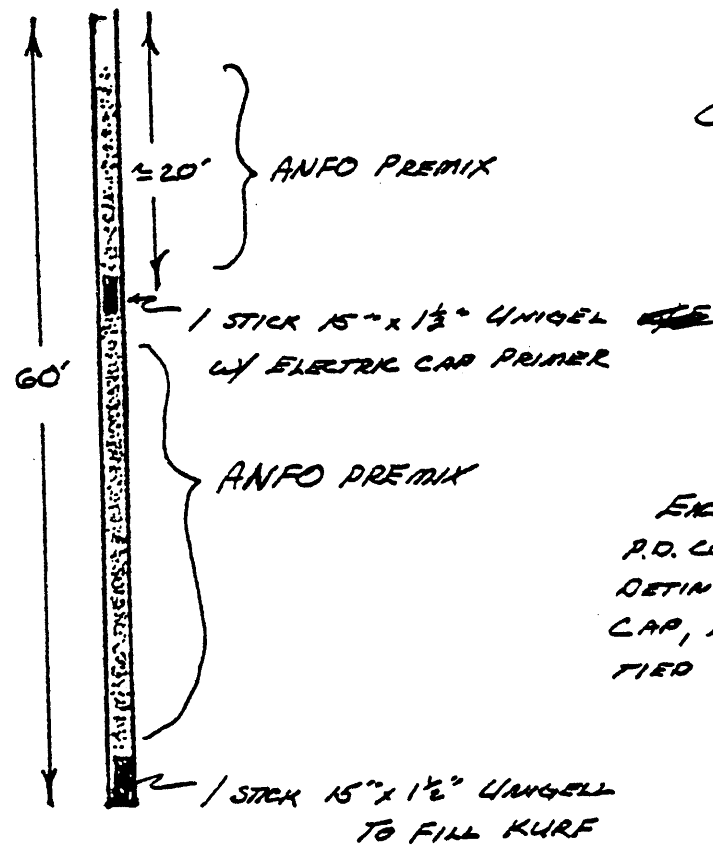
CARGILL, BELLE ISLE SALT MINE

T. FUDGE 7-26-79

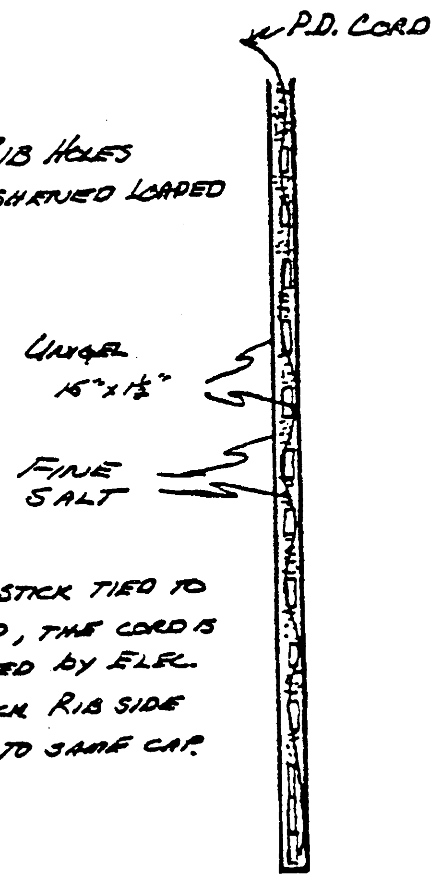
FLOOR ROUNDS



PLAN VIEW



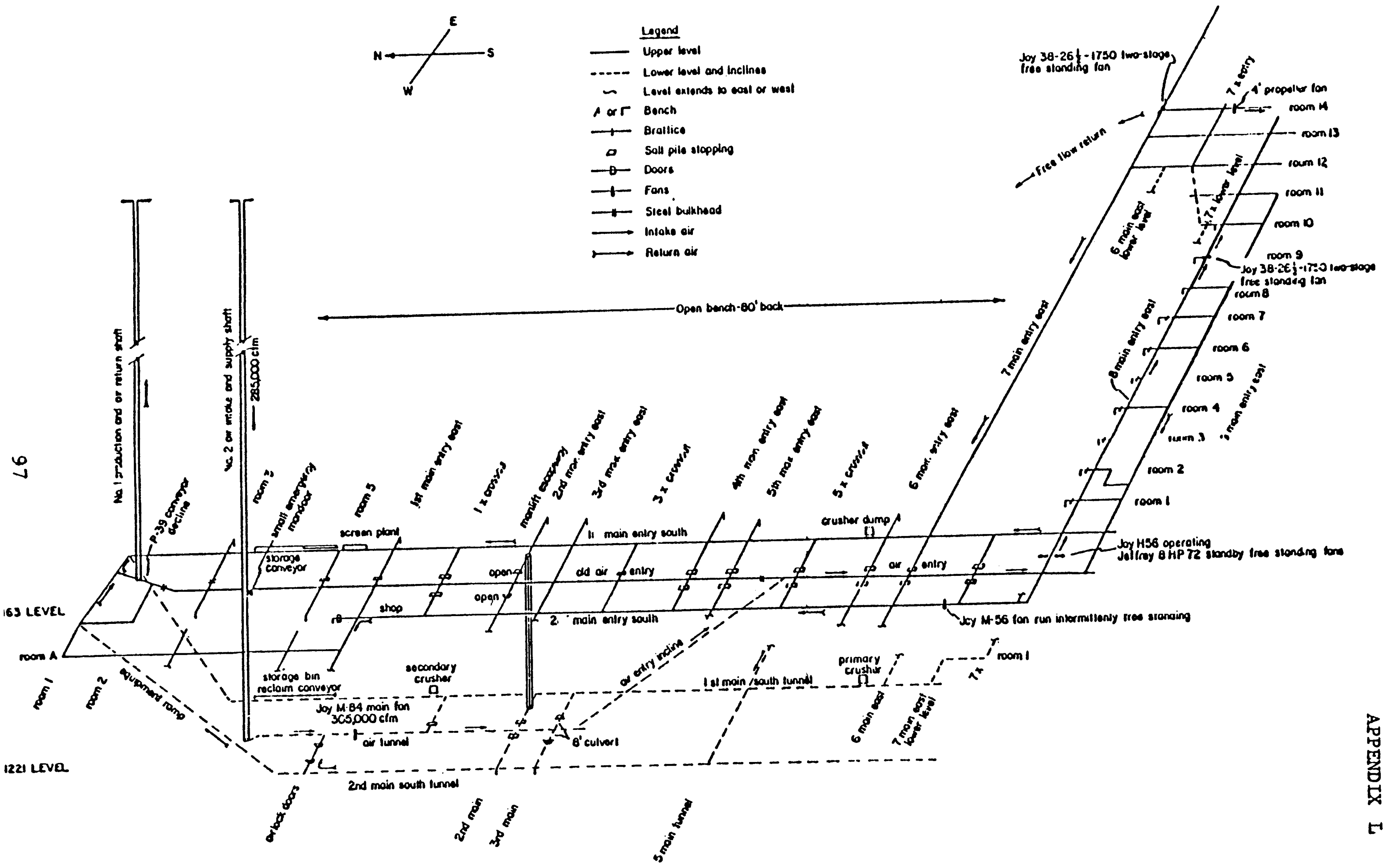
TYP FLOOR HOLE



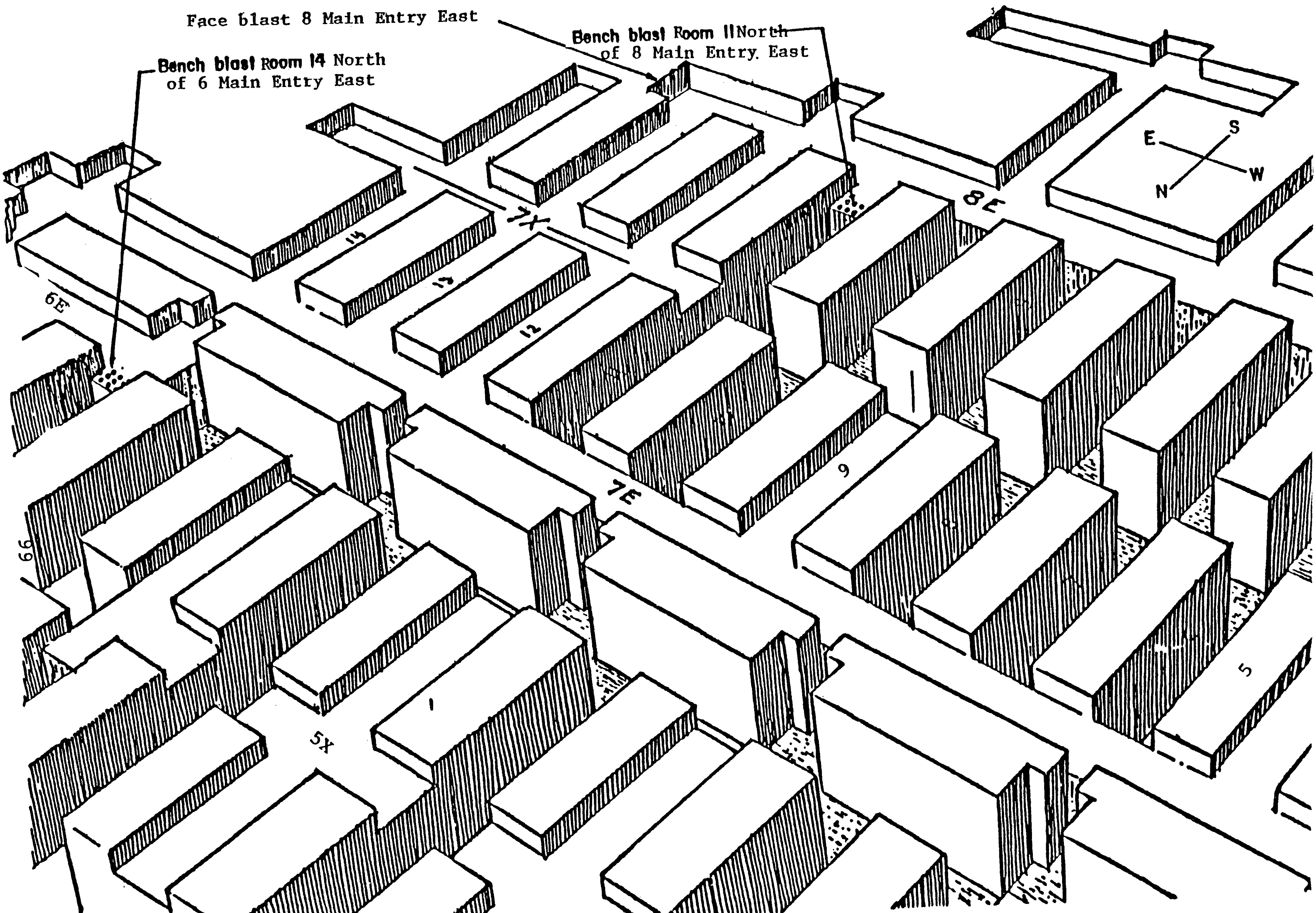
EACH STICK TIED TO P.D. CORD, THE CORD IS DETONATED BY ELEC. CAP, EACH RIB SIDE TIED * TO SAME CAP.

TYP RIB HOLE

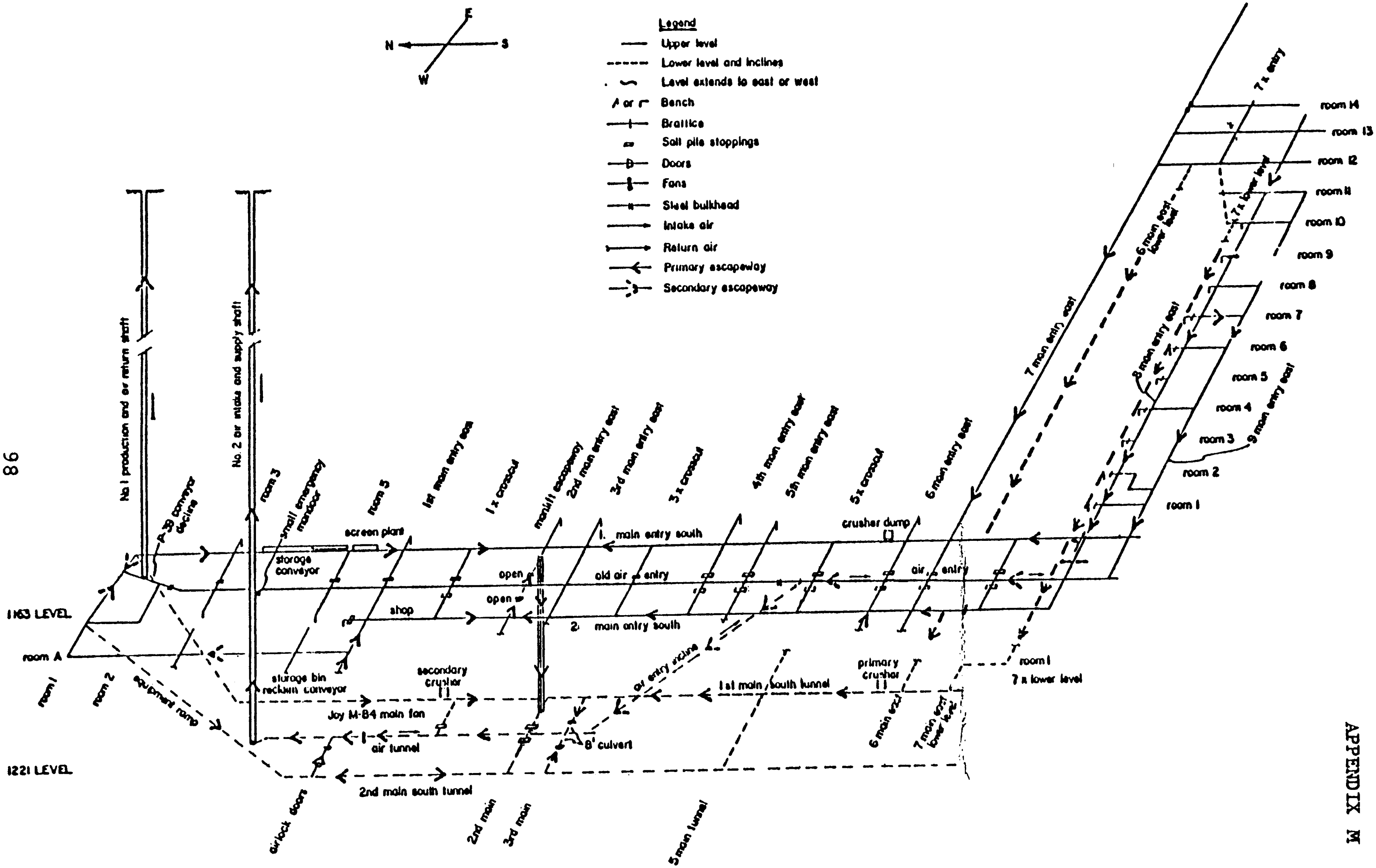
ALL FLOORS UNDER CUT WITH 8" KURF



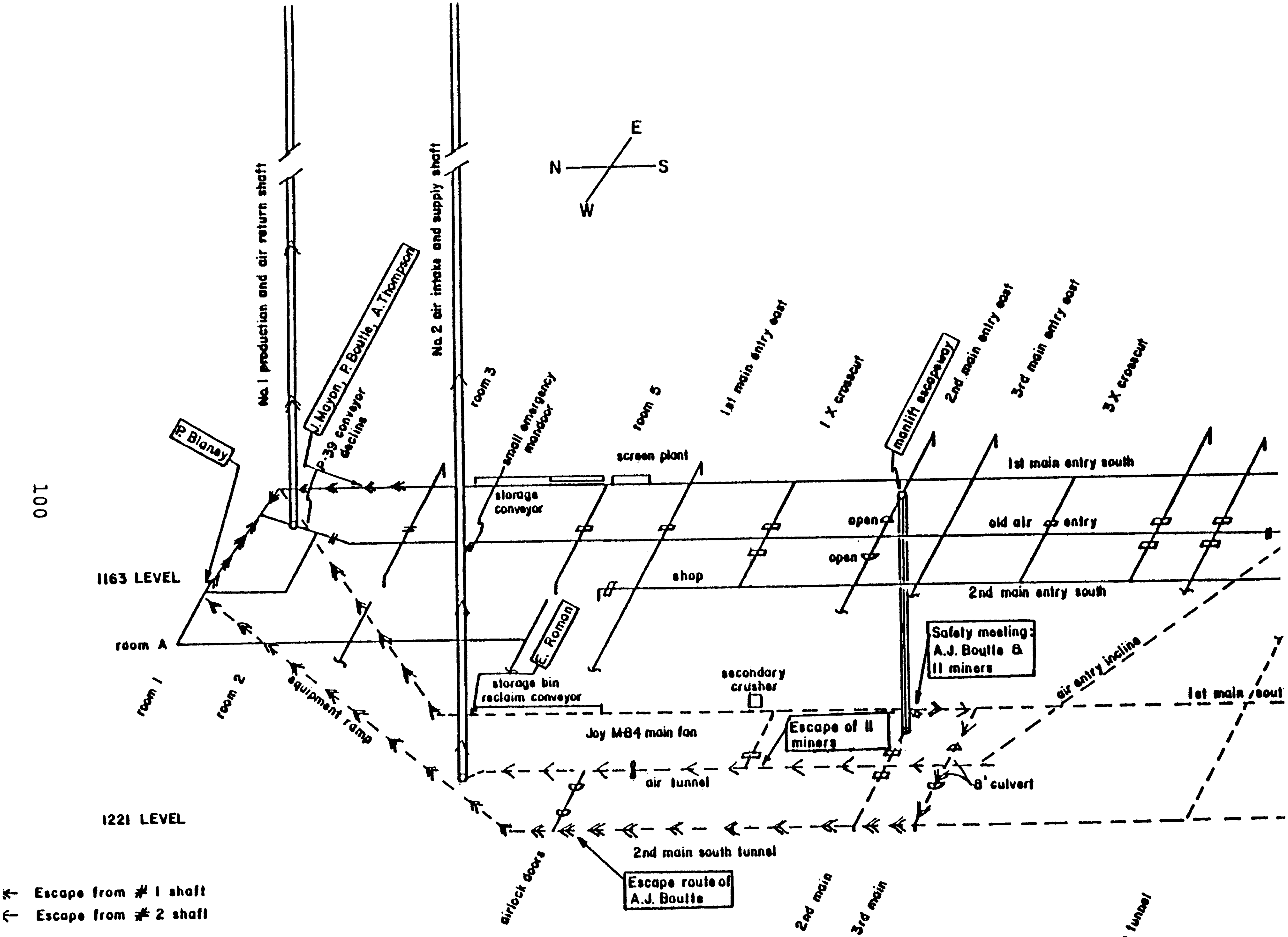
Schematic of Belle Isle ventilation system



ISOMETRIC OF OUTBURST SECTION OF BELLE ISLE MINE

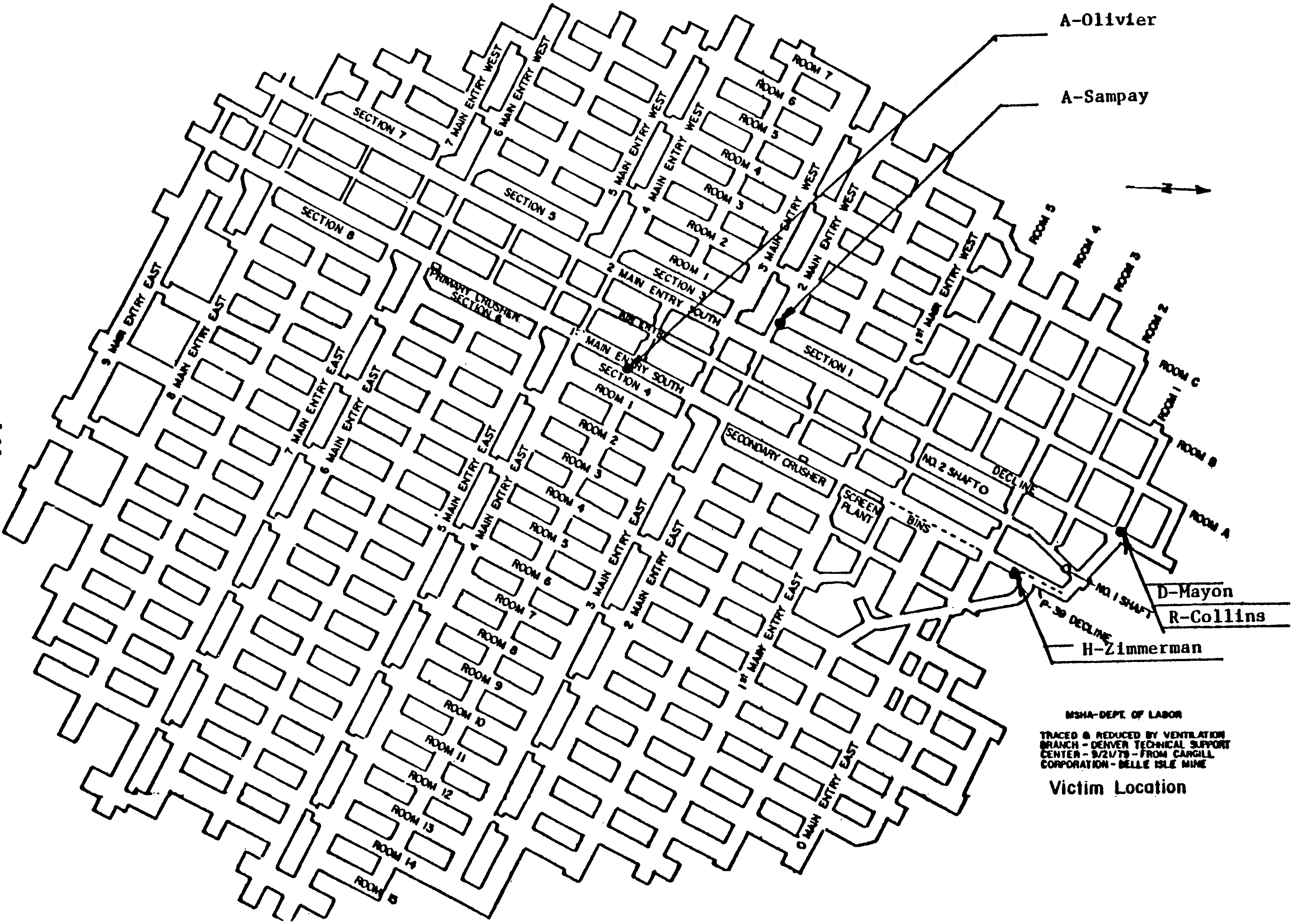


Schematic of Belle Isle ventilation system dnd escapeway



SURVIVORS ESCAPE ROUTES

APPENDIX C



MSHA-DEPT. OF LABOR

TRACED & REDUCED BY VENTILATION BRANCH - DENVER TECHNICAL SUPPORT CENTER - 9/21/79 - FROM CARGILL CORPORATION - BELLE ISLE MINE

Victim Location

APPENDIX Q

NON-FEDERAL PARTICIPANTS IN RESCUE AND RECOVERY OPERATIONS

Cargill, Inc.

Mine Rescue Personnel

Thomas F. Fudge, Jr.	Peter Delahoussaye	John McFarlain
Elray Granger	Murphy Olivier	Michael LeBlanc
Perry Herbert	Whitney Jeanminette	Eddie Burke
Raymond Nelson	Mike Ward	Athan Olivier
Charles Hidalgo, Jr.	Louis Boutte	John Francis

Equipment Personnel

Dale Wright

James Fuhrer

International Salt Company

Mine Rescue Personnel

Donald Pellerin	Rayward Segura	Murphy Henry
Glenn Meyers	Shelly Boudreaux	Oliver Brown
Ernest Broussard	Rogers Etic	Danny Rodrique
Robert Romero	Clayton Pellerin	Viola Johnson

Assisting Personnel

Lester Jay

Harry Anderson

Harold LeBlanc

Daniel Pillegrin

Morton Salt Company

No. 1 Team Members	No. 2 Team Members
Stoney Hotard, Jr.	Ronald Olivier
Gerald Meyers	Fred DeJean
Andrew Guidry, Jr.	Gene Rodrique
Chris Kapp, Jr.	Rick Ingulls
James Thibodeaux	Art Kozma
Clifford Olivier	Neil Nelson
Charles Henderson	Calvin Glaubrecht

Diamond Crystal Salt Company

Mine Rescue Personnel

Jim Frith	Paul Hebert
James Gustafson	Lee Fermin
Elmer Hebert	Ann Darby
Randy LaSalle	John Vice

NATIONAL METAL AND NONMETAL MINE RESCUE PERSONNEL

Name	Office	Subdistrict
Charles E. McDaniel	Knoxville, TN	Knoxville Subdistrict
Thomas J. Garcia	Albany, NY	Albany Subdistrict
Paul Grubb, Jr.	Reading, PA Field Office	Pittsburgh Subdistrict
Stephen J. Moyer, Jr.	Reading, PA Field Office	Pittsburgh Subdistrict
Larry J. Aubuchon	Hillsboro, IL Field Office	Vincennes Subdistrict
Steven R. Smith	LaSalle, IL Field Office	Vincennes Subdistrict
Willard J. Graham	Rolla, MO	Rolla Subdistrict
Larry R. Nichols	Rolla, MO	Rolla Subdistrict
Steve O. Viles	Fairfield, OH Field Office	Vincennes Subdistrict
Daniel J. Haupt	San Antonio, TX Field Office	Dallas Subdistrict
William Tanner, Jr.	Albuquerque, NM Field Office	Dallas Subdistrict
Rodric M. Breland	Grand Junction, CO F.O.	Denver Subdistrict
Michael T. Dennehy	Grand Junction, CO F.O.	Denver Subdistrict
Jake H. DeHerrera	Denver, CO	Denver Subdistrict
Thomas R. Aldrete	Tucson, AZ Field Office	Phoenix Subdistrict
Edmundo Archuleta	San Bernardino, CA F.O.	Phoenix Subdistrict
Cosme F. Gutierrez	San Bernardino, CA F.O.	Phoenix Subdistrict
John B. Austin	Boise, ID Field Office	Bellevue Subdistrict
Dan A. Kleinhesselink	Coeur d'Alene, ID F.O.	Bellevue Subdistrict
Dan E. MacMillan	Albany, OR Field Office	Bellevue Subdistrict
J. D. Pitts	Arlington, VA	MSHA Headquarters

APPENDIX S

PARTICIPATING MINE SAFETY AND HEALTH ADMINISTRATION PERSONNEL

Name	Title	Location
Thomas J. Shepich	Administrator Metal and Nonmetal Mine Safety and Health	Arlington, Va.
Roy O. Bernard	Deputy Administrator Metal and Nonmetal Mine Safety and Health	Arlington, Va.
Donald P. Schlick	Director Technical Support	Arlington, Va.
Bernard McGuire	Attorney-Advisor	Arlington, Va.
Edward H. Fitch, Jr.	Trial Attorney Task Force Legal Advisor	Arlington, Va.
Wilbert B. Forbes	Special Investigator	Arlington, Va.
William Craft	Special Assignment to Administrator	Arlington, Va.
David J. Park	Special Assignment to Administrator	Arlington, Va.

ROLLA SUBDISTRICT PERSONNEL WHO WENT TO BELLE ISLE

Name	Title	Location
Doyle D. Fink	Supervisory Mine Inspector	Cedar Rapids, IA
Edward D. Ammala	Supervisory Mine Inspector	Ft. Dodge, IA
Lloyd R. Caldwell	Mine Inspector	Topeka, KS
*Terry E. Phillips	Subdistrict Manager	Rolla, MO
*Larry R. Nichols	Special Investigator	Rolla, MO
*Willard J. Graham	Mine Inspector	Rolla, MO
Cathy A. Greig	Clerk-Typist	Rolla, MO
*James W. Ashton	Mine Inspector	Rolla, MO
Earl C. Wilson	Mine Inspector	Rolla, MO
Larry D. Feeney	Mine Inspector	Rolla, MO
Oneth L. Jones	Mine Inspector	Rolla, MO
James A. Ruble	Mine Inspector	Rolla, MO
*Paul A. Belanger	Mine Inspector	Rolla, MO
*Marshall S. Johnson	Mine Inspector	Rolla, MO
David A. Davis	Mine Inspector	Rolla, MO
Ronald J. Johns	Mine Inspector	Rolla, MO
Ernest D. Look	Mine Inspector	Rolla, MO
Troy Bullard	Mine Inspector	Rolla, MO
Howard J. Lucas	Supervisory Mine Inspector	Rolla, MO
Raymond F. Povondra	Supervisory Mine Inspector	Omaha, NB
	ROCKY MOUNTAIN DISTRICT	
Paul E. Talley	Mechanical Equip. Insp. Spec.	Denver, CO
	DESIGNATED PERSONS	
Leanna E. Sweet	Clerk-Stenographer	Albany, NY
Rita A. Williams	Clerk-Typist	Alameda, CA
Candice Patterson	Clerk-Typist	Madison, WI

*Indicates Mine Rescue Personnel involved in search and recovery

DALLAS SUBDISTRICT PERSONNEL WHO WENT TO BELLE ISLE

Name	Title	Location
Omer D. Williams	Mine Inspector	Dallas, TX
Allen L. Head	Mine Inspector	Dallas, TX
Michael C. Sanders	Mine Inspector	Norman, OK
Harold R. Yount	Mine Inspector	Dallas, TX
Alberta Sherfield	Clerk-Typist	Dallas, TX
Marta Marquez	Clerk-Typist	Dallas, TX
H. P. Richardson	Acting Subdistrict Manager	Dallas, TX
Wayne D. Kanack	District Manager	Dallas, TX
William Tanner	Mine Inspector	Albuquerque, NM
Sidney Kirk	Supervisory Mine Inspector	Carlsbad, NM
Billie Ritchey	Supervisory Mine Inspector	Little Rock, AK
Bill Turnbough	Mine Inspector	Little Rock, AK
Richard Feehan	Mine Inspector	Little Rock, AK
Russell E. Smith	Supervisory Mine Inspector	Norman, OK
George L. Newlin	Mine Inspector	Norman, OK
Archie L. Fuller	Mine Inspector	Norman, OK
James S. Smiser	Mine Inspector	Norman, OK
Pas P. Torres	Mine Inspector	Norman, OK
Millard F. Smith	Mine Inspector	Dallas, TX
Jay W. Durfee	Supervisory Mine Inspector	Baton Rouge, LA
Jerry A. Millard	Mine Inspector	Baton Rouge, LA
Robert W. White	Mine Inspector	San Antonio, TX
Ralph Gallegos	Mine Inspector	San Antonio, TX
Henry A. Narramore	Supervisory Mine Inspector	San Antonio, TX
Dan Haupt	Mine Inspector (Electrical)	San Antonio, TX
Edna M. Guerrero	Clerk-Typist	San Antonio, TX

PITTSBURGH TECHNICAL SUPPORT

Name	Title
James Banfield	Chief, Ventilation Branch
John Baran	Electronics Technician
Edward Chuhta	Electronics Technician
Edward Miller	Mining Engineer
Peter Turcic	Mining Engineer
Sam Toma	Chemist
James Lohrett	Physical Science Technician

DENVER TECHNICAL SUPPORT

Name	Title
Richard J. Kline	Chief, Division of Health Technology
J. Warren Andrews	Mining Engineer
Larry J. Cato	Engineering Aid
Wade E. Cooper	Mining Engineer
Lawrence T. Filek	Electrical Engineer
Ralph K. Foster	Mining Engineer
Jerry L. Fuller	Mining Engineer
Jerry W. Gregory	Chemist
Richard L. Kaplan	Chemist
Stephen Kneipple	Physical Science Technician
Faith Krohlow	Physical Science Technician
Craig Miller	Electrical Engineer
John R. Thompson	Engineering Technician
George W. Weems	Supervisory Physical Scientist

TABLE 1 - ANALYSES OF AIR SAMPLES COLLECTED 06/09/79

MINE/MILL BELLE ISLE COMPANY CARGILL, INC. STATE LA

COLLECTED BY J. MILLARD SUBDISTRICT OFFICE DALLAS, BATON ROUGE, DTSC DATE REC'D 06/15/79

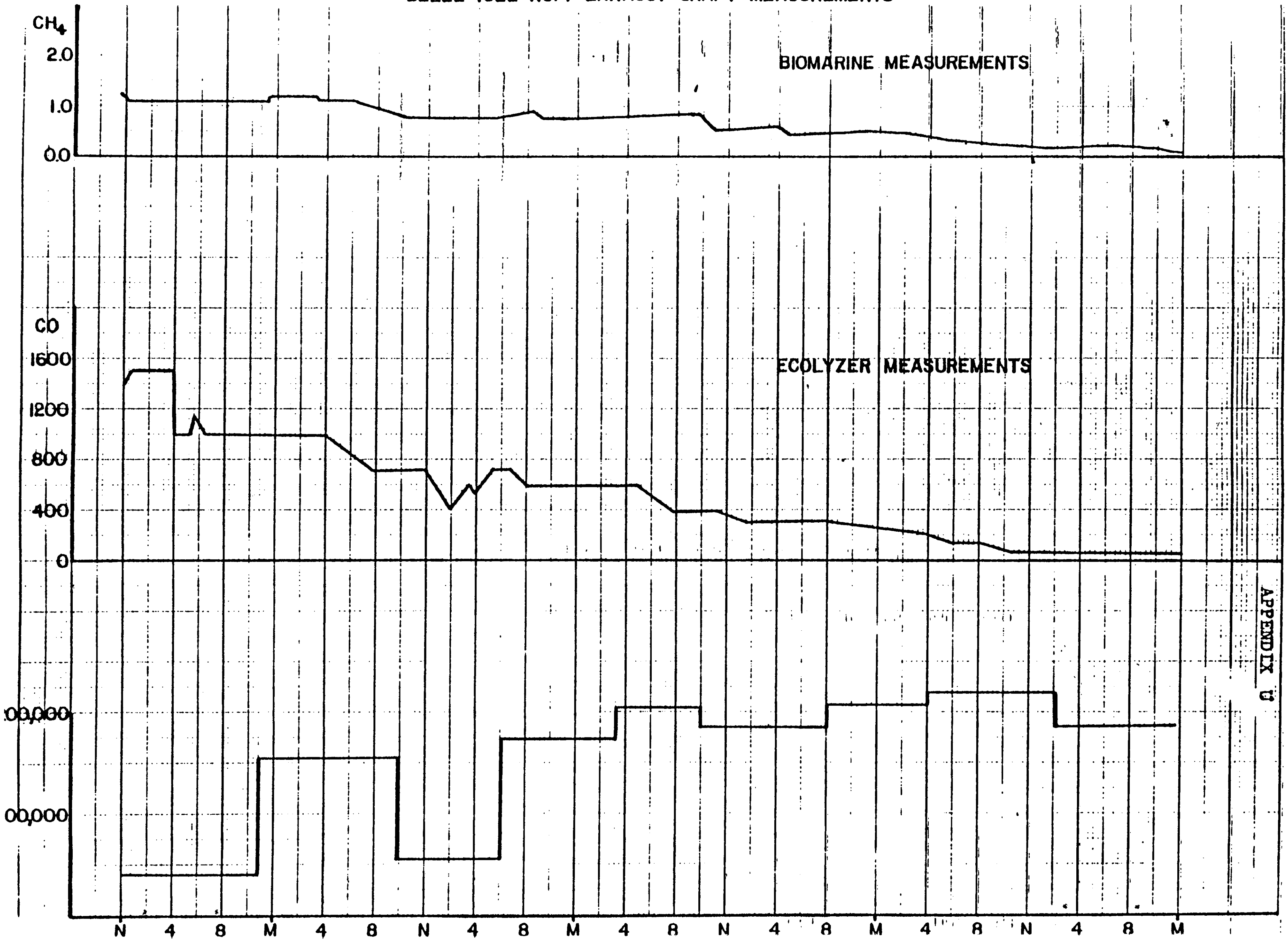
BOTTLE NUMBER	LAB. NUMBER	LOCATION IN MINE	DATE AND TIME	CARBON DIOXIDE	OXYGEN	METHANE	CARBON MONOXIDE	HYDRO-GEN
16337	G9-1478	#1 shaft collar	06/09/79 1500	.99	19.09	.917	.132	.06
				ETHANE - .022; PROPANE - .004; BUTANE - .001				
16313	G9-1479	shaft #1 collar	0630	1.08	18.90	.895	.148	.08
				ETHANE - .022; PROPANE - .004				

DATE 06/15/79 SIGNED Fred C Ryan

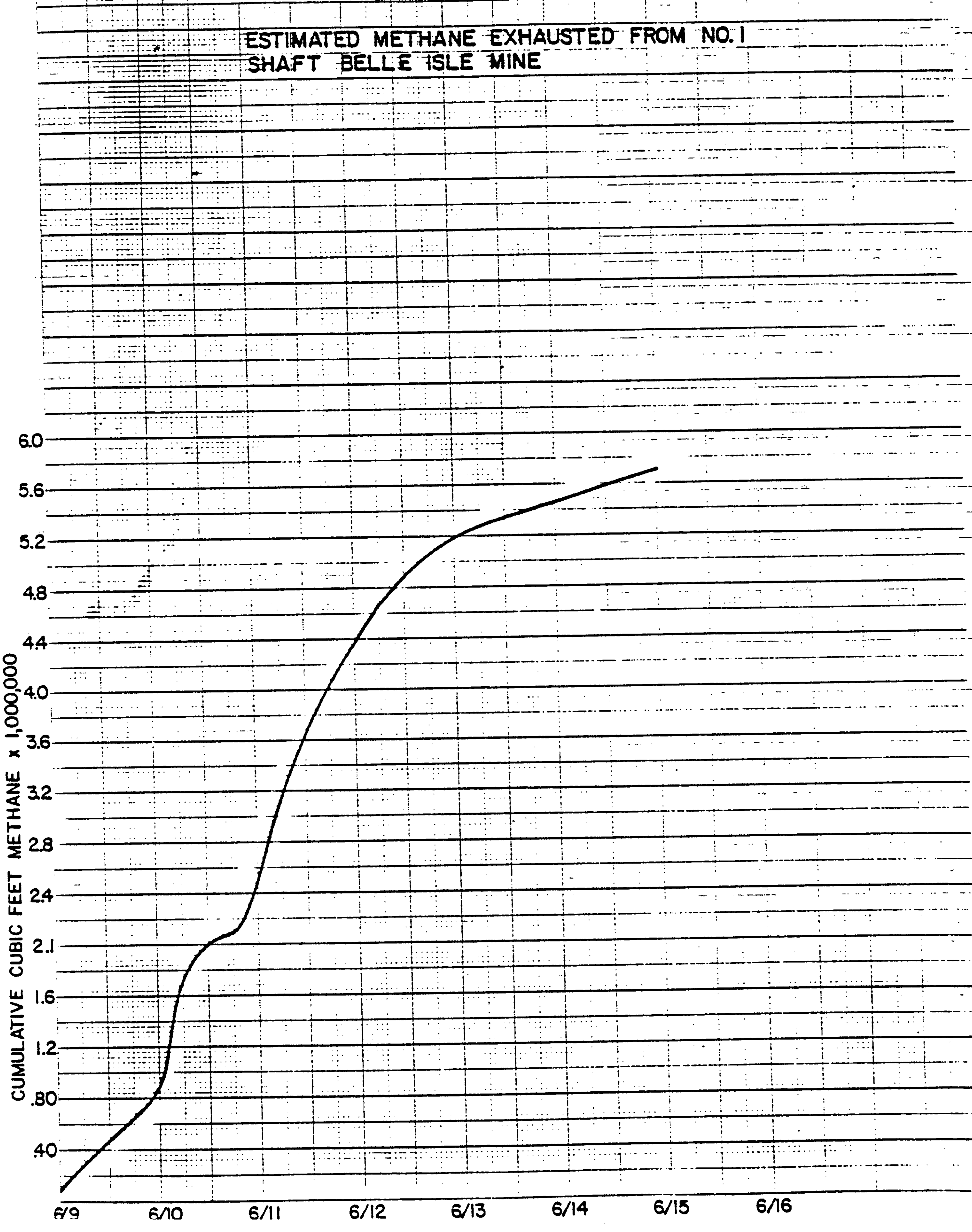
Denver Technical Support Center

APPENDIX 4

BELLE ISLE NO. 1 EXHAUST SHAFT MEASUREMENTS



APPENDIX U

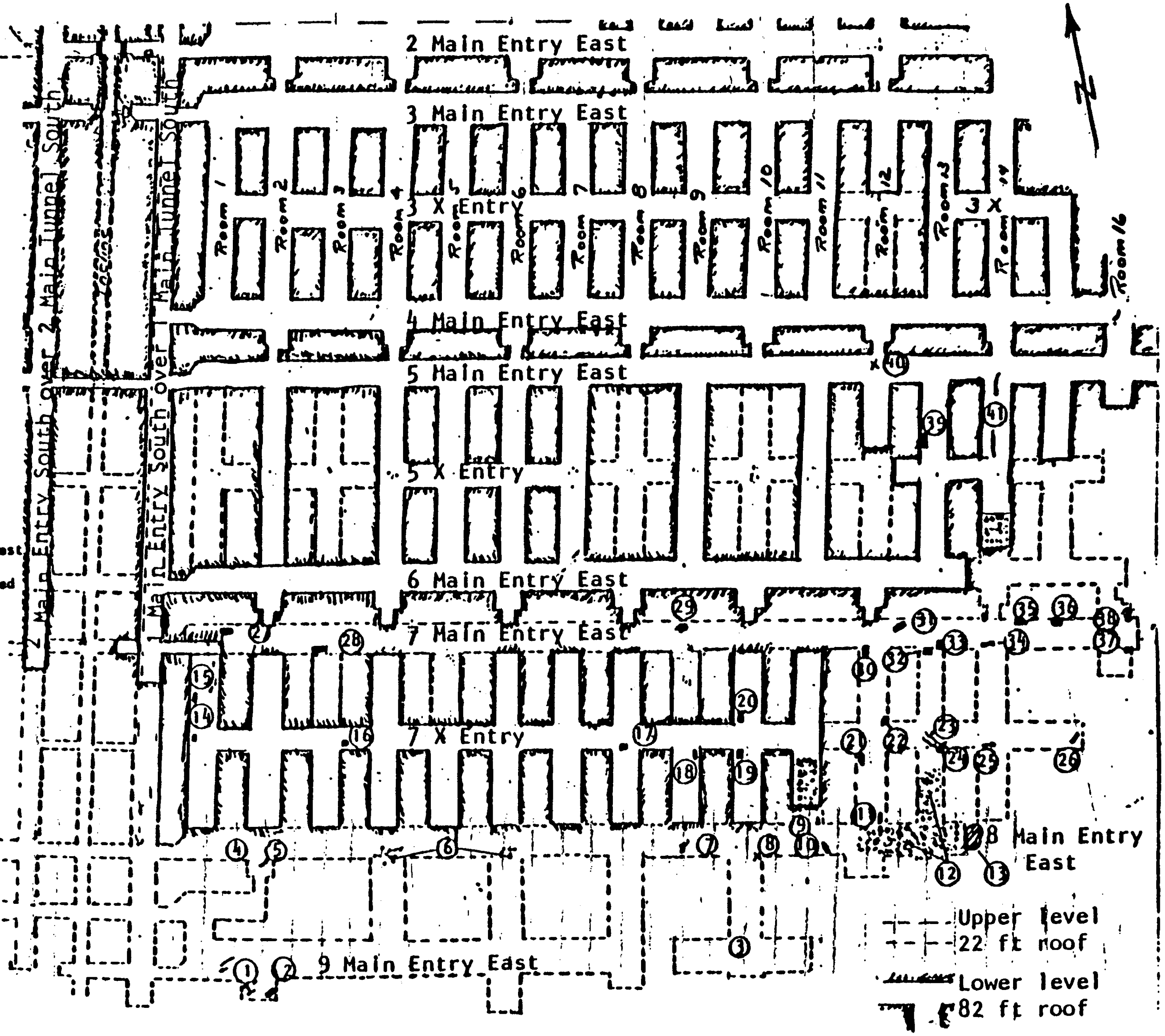

ESTIMATED METHANE EXHAUSTED FROM NO. 1
SHAFT BELLE ISLE MINE
CUMULATIVE CUBIC FEET METHANE x 1,000,000
6.0
5.6
5.2
4.8
4.4
4.0
3.6
3.2
2.8
2.4
2.1
1.6
1.2
.80
.40
6/9
6/10
6/11
6/12
6/13
6/14
6/15
6/16

UPPER LEVEL

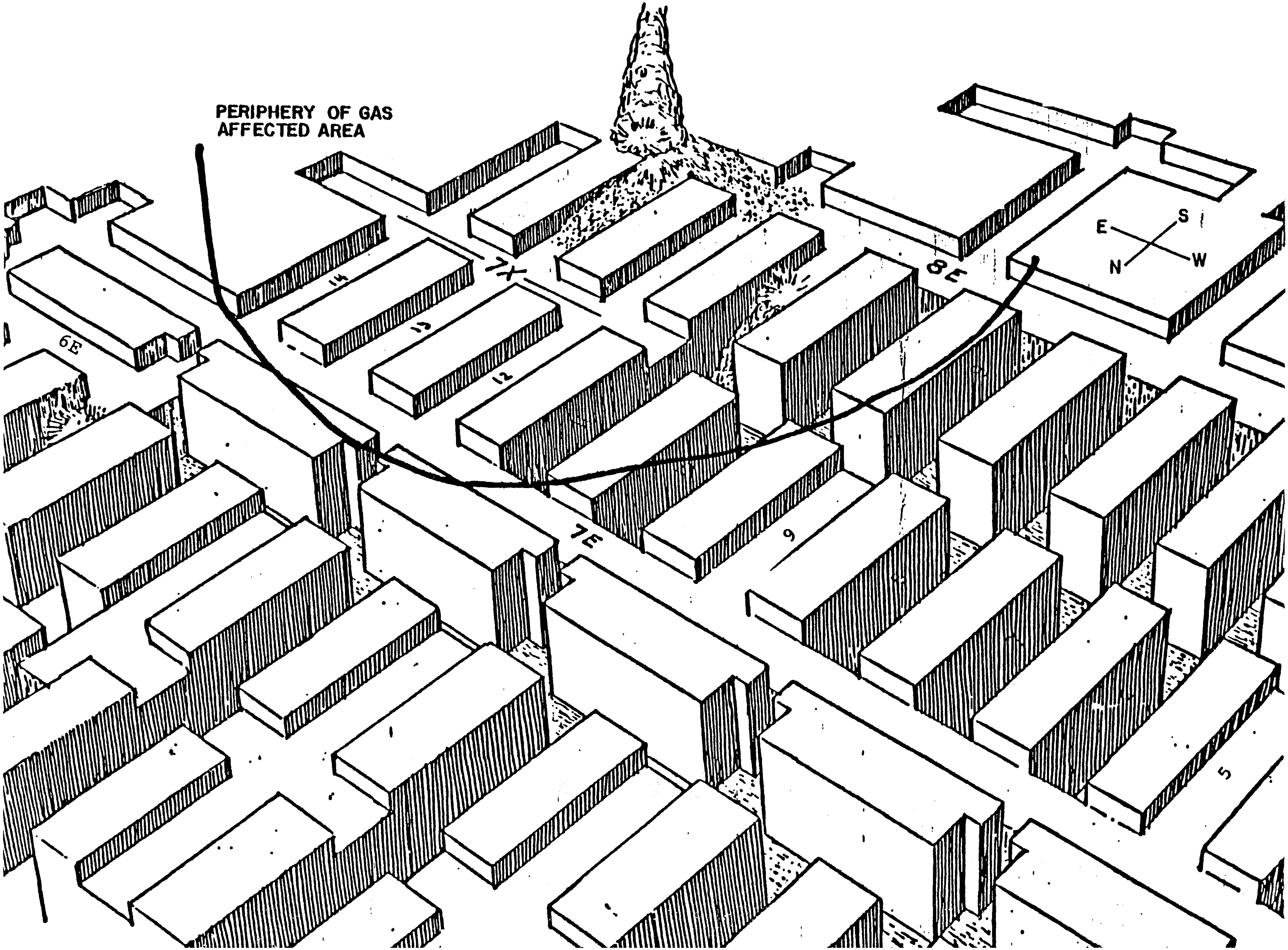
1 Broken up wagon
2 Turned over core drill
3 Roof and walls very black
4 Charred wood from powder wagon
5 Blown apart powder wagon
6 Salt blown north from 8 ft berm
7 Joy 2-stage fan showed no movement
8 Fan connector box gone. Burned lead wires hanging from the roof
9 Distribution box
10 Gradall scaler with loose battery terminal
11 Explossives loading jumbo
12 Salt piles from outburst
13 June 8, 1979 blowout
21 Floor drill
22 Connector box for face drill
23 Tracks along floor from the face drill
24 Turned over face drill
25 Propeller fan with very little movement
26 Gradall scaler - little damage
27 Tranformers with insulators blown off
28 Track mounted front end loader
29 Cable splice - armoured cable to the east and nonarmoured to the west
30 Roof bolter
31 Turned over red shop truck - burned out cab and loose battery cable
32 No. 2 portable load center
33 Original shotboard location
34 Joy axial fan
35 Floor drill with bent boom and damaged hydraulic controls
36 Fan switch box
37 Red shop truck hood
38 Scorched and broken shot board
39 Load center
40 Melted cable splice
41 Heavily charred blasting cable

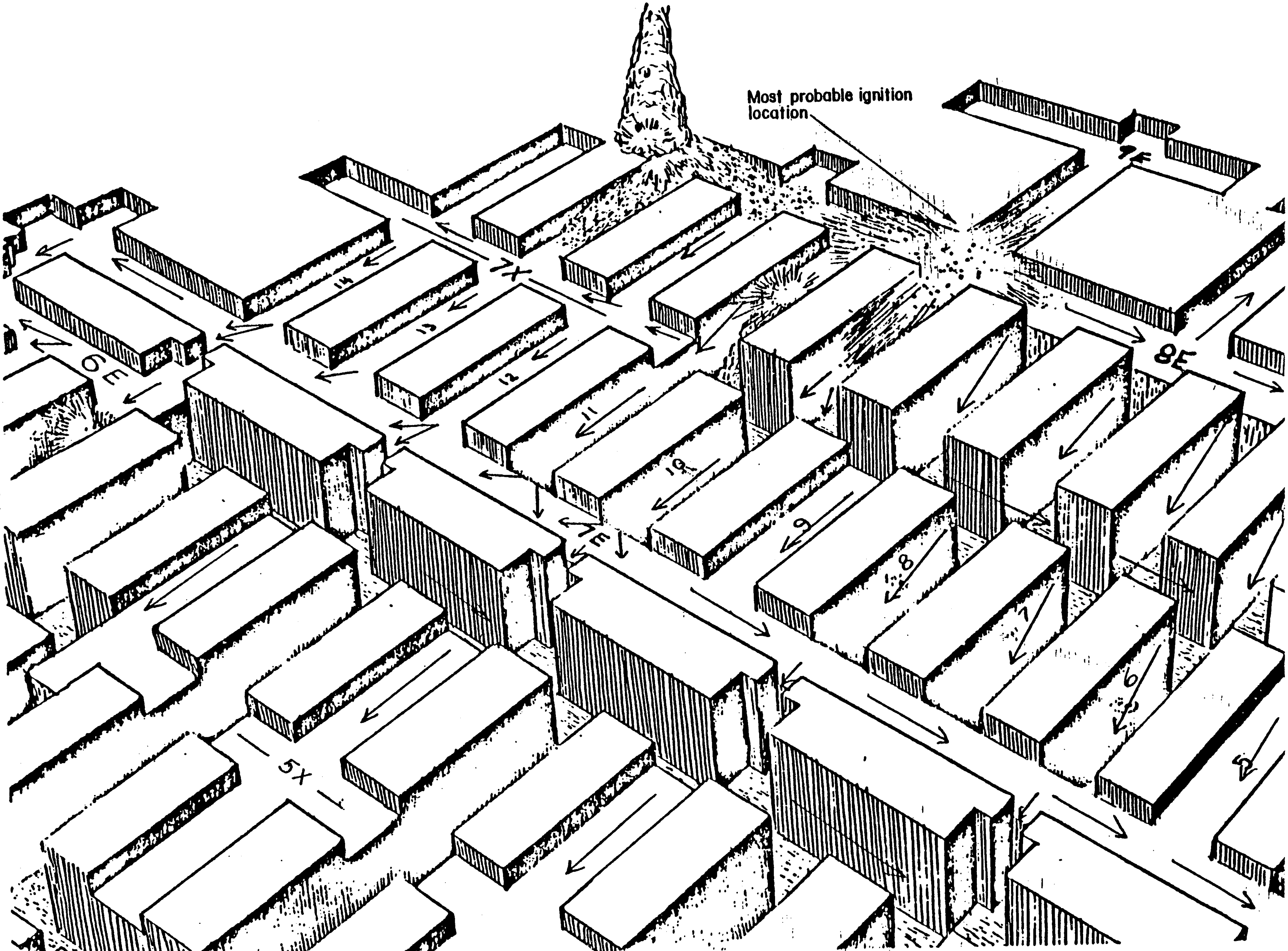
LOWER LEVEL

14 Tops from transformer
15 Charred wood
16 Transformer - tops blown west
17 No. 1 portable load center
18 Undercutter
19 Terex front end loader
20 M-39 Caterpillar haul truck



EQUIPMENT LOCATION IN THE OUTBURST AREA


PERIPHERY OF GAS
AFFECTED AREA
E
S
N
W
6E
7X
8E
7E
14
13
12
9
5



EXPLOSION FORCE DIRECTIONS

APPENDIX Z

FORCES AND CALCULATIONS

Part 1: Outburst Transmitted Overexposure

P_1 = Atmospheric pressure, psia = 15 psia

P_2 = Final pressure, psia = ?

N_1 = Initial molar volume = 4.0×10^6 ft^3

N_2 = Final molar volume = 4.95×10^6 ft^3

$$\frac{P_1}{N_1} = \frac{P_2}{N_2} \; ; \; P_2 = \frac{P_1 N_2}{N_1}$$

$$P_2 = \frac{15 \times 4.95 \times 10^6}{4.0 \times 10^6} = 18.6 \text{ psia} \; ; \; P_2 = 18.6 - 15 = 3.6 \text{ psig}$$

Part 2: Explosion Transmitted Overexposure

P_1 = Atmospheric pressure, psia = 15 psia

P_2 = Final pressure = ?

N_1 = Initial molar volume = 56.3×10^6 ft^3

N_2 = Final molar volume = 76.3×10^6 ft^3

$$\frac{P_1}{N_1} = \frac{P_2}{N_2} \; ; \; P_2 = \frac{P_1 N_2}{N_1}$$

$$P_2 = \frac{15 \times 76.3 \times 10^6}{56.3 \times 10^6} = 20.3 \text{ psia}$$

$$P_2 = 20.3 - 15 = 5.3 \text{ psig}$$

Part 3: Forces on the Cage in Number 2 Shaft

The upward force (F_1) on the cage would be:

$F_1 = 54\ Ft^2 \times 144\ in^2/ft^2 \times 4.0\ lbs/in^2$

$F_1 = 31{,}104\ lbs$

The downward force (F_2) or weight of cage would be:

$F_2 = 2000\ lbs/ton \times 1.5\ tons$

$F_2 = 3000\ lbs$

The unbalanced force (F) is:

$F = F_1 - F_2 = 31{,}104 - 3000 = 28{,}104\ lbs$

The total mass $(M_1) = 3000\ lbs/32.2\ ft/sec^2 = 93.2$ slugs

$F = M_1 a$ where $F = 28{,}104$ lbs

$M_1 = 93.2$ slugs

a = Upward acceleration, ft/sec^2

Therefore,

$$a = \frac{F}{M_1} = \frac{28{,}104}{93.2} = 301.5\ ft/sec^2$$

The total upward force on the 1.5 ton cage would be:

$F_t = Ma$ where $F_t = ?$

$M = 28{,}104/32.2 = 872.8$ slugs

$a = 301.5\ ft/sec^2$

$F_t = 872.8 \times 301.5 = 263{,}149\ lbs$

Minimum expected short-circuit current—three-phase 480, 600, and 1040 V trailing cables

Conductor size (AWG or MCM)	Cable length (feet)	Minimum expected phase-to-phase short-circuit current 480 V	600 V	1040 V
14............	0- 500	108	141	-
12............	0- 500	171	223	-
10............	0- 500	268	347	-
8............	0- 500	405	521	-
6............	0- 550	570	722	1110
4............	0- 500	936	1146	1563
	501- 600	797	987	1405
3............	0- 500	1131	1357	1746
	501- 650	904	1107	1521
2............	0- 500	1348	1580	1914
	501- 600	1164	1389	1765
	601- 700	1023	1237	1635
1............	0- 500	1578	1802	2060
	501- 600	1375	1602	1921
	601- 750	1150	1370	1741
1/0............	0- 500	1842	2040	2253
	501- 600	1622	1837	2129
	601- 750	1379	1595	1962
	751- 800	1307	1527	1911
2/0............	0- 500	2062	2227	2364
	501- 600	1834	2026	2253
	601- 750	1572	1782	2101
	751- 850	1434	1648	2009
3/0............	0- 500	2439	2547	2459
	501- 600	2197	2350	2360
	601- 750	1908	2101	2223
	751- 900	1685	1896	2100
4/0............	0- 500	2673	2721	2535
	501- 600	2434	2536	2447
	601- 750	2142	2297	2324
	751-1000	1781	1979	2141
250............	0- 500	2814	2819	2574
	501- 600	2581	2643	2492
	601- 750	2293	2414	2378
	751-1000	1929	2105	2207
300..........	0- 500	2963	2923	2617
	501- 600	2737	2757	2542
	601- 750	2453	2538	2437
	751-1000	2088	2238	2277
350..........	0- 500	3070	2995	2646
	501- 600	2851	2837	2576
	601- 750	2573	2627	2476
	751-1000	2210	2335	2325
400..........	0- 500	3146	3046	2673
	501- 600	2933	2893	2607
	601- 750	2660	2690	2513
	751-1000	2300	2406	2370
500..........	0- 500	3278	3133	2702
	501- 600	3073	2991	2640
	601- 750	2810	2799	2552
	751-1000	2456	2527	2418
600..........	0- 500	3355	3184	2729
	501- 600	3157	3047	2672
	601- 750	2400	2863	2590
	751-1000	2553	2599	2463
700..........	0- 500	3400	3213	2742
	501- 600	3207	3080	2686
	601- 750	2954	2900	2607
	751-1000	2610	2642	2484
800..........	0- 500	3459	3252	2457
	501- 600	3269	3123	2704
	601- 750	3021	2948	2628
	751-1000	2681	2696	2510
900..........	0- 500	3489	3272	2765
	501—600	3302	3146	2713
	601- 750	3057	2973	2639
	751-1000	2720	2724	2524
1000..........	0- 500	3519	3291	2773
	501- 600	3335	3167	2723
	601- 750	3093	2998	2650
	751-1000	2758	2752	2537

Excerpted from IEEE 1977 IAS Conference Record Page 802

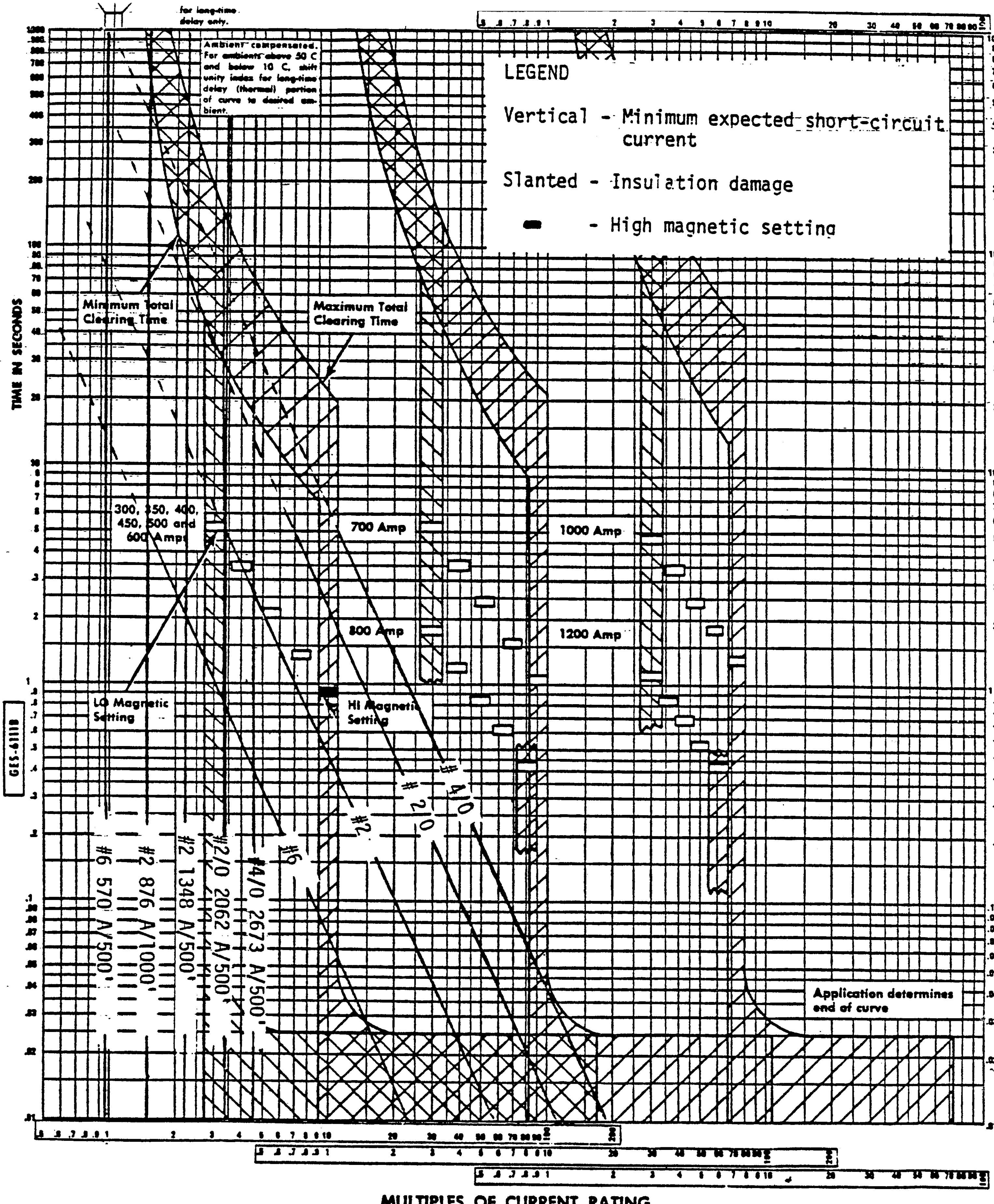
(See footnote 8, page 62)

TABLE III

Maximum allowable circuit breaker settings—three-phase 480, 600, and 1040 V trailing cables

Conductor size (AWG or MCM)	Cable length (feet)	Maximum instantaneous circuit breaker setting (amps) 480 V	600 V	1040 V
14	0- 500	75	100	-
12	0- 500	125	150	-
10	0- 500	200	250	-
8	0- 500	300	400	-
6	0- 550	400	550	850
4	0- 500	700	850	1200
	501- 600	600	750	1050
3	0- 500	850	1050	1350
	501- 650	700	850	1150
2	0- 500	1000	1200	1450
	501- 600	900	1050	1350
	601- 700	750	950	1250
1	0- 500	1200	1350	1600
	501- 600	1050	1200	1450
	601- 750	850	1050	1350
1/0	0- 500	1400	1550	1750
	501- 600	1250	1400	1650
	601- 750	1050	1200	1500
	751- 800	1000	1150	1450
2/0	0- 500	1600	1700	1800
	501- 600	1400	1550	1750
	601- 750	1200	1350	1650
	751- 850	1100	1250	1550
3/0	0- 500	1900	1950	1900
	501- 600	1700	1800	1800
	601- 750	1450	1600	1700
	751- 900	1300	1450	1600
4/0	0- 500	2050	2100	1950
	501- 600	1850	1950	1900
	601- 750	1650	1750	1800
	751-1000	1350	1500	1650
250	0- 500	2150	2150	1950
	501- 600	2000	2050	1900
	601- 750	1750	1850	1800
	751-1000	1450	1600	1700
300	0- 500	2300	2250	2000
	501- 600	2100	2100	1950
	601- 750	1900	1950	1850
	751-1000	1600	1700	1750
350	0- 500	2350	2300	2050
	501- 600	2200	2200	2000
	601- 750	1950	2000	1900
	751-1000	1700	1800	1800
400	0- 500	2400	2350	2050
	501- 600	2250	2200	2000
	601- 750	2050	2050	1950
	751-1000	1750	1850	1800
500	0- 500	2500	2400	2050
	501- 600	2350	2300	2050
	601- 750	2150	2150	1950
	751-1000	2000	1950	1850
600	0- 500	2600	2450	2100
	501- 600	2450	2350	2050
	601- 750	2250	2200	2000
	751-1000	1950	2000	1900
700	0- 500	2600	2450	2100
	501- 600	2450	2350	2050
	601- 750	2250	2250	2000
	751-1000	2000	2050	1900
800	0- 500	2650	2500	2100
	501- 600	2500	2400	2100
	601- 750	2300	2250	2000
	751-1000	2050	2050	1950
900	0- 500	2700	2500	2100
	501- 600	2550	2400	2100
	601- 750	2350	2300	2050
	751-1000	2100	2100	1950
1000	0- 500	2700	2550	2150
	501- 600	2550	2450	2100
	601- 750	2400	2300	2050
	751-1000	2100	2100	1950

Excerpted from IEEE 1977 IAS Conference Record Page 803
(See footnote 8, page 62)



GENERAL ELECTRIC

MOLDED-CASE CIRCUIT BREAKER

K-1200 LINE

Types TKMA and THKMA (300–1200 Amperes)

Long-time Delay and Instantaneous Time-current Curves

(Curves show ambient-compensated circuit breaker in open air, 10 to ...)

GES-6111B

Supersedes GES-6111A and GES-6111A

Current Ratings

300, 350, 400, 450, 500, 600, 700, 800, 1000 and 1200 amperes

Voltage Ratings

600 volts a-c (250 volts d-c)

Frequency Ratings

Adjustments

Long-time delay thermal trip: not adjustable.
Instantaneous magnetic trip: continuously adjustable, factory set on HI.
Blocks show trip range at marked points on instantaneous dials.

Ambient Temperature Compensated

The thermal action of the bimetal provides a time-delay which prevents service interruptions on normal in-rush currents or temporary overloads. Continuous overloads will cause the bimetal to deflect sufficiently to release the trip latch and open the contacts.

Trip units in each of the four frame sizes are ambient compensated as a standard feature.* They are designed to carry rated current in open air ambients from 10 to 50°C. At temperatures above 50°C, they derate themselves to protect conductors (and the breaker) against dangerously high temperatures, as well as fault currents.

Ambient compensated breakers mounted in individual enclosures can normally carry rated current in room ambients up to 35°C.

*E100 Line Types TEB 240-volts, TED 277-volt, and TED 480-volt ratings will carry rated trip current in open air ambient of 40°C. These breakers in individual enclosures can normally carry rated current in room ambients up to 25°C.

Refer to Table 6, page 18, for requirements of NEC covering ratings of breakers for continuous current loads.

Adjustable Magnetic Trip—F225, J600 and K1200

An electromagnet which partially surrounds the bimetal is used to provide instantaneous trip in the event of a short circuit. The high current creates a strong magnetic field attracting the armature and releasing the trip latch in the same manner as the bimetal does on overload.

For short circuit protection, the adjustable magnetic trip provides high, low and intermediate trip settings.* Tolerance on any setting is ±10%.

Note: See Bulletin GEA-7498 for information on magnetic-only Mag-Break motor circuit protectors.

*Adjustable magnetic trip only circuit breaker. Refer to curves pages 30-35 for tolerances of conventional circuit breakers.

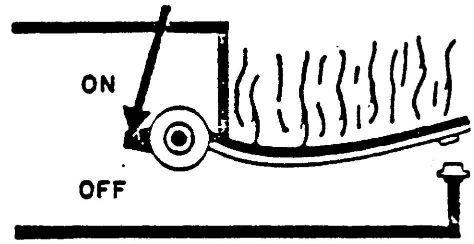
Interchangeable and Fixed Trips

Interchangeable trips for F225, J600 and K1200 Line Breakers make it practical to carry a full inventory with minimum stock. Three basic frame sizes with interchangeable trips in various ratings cover application requirements from 70 through 1200 amperes.

Interchangeable trips provide flexibility in the field, too. Even after the breaker has been installed and is in operation, its rating can be easily changed.

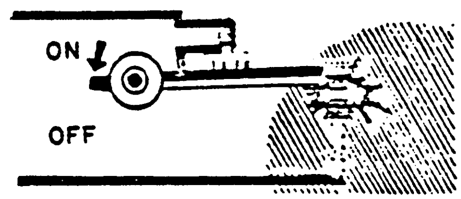
Where lower first cost is the prime consideration, or where future up-rating of circuits is unlikely, non-interchangeable-trip breakers are available in F225 and J600 Lines (to 400 amperes.) E100 Line Breakers are available with non-interchangeable (fixed) trips *only*.

Overload Protection



NOTE: K1200 Line breakers with 1000 and 1200 ampere trip units, utilize a specially designed current-transformer trip unit.

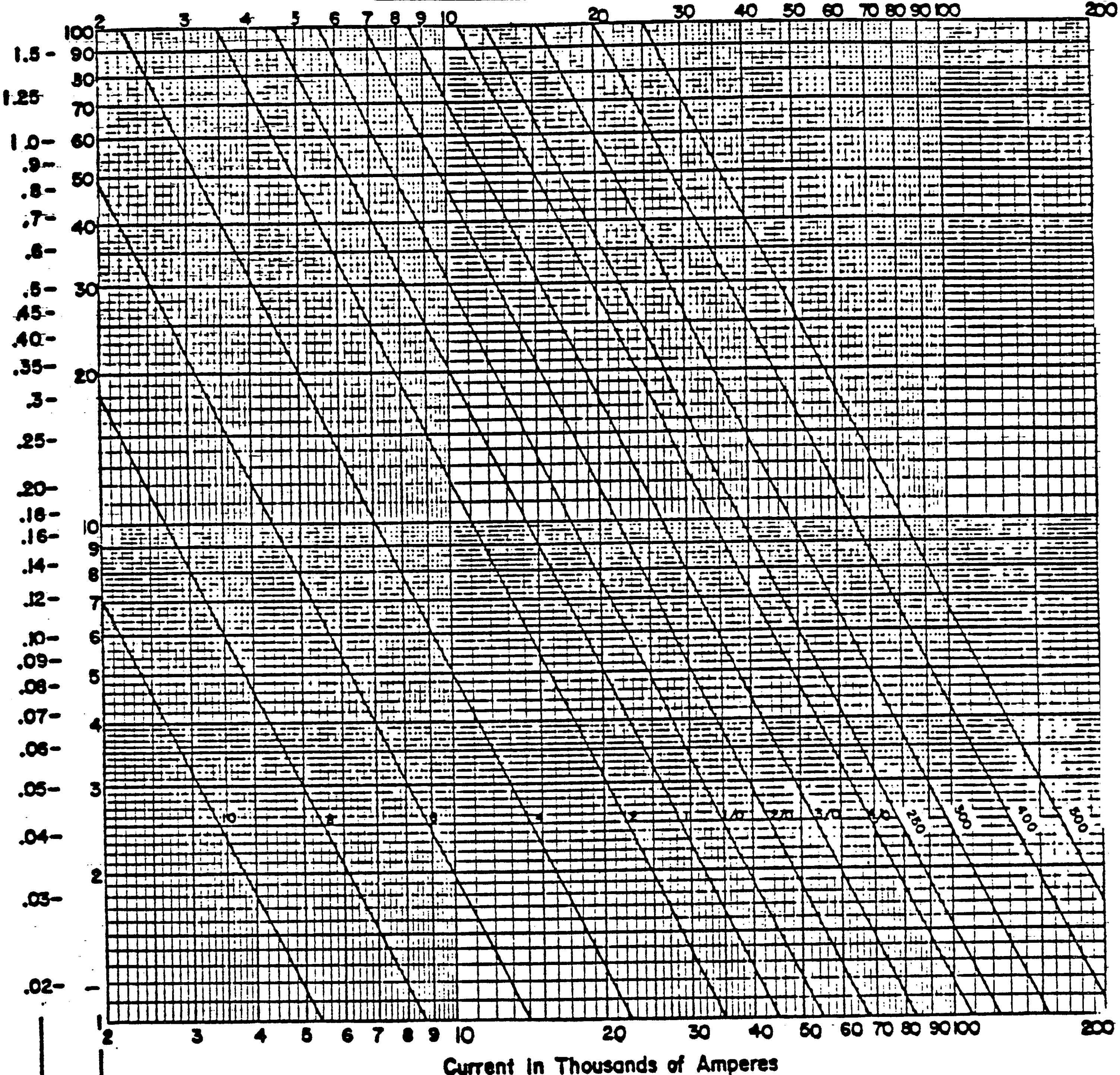
Short-Circuit Protection



E 100		F 225	
Type	Trip	Type	Trip
TEB	Non-Inter.	TFJ	Non-Inter.
TED	Non-Inter.	TFK	Inter.
THED Hi-Break	Non-Inter.	THFK Hi-Break	Inter.

J 600		K 1200	
Type	Trip	Type	Trip
TJJ	Non-Inter. (400 amps max.)	TKM-800	Inter.
TJK	Inter.	TKM-1200	Inter.
THJK Hi-Break (400 amps max.)	Inter.	THKM-1200	Inter.

INSULATION DAMAGE CHART



MAXIMUM SHORT CIRCUIT CURRENT VS TIME

This chart for Copper conductors w/ rubber, paper, or cloth insulation.

For thermoplastic insulation, enter 1 size smaller, e.g.: 1 in TW=2 in R.

Chart basis: $\left(\frac{I}{A}\right)^2 t = .0297 \log\left(\frac{T_2+234}{T_1+234}\right)$

$T_2 = 200°C$ for rubber, etc.
$T_2 = 150°C$ for thermoplastic.
$T_1 = 75°C$ operating temp.
A = Circular mils of area
t = Time, in seconds

U.S. DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
APPROVAL AND CERTIFICATION CENTER
R. R. 1, Box 201B
Industrial Park Blvd.
Triadelphia, West Virginia 26059

SEP 12 1979

MEMORANDUM FOR: RALPH K. FOSTER
Mining Engineer, Denver Technical Support Center

Robert P. Lenart

FROM: ROBERT P. LENART
Chief, Intrinsic Safety and Instrumentation Branch

SUBJECT: Operation Evaluation of a Model M502 Methane Detector, Serial No. 3722M-1-77, from the Belle Isle Mine.

In accordance with your memorandum of August 28, 1979, the Intrinsic Safety and Instrumentation Branch of the Approval and Certification Center has evaluated the subject methane detector and found it to be in proper operating condition.

The detector was used to measure several percentages of methane-in-air in the condition in which it was received, without charging the battery. Then the battery was charged overnight and the tests were repeated. All readings were within the allowable variations specified in 30 CFR 22.7 (d) (2). The experimental data and test procedure are shown in enclosure No. 1.

The methane detector will be returned via certified mail, under separate cover.

Enclosure

MSHA
Mine Safety and Health Administration

I.S.& I. TEST SHEET

TEST SHEET NO. 001
PAR NO.
CO. NAME DENVER TECH SUPPOR
TESTER BUD PAGE
DATE SEPT 7 1979

SUBJECT: TEST TO DETERMINE THE ACCURACY OF A M.S.A. MODEL M-502 METHANE DETECTOR, SERIAL NUMBER 3722M-1-77, AS REQUESTED BY RALPH K. FOSTER OF THE DENVER TECHNICAL SUPPORT CENTER IN A MEMO TO ROBERT P. LENART DATED AUGUST 28, 1979.

PROCEDURE:

1. Methane calibration gasses were introduced to the detector from a .5 liter gas sampling bottle.
2. The sampling bottle was flushed for several minutes using the calibration gas to be detected.
3. A sample of the calibration gas was taken at a pressure of 2 psig in the sampling bottle.
4. The gas was released directly into the methane detector and the pump (P) switch was pressed for three (3) seconds.
5. After a five (5) second pause, switch "2" (2% full scale reading) was depressed until the meter needle indicated a maximum value. This reading is the percentage of methane as determined by the detector.

REF: DWG. NO. ________ REV. ____

TEST NO.	ZERO	.25 % CH_4	.50 % CH_4	1.0 % CH_4	1.5 % CH_4	2.0 % CH_4	← SAMPLE CONCENTRATION (CHROMATOGRAPH ANALYSIS)
1	0.0	.22	.45	1.05	1.55	2.05	TESTED AS RECEIVED
2	0.0	.25	.50	1.00	1.58	2.01	TESTED AFTER BATTERY CHARGED

TEST CONDITIONS: ____ % CH_4 72 °F 25 %REL HUM ____ (mm Hg) BAROMETER

PRETEST CALIBRATION: V = ____ I = ____ ma L = ____ mH IGNITION CYCLE - ____

POST-TEST CALIBRATE: V = ____ I = ____ ma L = ____ mH IGNITION CYCLE - ____

Enclosure No. 1

U.S. DEPARTMENT OF LABOR
MINE SAFETY AND HEALTH ADMINISTRATION
4800 Forbes Avenue
Pittsburgh, Pennsylvania 15213

Pittsburgh Technical Support Center

November 19, 1979

MEMORANDUM FOR: EDWARD M. KAWENSKI

FROM: STEVEN J. LUZIK S. J. Luzik
Chemical Engineer, Industrial Safety Branch
Division of Safety Technology

SUBJECT: Exposure of neoprene cable to elevated temperature

Tests were conducted to determine the effect of elevated temperatures on a neoprene-covered electrical cable. The cable was stripped of the neoprene covering; 1/8" thickness. Two-inch lengths of the cable were placed in a porcelain boat, inserted in a combustion tube, and subjected to pre-determined temperatures for 15 minutes. Following removal and cooling of the sample, surface effects were noted. Test results are listed in Table 1 attached.

The samples were saved for future reference work.

Attachment

TABLE 1 - 15-minute Exposures of Neoprene Covering in Combustion Furnace

Test	Temperature	Comments
1	227°C	Some smoking observed; no change in physical appearance.
2	280°C	Sample semi-brittle after exposure; no visual change.
3	324°C	Smoke evolved from heated sample odor of H_2S detected. Sample became brittle, glassy in appearance.
4	364°C	Smoke evolved; sample brittle "V"-shaped cracks appeared along length of sample.
5	*415°C	Sample decomposed; brittle carbonaceous residue.

*30 minutes of exposure

U. S. Department of Labor

Mine Safety and Health Administration
1100 Commerce Street, Room 4C50
Dallas, Texas 75242

June 12, 1979
14:30 hours

OFFICIAL NOTIFICATION OF GASSY MINE CLASSIFICATION

To Whom It May Concern:

In accordance with the provisions of 30 CFR, Chapter 1, Part 57.21-1 as to the occurrences of June 8, 1979 (specifically, an explosion underground followed by fire and emission of methane gas in excess of 0.25%) the Mine Safety and Health Administration has determined that Cargill, Inc., Belle Isle Mine, I.D. No. 16-00246, is a gassy mine.

Effective immediately, following delivery of this notice to mine management, Cargill, Inc. (served to Charles Von Dreusche) must comply with the provisions of mandatory standards 57.21-1 through 57.21-101 and any other applicable standards as listed in Title 30, Code of Federal Regulations.

A copy of this letter typed on MSHA letterhead will be followed by mail.

Wayne D. Kanack
Wayne D. Kanack
AR 0037

SOUTHERN PETROLEUM LABORATORIES, INC.

P.O. BOX 52768
LAFAYETTE, LOUISIANA 7
(318) 984-2374

CERTIFICATE OF ANALYSIS No. 63970

COMPANY: CARGILL, INC.
SAMPLE IDENT: AIR

FOR: CARGILL, INC.
P.O. BOX 339
PATTERSON, LOUISIANA 70392

INVOICE NO. 56794

MAY 31, 1976

ATTN. .TERRELL P. LAVIOLETTE

MASS SPECTROMETER ANALYSIS

	WT%	MOL. %
OXIDES OF NITROGEN	NONE DETECTED	NONE DETEC
NITROGEN	4.51	2.83
OXYGEN	.71	.39
ARGON	NONE DETECTED	NONE DETECT
CARBON MONOXIDE	NONE DETECTED	NONE DETECT
CARBON DIOXIDE	10.26	4.10
METHANE	84.15	92.47
ETHANE	.32	.19
PROPANE	.05	.02
ISO-BUTANE	NONE DETECTED	NONE DETEC
N-BUTANE	NONE DETECTED	NONE DETECT
	100.00	100.00

SOUTHERN PETROLEUM LABORATORIES, INC.

BY F. M. Davidson

F. M. DAVIDSON / L.W.

United States Department of the Interior

MINING ENFORCEMENT AND SAFETY ADMINISTRATION

ROOM 4C50, 1100 COMMERCE STREET

DALLAS, TEXAS 75202

Metal and Nonmetal Mine
Health and Safety
South Central District

March 23, 1976

Memorandum

To: All Dallas Subdistrict Personnel

From: Subdistrict Manager, Dallas, Texas

Subject: Methane in Underground Salt and Potash Mines

As you know, we consistently encounter methane (natural gas) in our underground salt and potash mines. Standard No. 57.21-1 (Mandatory) states: "A mine SHALL be deemed gassy, and thereafter operated as a gassy mine, if:

(a) The State in which the mine is located classifies the mine as gassy; or

(b) Flammable gas emanating from the orebody or the strata surrounding the orebody has been ignited in the mine; or

(c) A concentration of 0.25 percent or more, by air analysis, of flammable gas emanating only from the orebody or the strata surrounding the orebody has been detected not less than 12 inches from the back, face, or ribs in any open workings; or

(d) The mine is connected to a gassy mine."

(57.21-2 Mandatory. Flammable gases detected while unwatering mines and similar operations shall not be used to class a mine gassy.)

This Standard must be called to the attention of officials at the subject operations. It should be emphasized that any deterioration of their ventilation system could easily set up a condition wherein the concentration of methane -- 12 inches from the back, face, or ribs -- at some place in the mine could exceed 0.25 percent (subsection (c) of the Standard). Additionally, if strata gas is EVER ignited in the mine -- no matter what the source of ignition -- subsection (b) of the Standard would apply.

Memorandum to All Dallas Subdistrict Personnel, Subj: Methane in Underground Salt and Potash Mines

It is your responsibility, during inspection activities, to maintain constant vigilance for the presence of methane gas in the mine atmosphere and, if detected, to alert all people concerned.

Effective immediately, you are hereby DIRECTED, on each and every inspection of a salt or potash mine, to make direct-reading (methanometer) tests for methane -- and other appropriate gases -- in all areas of the mine covered by your inspection.

In addition, a sufficient number of vacuum bottle or Bistable (cricket) samples must be taken to ensure documentation of your findings. Such samples should be taken in the return (exhaust) air, poorly ventilated areas, and any other area where your direct-reading tests indicate the presence of methane.

You must keep accurate records -- separate and independent of that which is recorded on each bottle or Bistable sample -- as to the time and date the sample was taken, the bottle or Bistable number, the specific location (be sure to indicate if sample collected less than 12 inches from the back, face, or ribs), and the concentration from the direct-reading tests.

Methanometers are delicate instruments and should be protected accordingly when they are being transported (in a vehicle) or carried by you. You must be sure they are maintained in proper working condition and they should be calibrated at least every 6 months, sooner if there are indications that they are not working properly.

Your inspection report, under remarks, should indicate that direct-reading field test instruments were used to measure methane concentrations in the mine air during the inspection. In addition, you must record on the Metal/Nonmetal Area Sample Form the data requested for each direct-reading test made, including negative results.

Similarly, your inspection report should indicate that air samples were collected and have been sent for analysis. Results of these samples must also be recorded on the Metal/Nonmetal Area Sample Form.

Memorandum to All Dallas Subdistrict Personnel, Subj: Methane in Underground Salt and Potash Mines

Metal/Nonmetal Area Sample Forms are attached to, and become a part of, the official "file copy" of the report. A sample copy of this form, made as a result of an underground inspection, is attached. Also attached is Form 2 (inspector's worksheet) which must be included in your inspection report for all underground inspections.

We do not want to classify any mine gassy; BUT, neither do we want to remove "bodies" from a mine! Witness the recent disaster in Kentucky.

Methane gas in ANY underground environment can, and has, been hazardous.

Hugh D Graham

Hugh D. Graham

Attachments

WORK SHEET - - - - - - - INSPECTORS USE ONLY

PLEASE CROSS OUT ALL WORDS, SENTENCES AND/OR PARAGRAPHS
WHICH ARE NOT APPLICABLE

NOTE:

REGULAR REPORT
(remarks, continued)

Direct-reading field test instruments were used to measure (carbon monoxide) (nitrogen dioxide) (hydrogen sulfide) (carbon dioxide) (methane) concentrations in the mine air during this inspection. These tests indicate that the air was of satisfactory quality at the times and places of sampling (except ______________________________ ______________________________)

(Air) (and) (dust) samples were collected during this inspection and have been sent to MESA laboratory facilities for analysis. A supplement to this report will be prepared when analytical results of these samples are received.

SUPPLEMENTAL REPORT
(Air and/or Dust)

Company: ______________________________
Mine: ______________________________
Mailing Address: ______________________________

SUPPLEMENT to Inspection No. ______________
Date(s) of Inspection ______________
Inspector(s) ______________
Identification No ______________

Air samples collected during the above-referenced inspection indicate the air was of satisfactory quality at the times and places of sampling (except ______________________________ ______________________________)

Dust sampling results and other pertinent data included in the attached table.

MET. NONMETAL
AREA SAMPLES

OFFICE 41 MINE I.D. 1609999 DATE 03 23 76 (MO DAY YR) DAR 013

AREA (LOCATION)	CONT CODE	CONCENTRATION	SAMPLE TYPE	TIME ON	TIME OFF
RETURN AT SHAFT	93	.10	06	1230	
	71	2.00	01		
	73	20.00	01		
	74	300.00	02	1245	
	91	20.60	02		
	93	.09	02		
	73	22.00	02		
3W X AT 2 DRIFT	93	.02	06	1315	
	73	10.00	01		
FACE	93	.01	06	1345	
	73	10.00	01		
	71	3.00	01		
1W X AT 1 DRIFT	93	.02	06	1430	
	71	1.00	01		

2 to 4 Sheets Would Probably Be Needed For A Typical Salt Mine Inspection

SIGNATURE Hugh D. Graham

TABLE 1 - ANALYSES OF AIR SAMPLES COLLECTED ______ MINE ID ______

MINE/MILL Belle Isle COMPANY Cargill, Inc. 12060-12067 STATE LA

COLLECTED BY R.L. Beason SUBDISTRICT OFFICE Dallas, TX DATE REC'D 3-23-77

BOTTLE NUMBER	LAB NUMBER	LOCATION IN MINE	DATE AND TIME	CARBON DIOXIDE	OXYGEN	METHANE	CARBON MONOXIDE	
12060	G7-0766	7 main east 15 south 10' back 6' face center drift	3-15-77 2:55	.08	20.81	.09	.0006	
12061	G7-0767	6 main east center face 4 ft face 5' high	3-15-77 2:10pm	.08	20.82	.22	.0000	
12062	G7-0768	6 main east 15 north 10' right rib 4' back, 10' face	3-15-77 2:00pm	.09	20.85	.23	.0000	
12063	G7-0769	7 main east 13-6' left rib, 4' fack 230' center	3-15-77 10:15	.10	20.80	.10	.0000	
12064	G7-0770	6 main east center drift 10' face, 10' back	3-16-77 2:10	.23	20.64	.16	.0032	
12065	G7-0771	6 main east 15 center drift 3' face, 5' back	3-16-77 10:00am	.11	20.78	*.30	.0001	
12066	G7-0772	6 main east	3-16-77 10:10am	.08	20.80	.23	.0010	
12067	G7-0773	9 main east center face 5' back	3-16-77 10:30	.20	20.67	.15	.0032	

INFORMED DALLAS OFFICE BY PHONE 3:00pm, 3-24-77, OF ANALYTICAL RESULTS.

*Inconclusive Sample

DATE 3-25-77 SIGNED [illegible signature]

Denver Technical Support Center

CARGILL
SALT DEPARTMENT

15407 McGinty Road
Minnetonka, Minnesota
Mail Address: Box 9300
Minneapolis, Minnesota 55440

CARGILL SALT

April 1, 1977

Mr. Hugh Graham, District Chief
U.S. Department of the Interior/MESA
Metal/Nonmetal Mine Health & Safety
1100 Commerce Street
Dallas, Texas 75242

Dear Mr. Graham:

Confirming our discussion that took place on 3/29/77 at the Belle Isle Salt Mine between MESA representatives and Cargill, Incorporated regarding ventilation and orders or notices issued by MESA, we would like to submit the following plan.

1) Effective 3/29/77, Cargill will only mine the benches. We estimate 1½ years production if only benches are mined. We will not continue normal face advancement at the upper and lower levels until such time as our ventilation plan has been completed and air can be properly coursed to all operating faces.

2) The nine (9) barges that were at the mine on 3/29/77 will be loaded. All production will then be discontinued until 4/11/77. We will then resume production.

3) Cementation will continue working in the number 1 shaft from Midnight Thursday to Midnight Sunday of each week. The ventilation fan will be turned off at midnight on Thursdays and turned back on at Sunday noon.

4) Major below-ground emphasis will be placed on ventilation. We will add a crew of nine (9) to our labor group to build the stoppings required. If nine are not available from the outside labor force, this crew will be made up from our production crew. Priority will be (1) complete the stoppings; and (2) produce salt as miners become available.

5) The following is the timetable to complete stoppings.

LOCATION	COMPLETE BY:
3 ME Air Entry	4/8/77
Lower Level B & C	4/8/77
Lower Level D	5/12/77
Lower Level A	Completed
Upper Level Low Roof E #1	4/8/77
Upper Level Low Roof E #2	4/22/77
Upper Level Low Roof E #3	4/29/77
Upper Level Low Roof E #4	4/22/77
Upper Level Low Roof E #5	5/6/77
Upper Level Low Roof E & W #6	5/13/77
Upper Level Low Roof W #1	5/20/77
Upper Level Low Roof W #2	5/27/77
Upper Level Low Roof W #3	6/3/77

6) Kingston Construction is building the air lock doors at the lower level off the Main air entry. This project will be completed by 4/15/77.

7) We have advised Ed Holeman, Mine Manager, that all orders and notices issued by MESA will be abated on time. The only exceptions to this order would be in the event parts or materials necessary to abate orders are not available to complete the job.

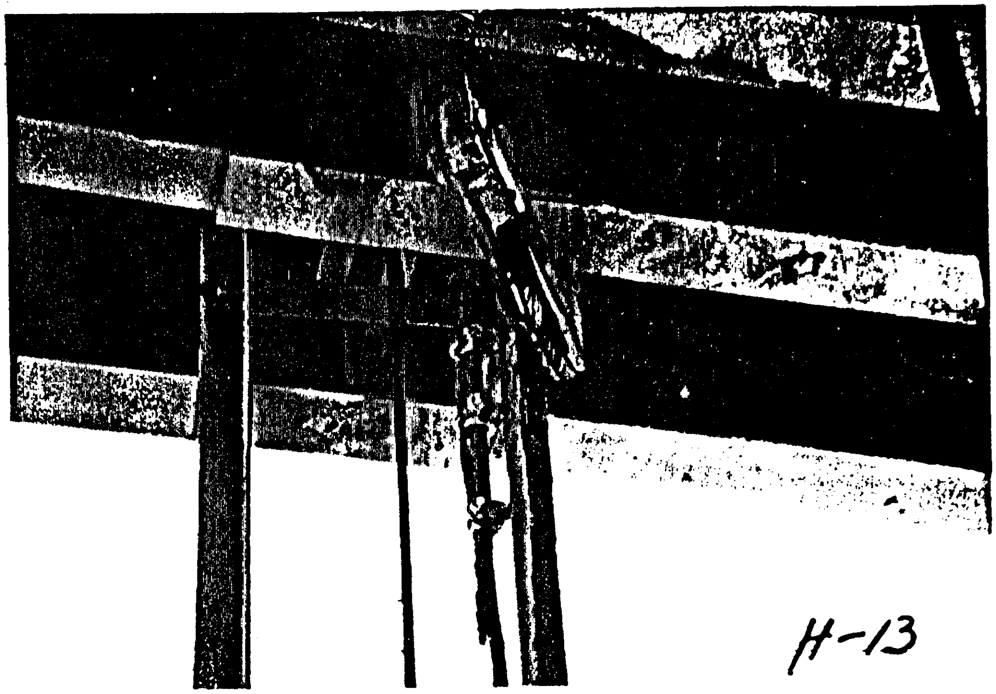
8) Cementation is estimating completion of the #1 shaft by October 1, 1977.

We thank you for your time and professional guidance in assisting us to develop this plan. Ongoing program reports will be submitted to your office.

Sincerely yours,

Stuart J. Leisz
Assistant Vice President

SJL/rml
cc: Joe Kennedy/MESA
Ed Holeman/Belle Isle
Nick Nicola/Cargill
Bob Burge/Cargill

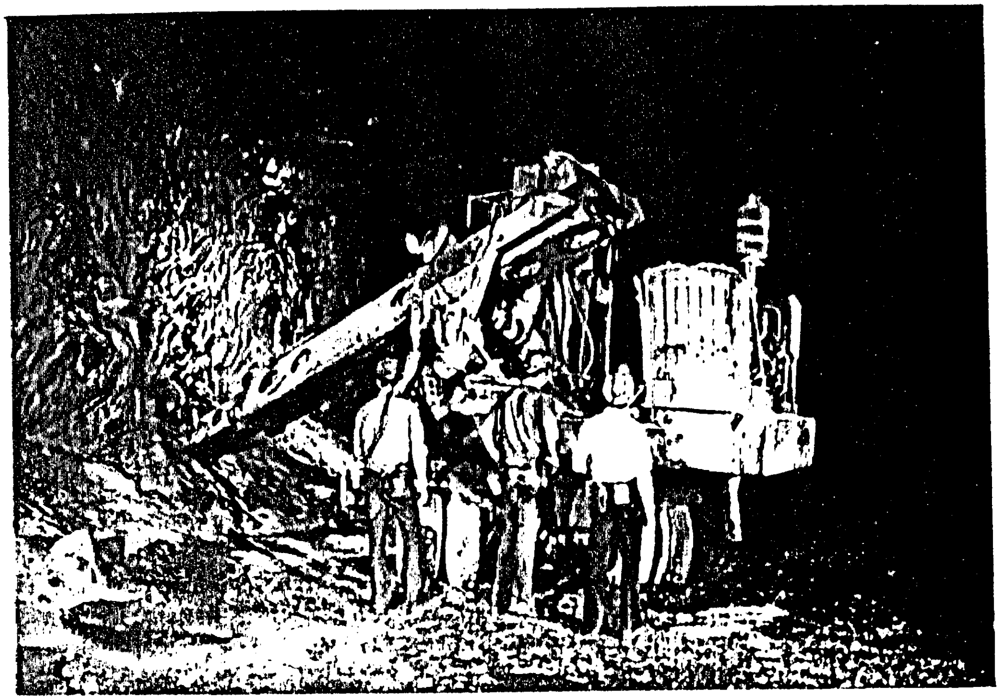


H-13

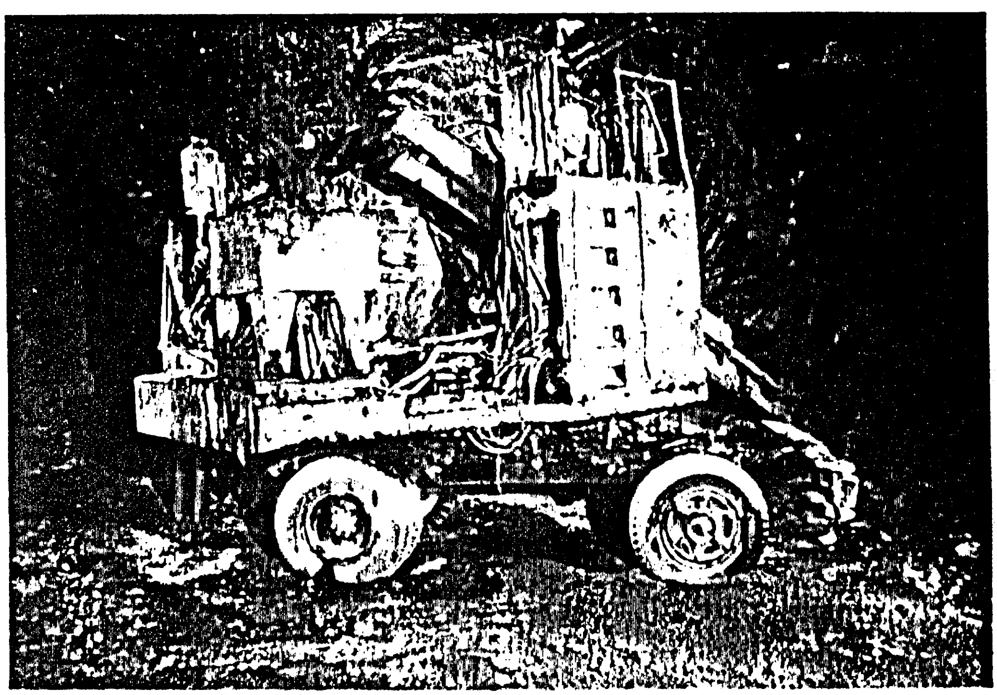
View of rope damaged when cage was blown to the top of No. 2 shaft headframe.

Plumb line and signal wire pulled up from No. 2 Shaft sump. Rope around the cage in the headframe and around the cage guide rope delayed recovery of survivors.

APPENDIX NN

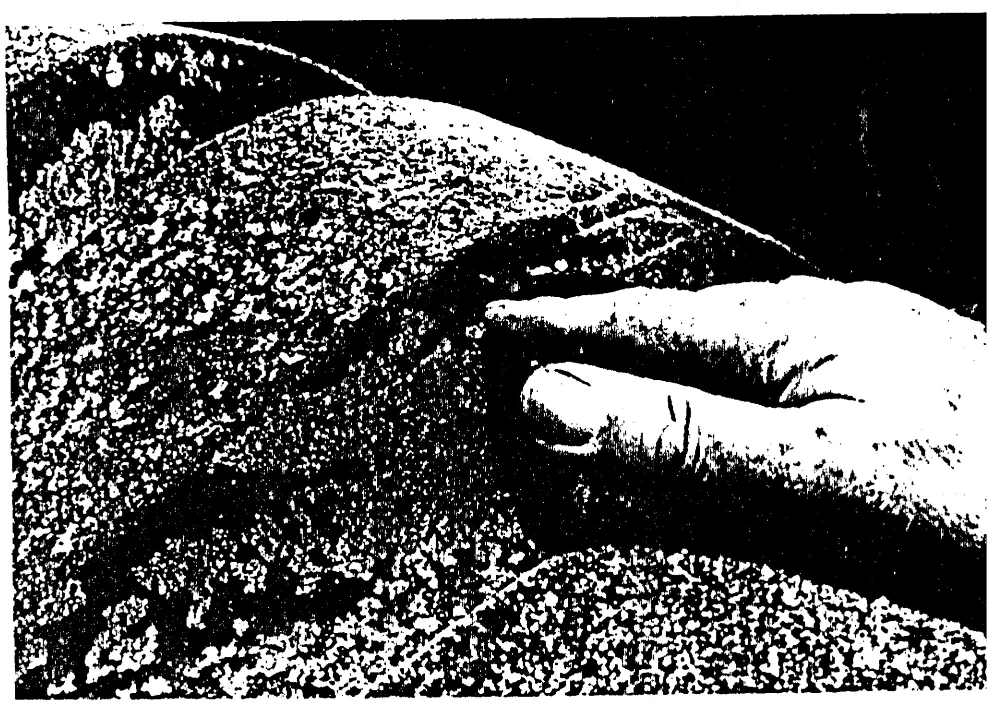


Viewing east or inby side of the Gradall scaler along south rib at 8 Main Entry East at Room 11. Paint does not show heat deterioration.

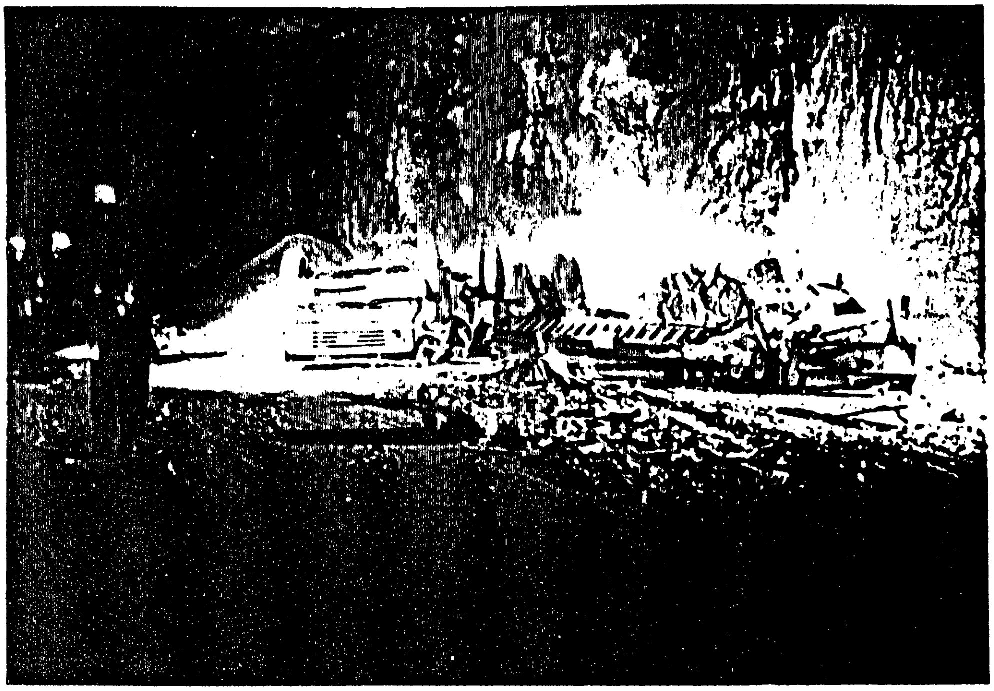


Viewing the west or outby side of the Gradall. Paint shows heat deterioration and a heavy salt encrustation from a high, hot wind moving east is evident.

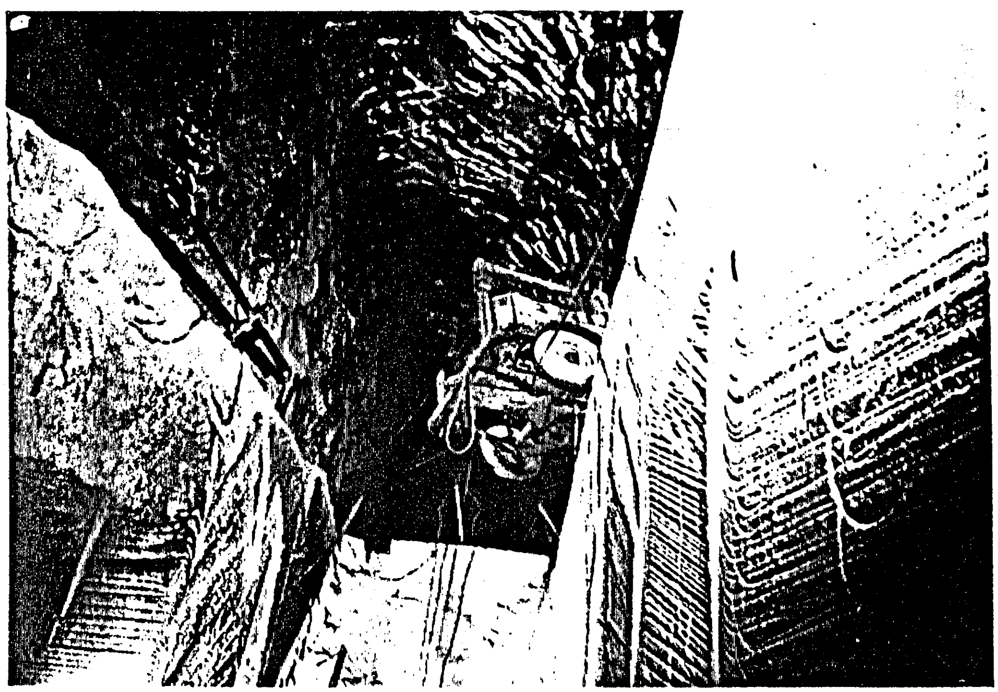
Heat damage in cab of the Terex loader at 7X Entry East and Room 10 lower level. Vinyl seat covering burned off, leaving edge -.. scorched foam.



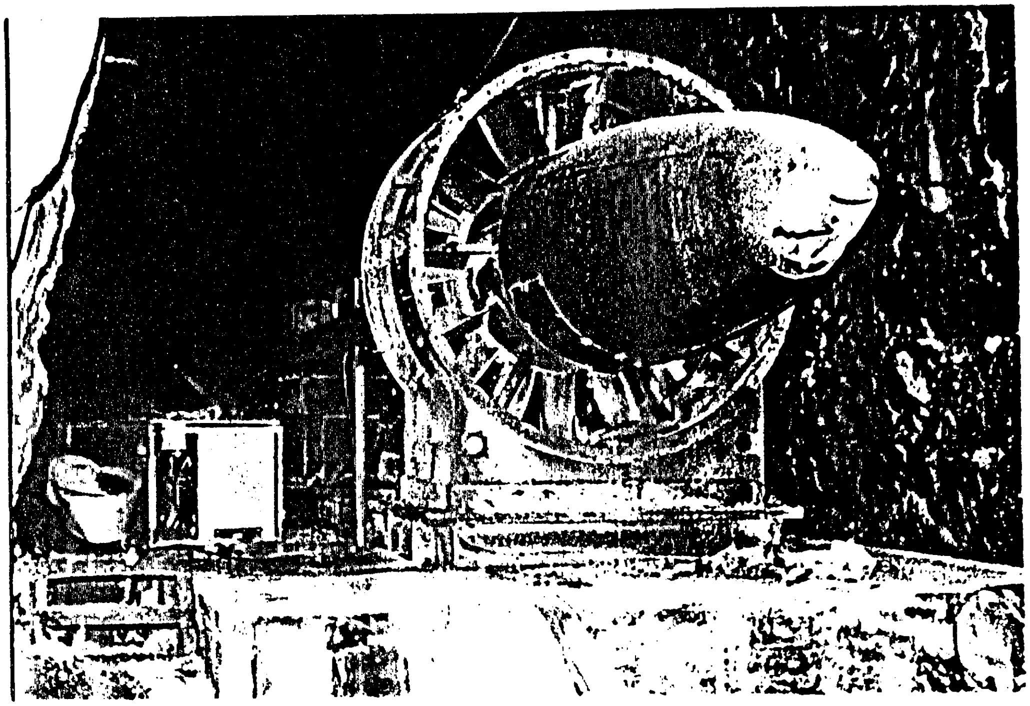
Rear recapped tires showing chars and salt on Terex loader at 7X Entry East and Room 10 lower level.



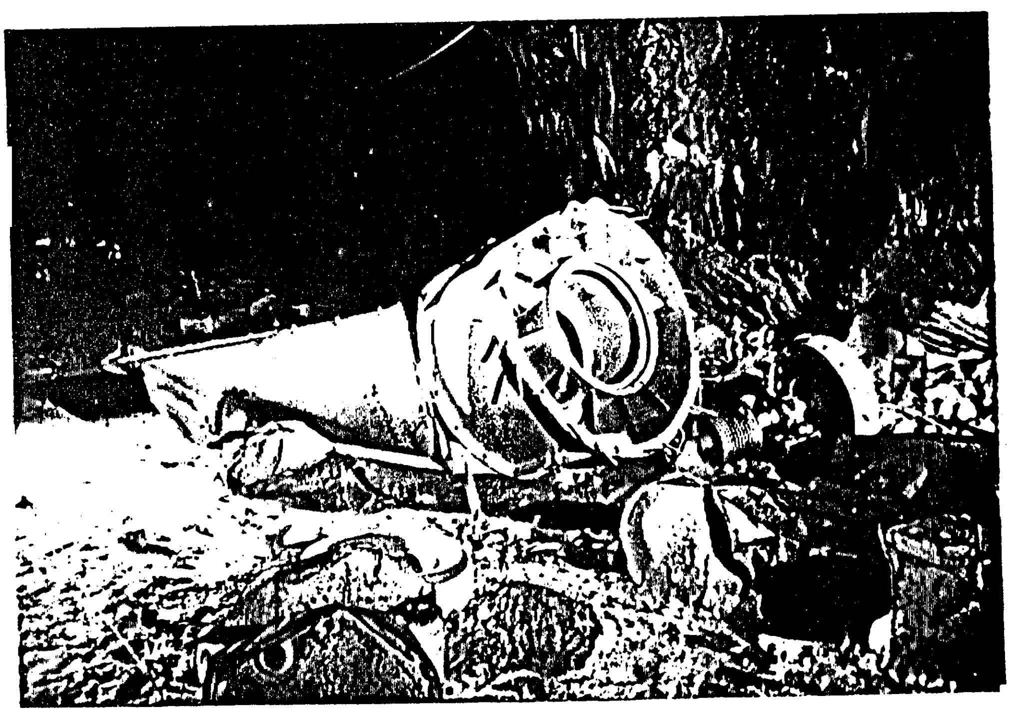
Viewing west from 2 Main Entry South just west of No. 1 shaft station. Overturned cart at the right was one in which two victims and one survivor were riding.



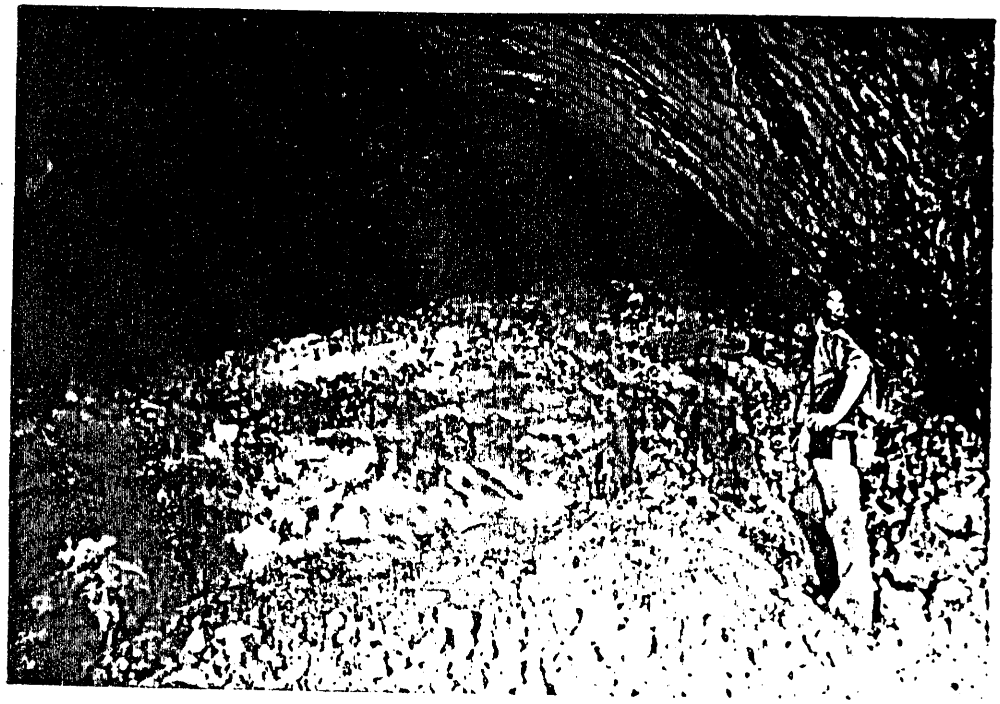
Viewing north to south from the P-39 belt line decline in 1 Main Entry South. A survivor and victim were riding in the Jeep shown overhanging the decline cut.



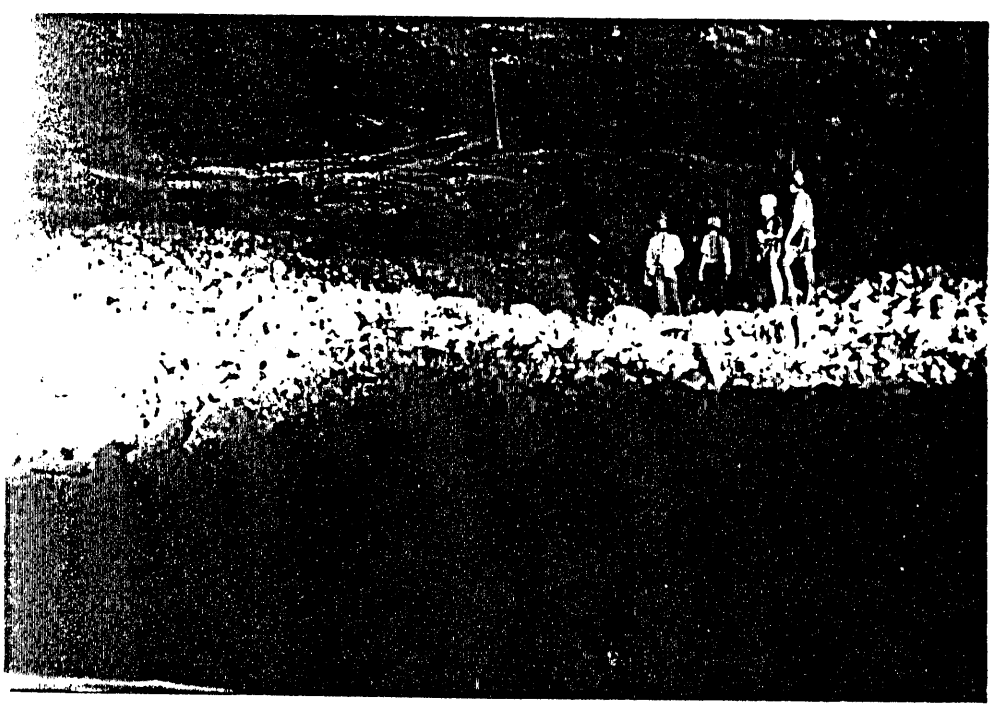
Main fan in airway tunnel south of No. 2 shaft. Portion of the metal fan bulkhead found in No. 2 shaft sump.



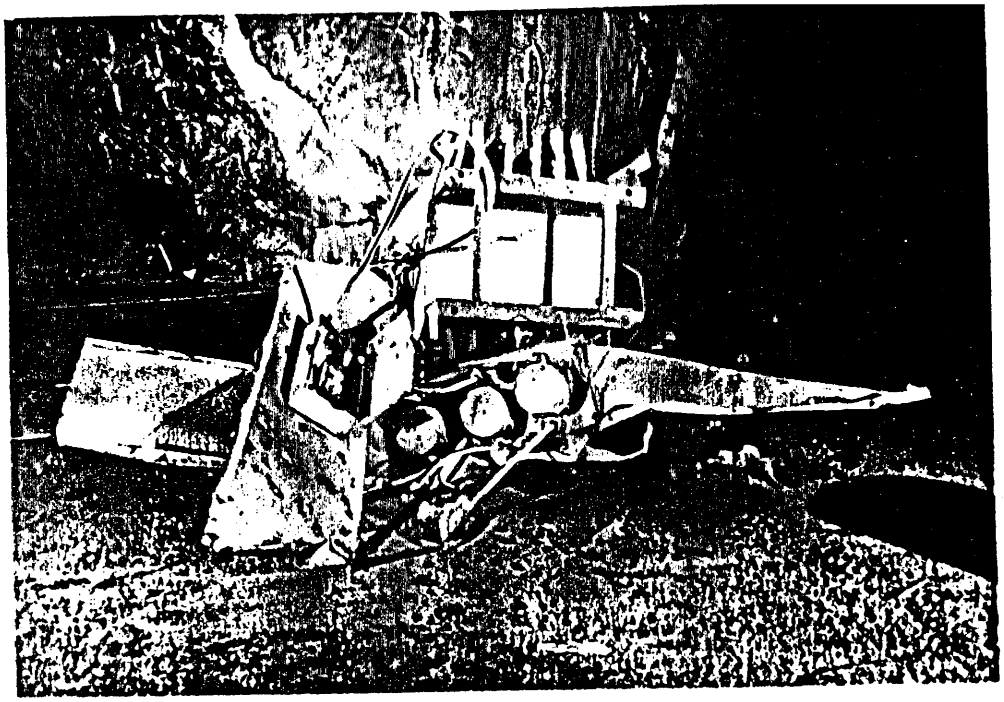
Remnants of free-standing fan originally in No. 2 Main Entry South, south of 7 Main Entry East, blown north to between 4 and 5 Main Entry East in 2 Main Entry South.



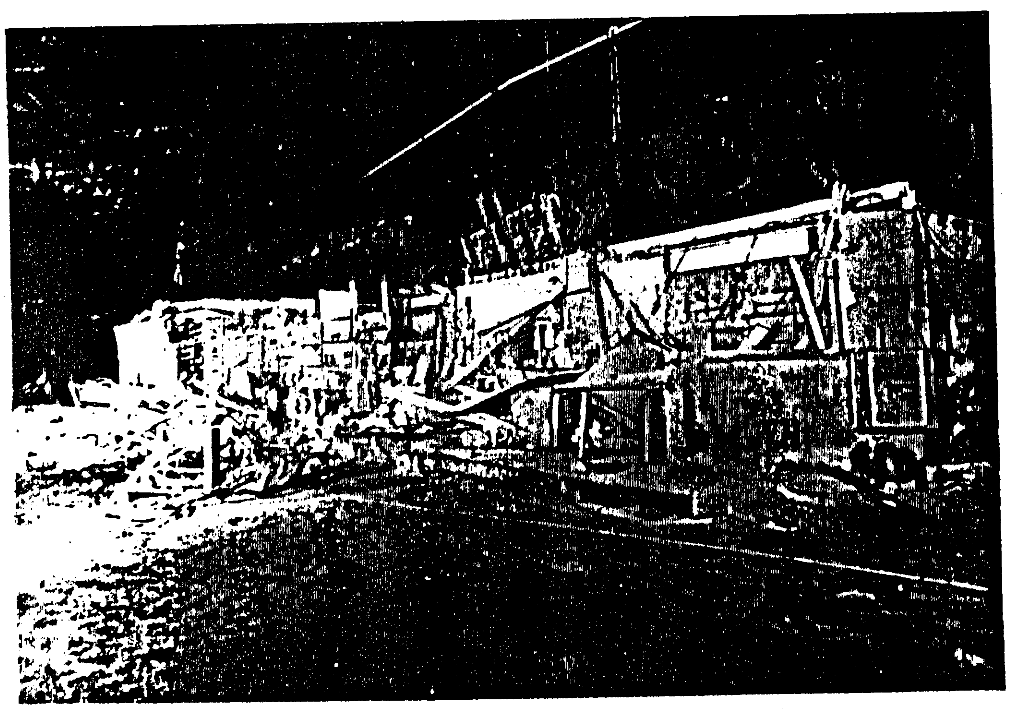
1975 blowout in 7 Main Entry West Room 4.



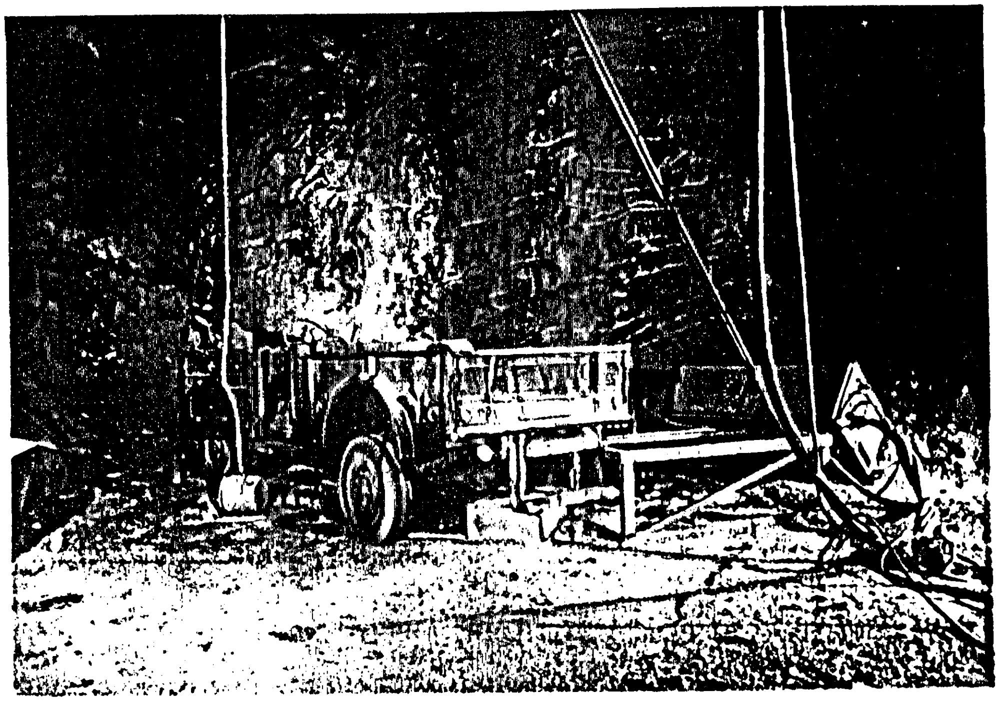
Viewing south from 7X Entry East at outburst salt piled in Room 13.



Transformer blown west from 1X crosscut east of 2 Main Entry South into middle of 2 Main Entry South.

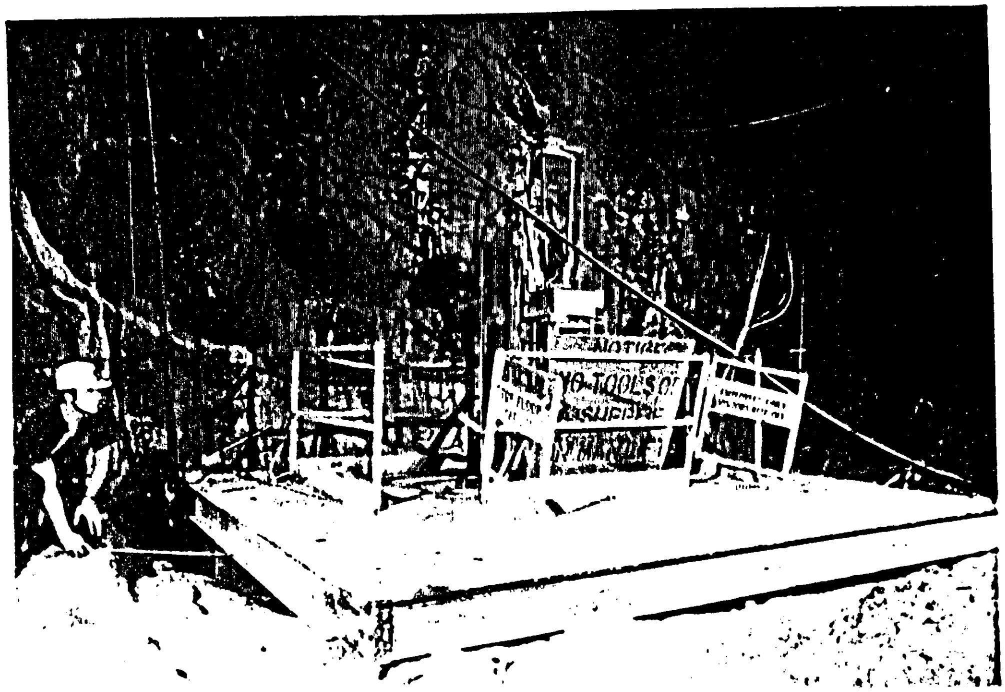


Viewing north at damaged maintenance office and parts room in 2 Main Entry South, north of 1X crosscut.

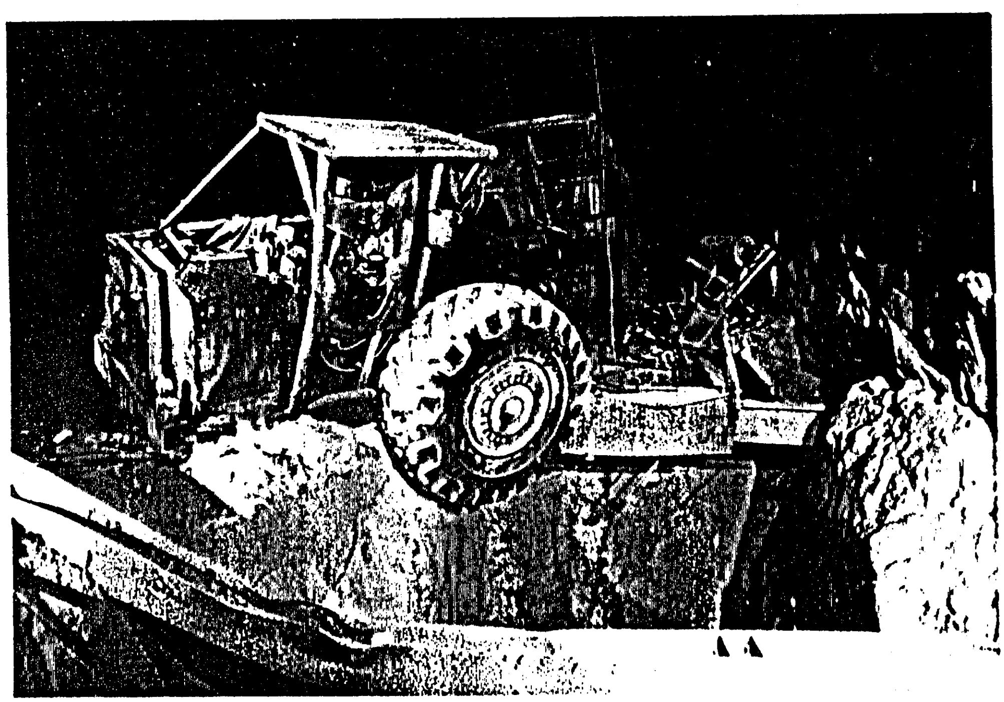


Truck at 2 Main Tunnel West of 1 Main Tunnel South in which the 11 men were sitting and one standing for the safety meeting.

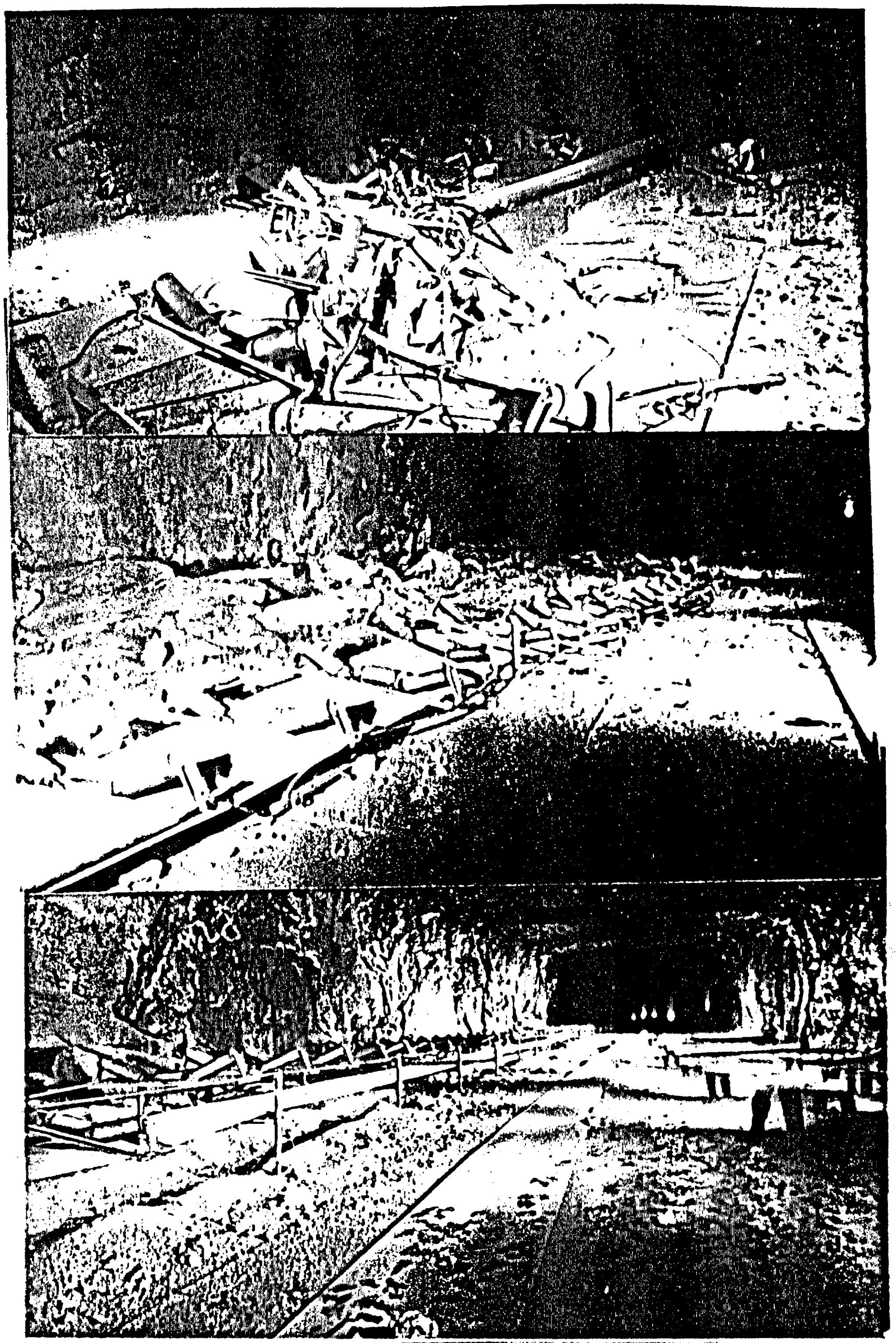
Pictures at the same location as above. Manlift escapeway in background with wood debris from cabinets.



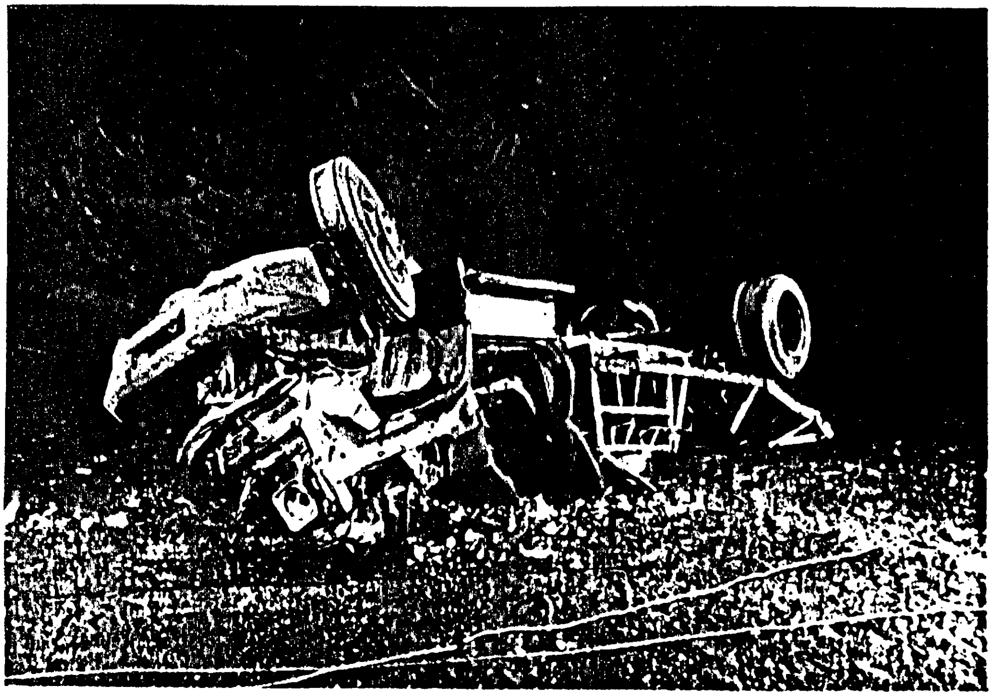
Top of manlift at 2 Main Entry East just west of 1 Main Entry South. Entire frame moved to the west 2 feet.



Terex truck in 1 Main Entry South moved north by the explosion into the reclaim bin located just north of 2 Main Entry East.

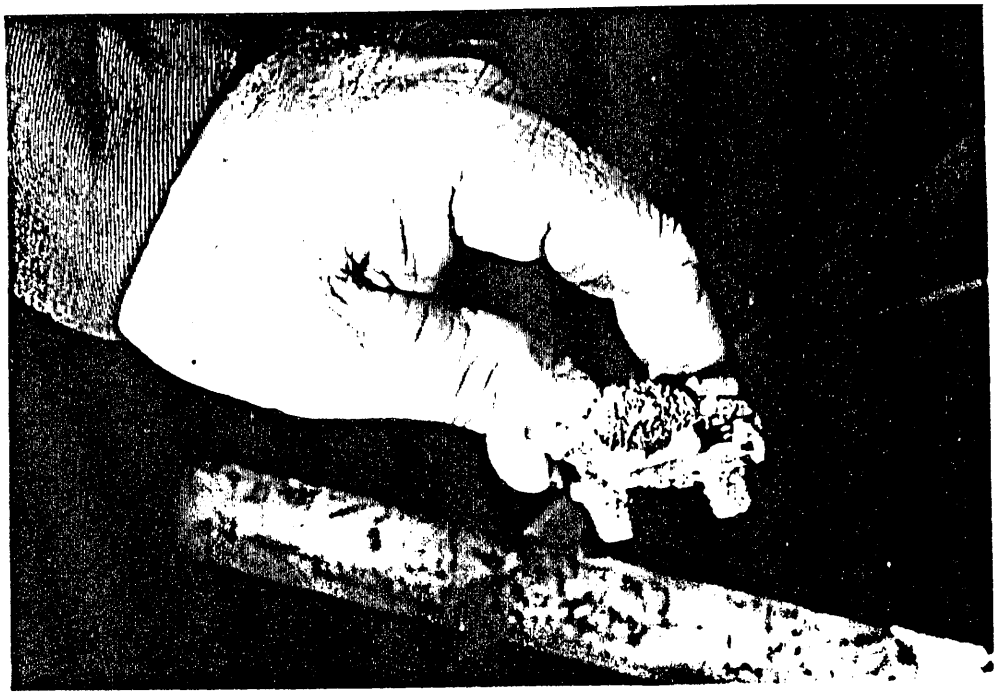


Pictures show the decay of the explosion forces as they moved north in 1 Main Tunnel South. Conveyor system in 1 Main Tunnel South. Upper picture shows complete destruction of the conveyor just north of the primary crusher between 5X crosscut and 5 Main Entry East. The middle picture shows partially damaged conveyor north of 5 Main East and the lower picture shows the conveyor just south of 3 Main Entry East.

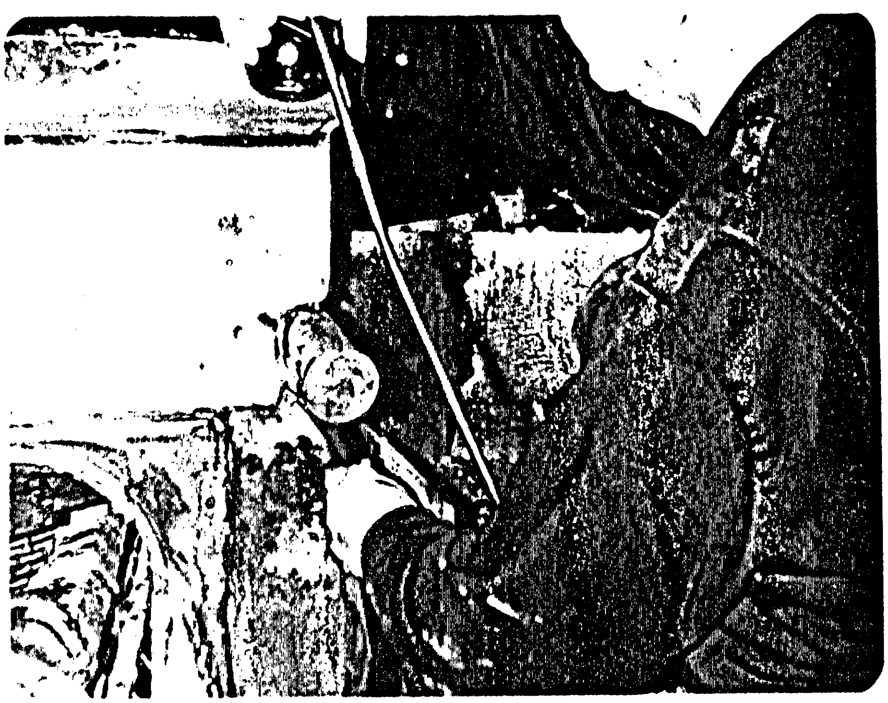


Turned over red shop truck. Picture taken viewing the truck from the south. Truck was located in 7 Main East Entry just west of Room 13.

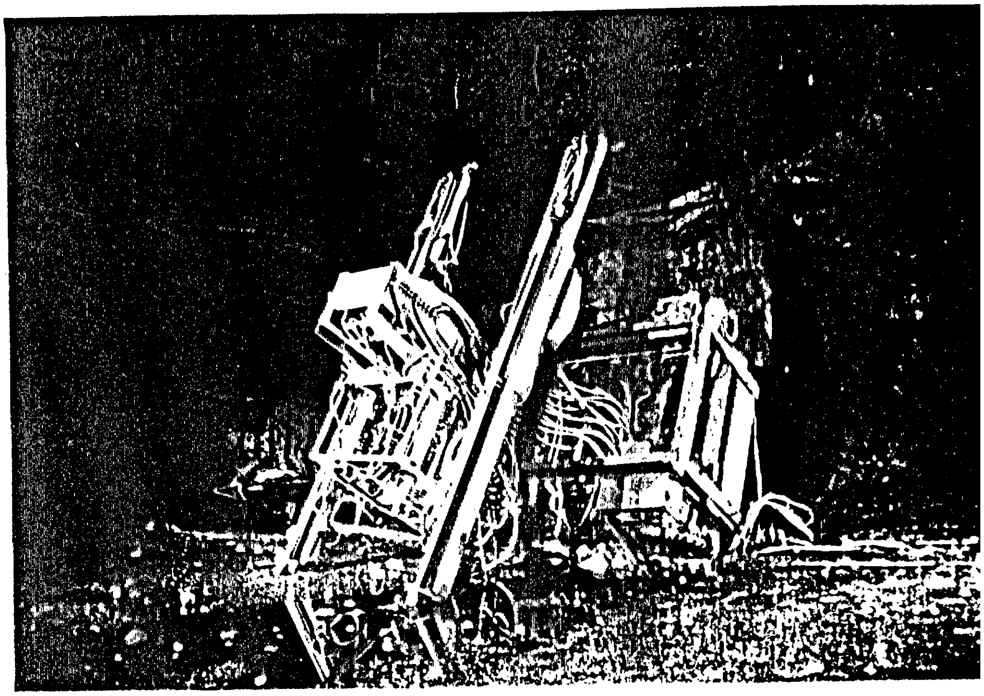
Turned over core drill in the southeast corner of Room 2 cutout just south of 9 Main Entry East.



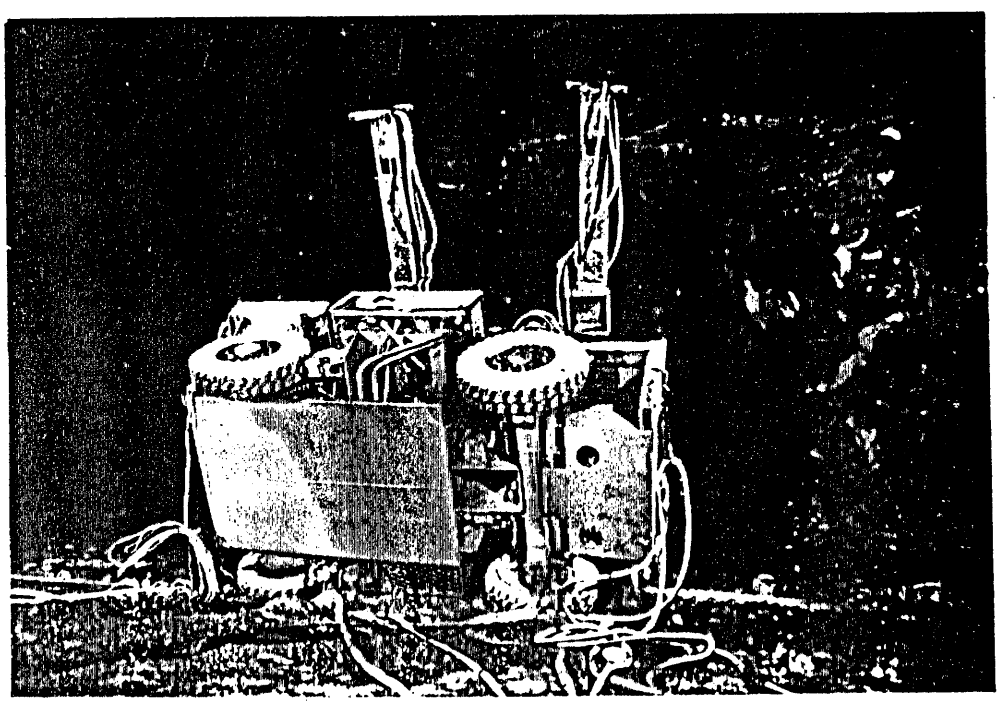
Negative terminal on overturned maintenance shop truck in 7 Main Entry East and west of Room 13. The terminal exhibited that lead had melted.



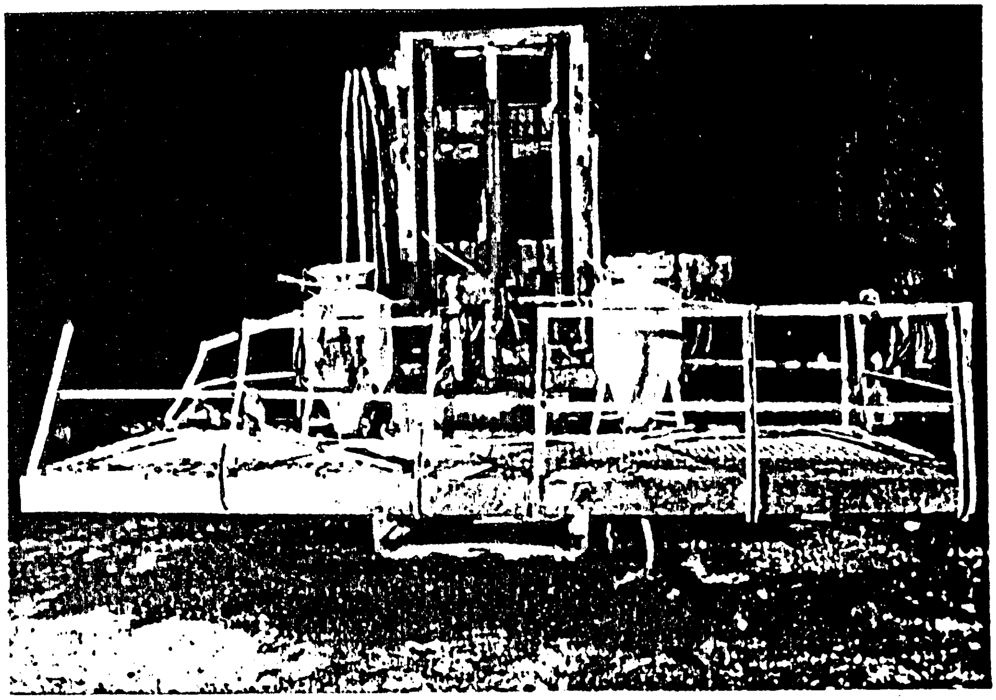
Pinched positive conductor on overturned truck. Bare copper wire exposed.



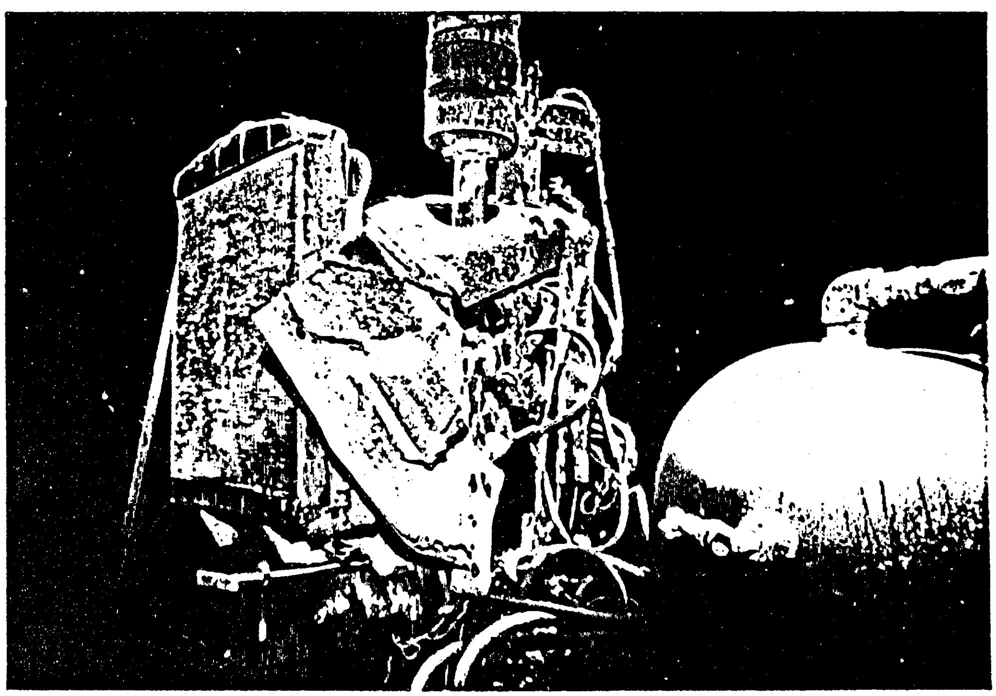
Viewinq to the southwest at the face drill located at the southeast corner of 7X Entry East and Room 13. Drill was blown 50 feet to the southeast.



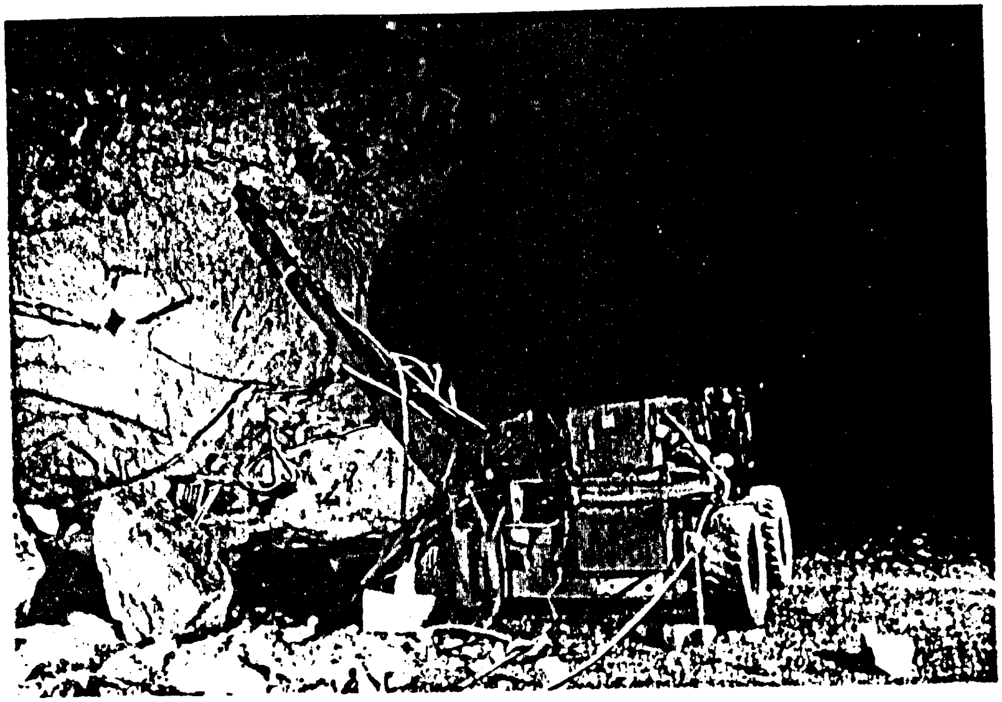
Viewing southeast at the bottom side of the face drill above.



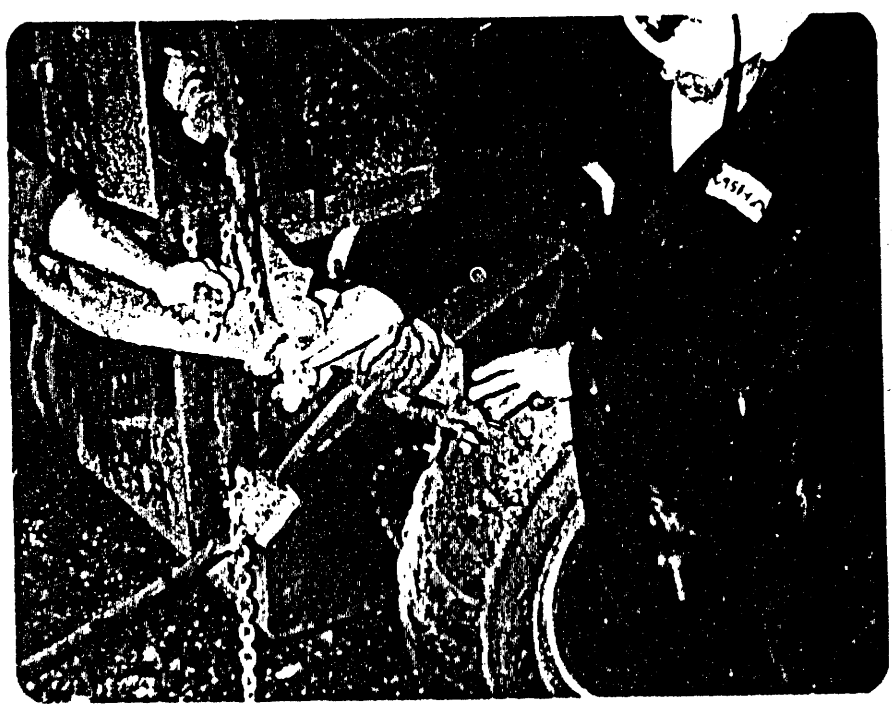
Explosives loading Jumbo facing south. Located just north of 8 Main Entry East along the east rib at Room 12.



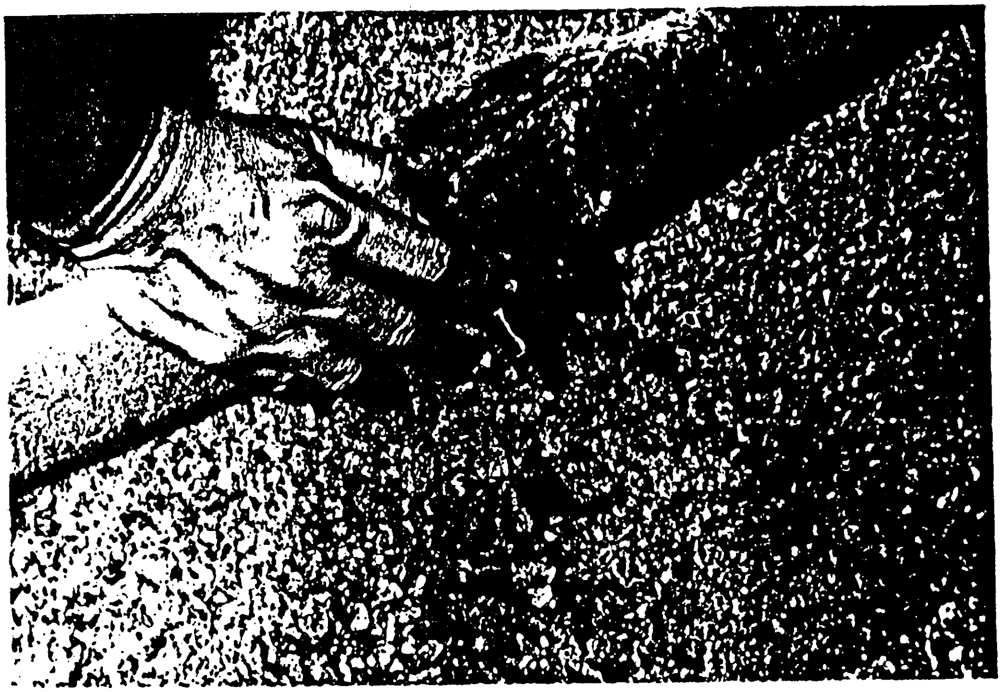
Portable blasting board impaled on south side of engine of loading Jumbo. Board was located between Rooms 11 and 12 in 8 Main Entry East before the blast and distributed power to the 8 Main East face shot and bench shot at Room 11X.



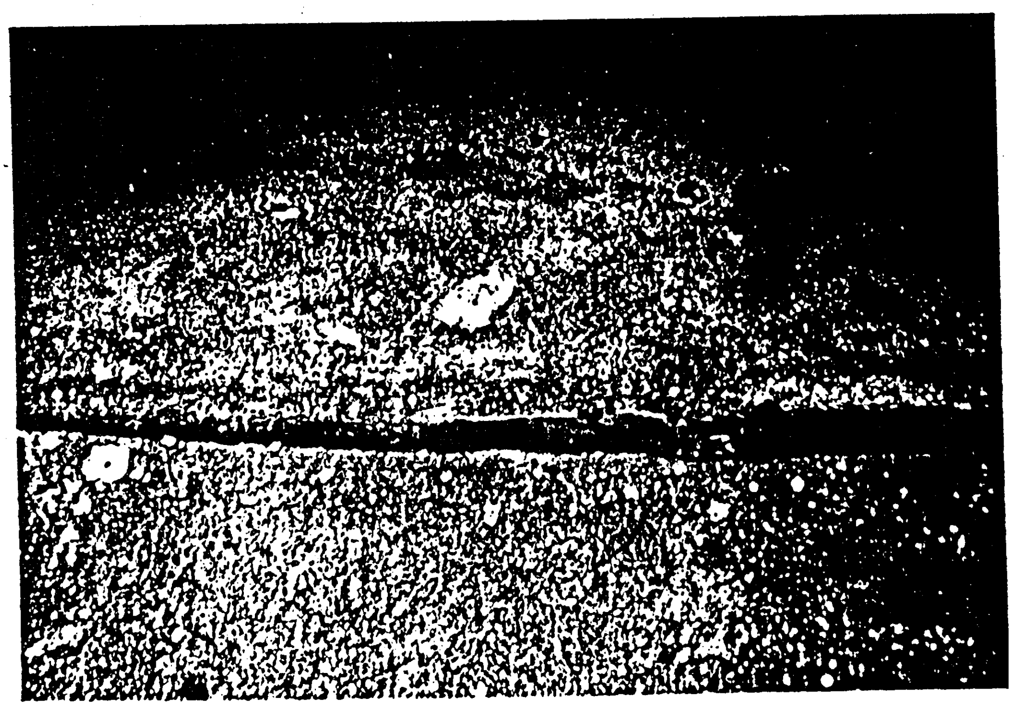
Viewing floor drill at northeast corner of 7 Main Entry East and Room 14. Boom bent away from normal vertical position. Hydraulic unit on left side badly damaged and pushed to the east. Electric cable on right side pulled apart.



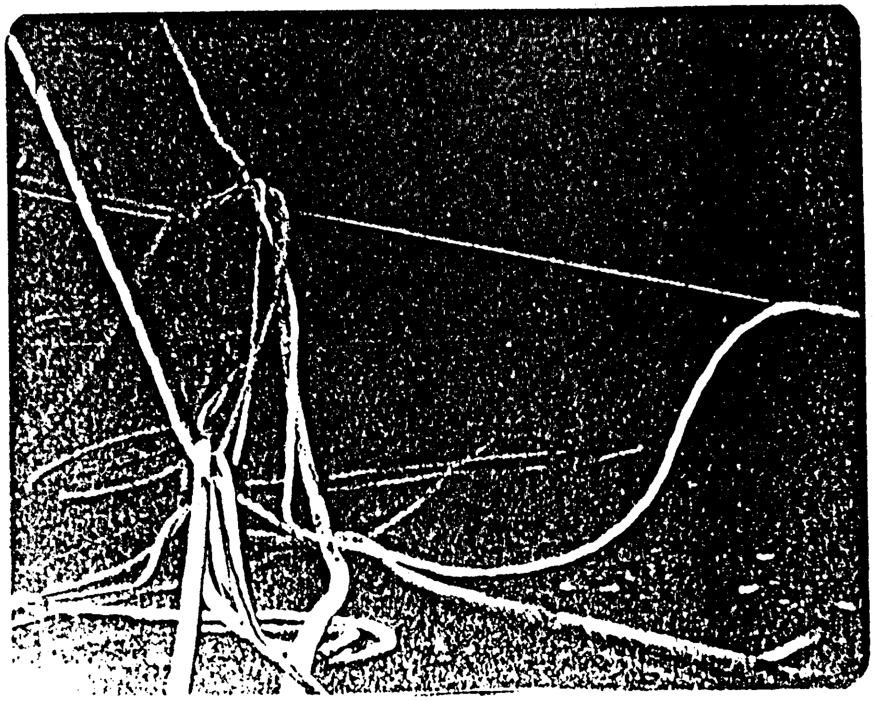
Close-up view of parted cable.



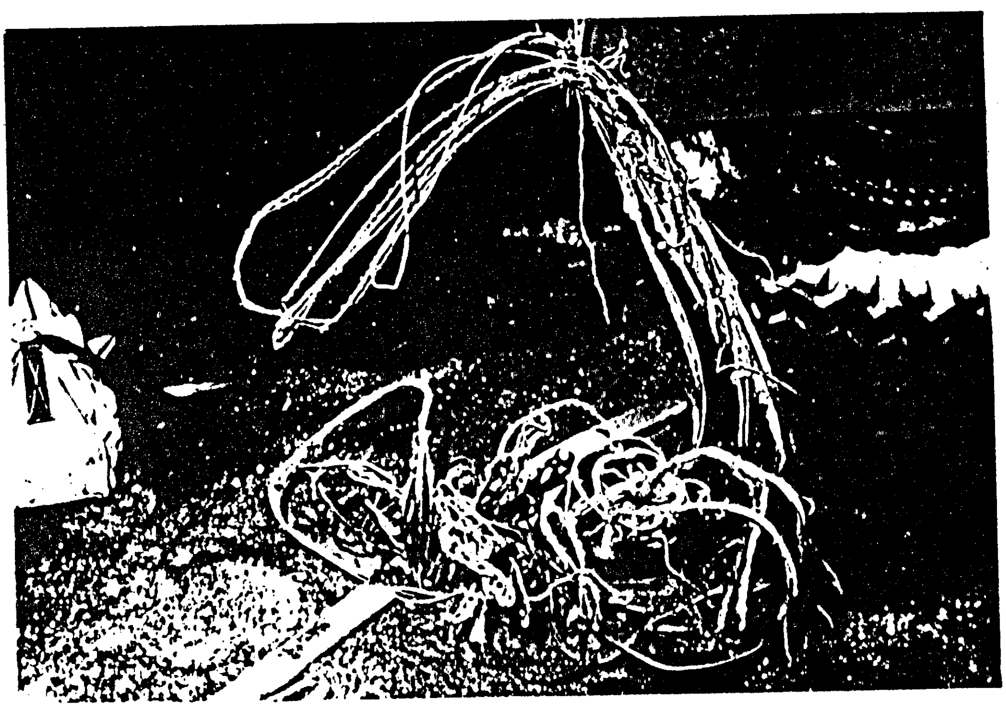
Damaged 4160 V cable blown north from roof in 7 Main Entry East into intersection of Room 12.



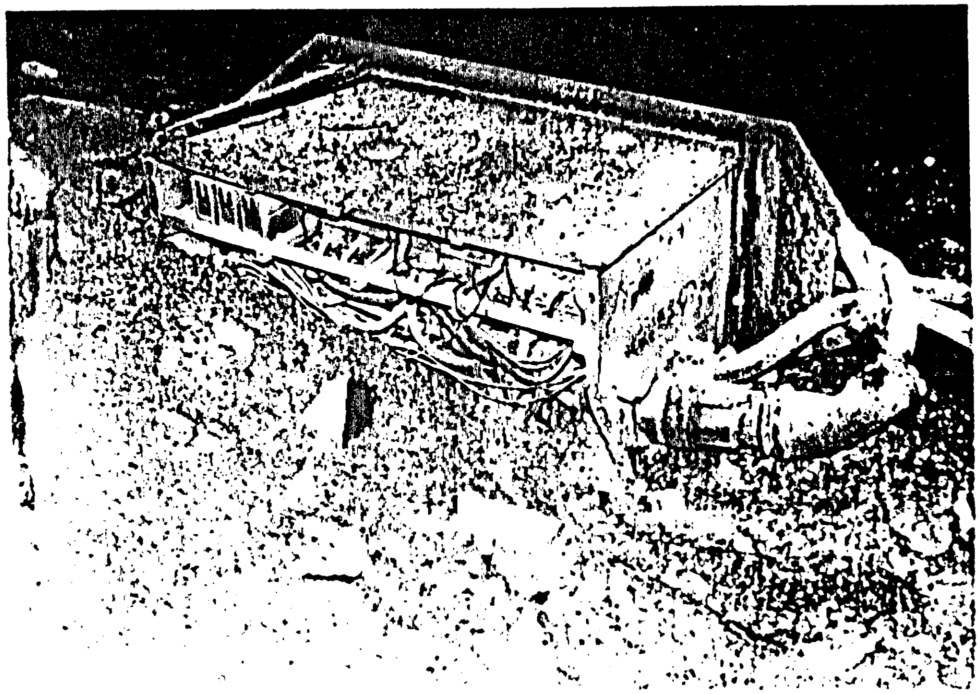
Spliced 4160 V cable in 7 Main Entry East just west of Room 10. Unshielded cable at the left shows more heat deterioration than shielded cable to the



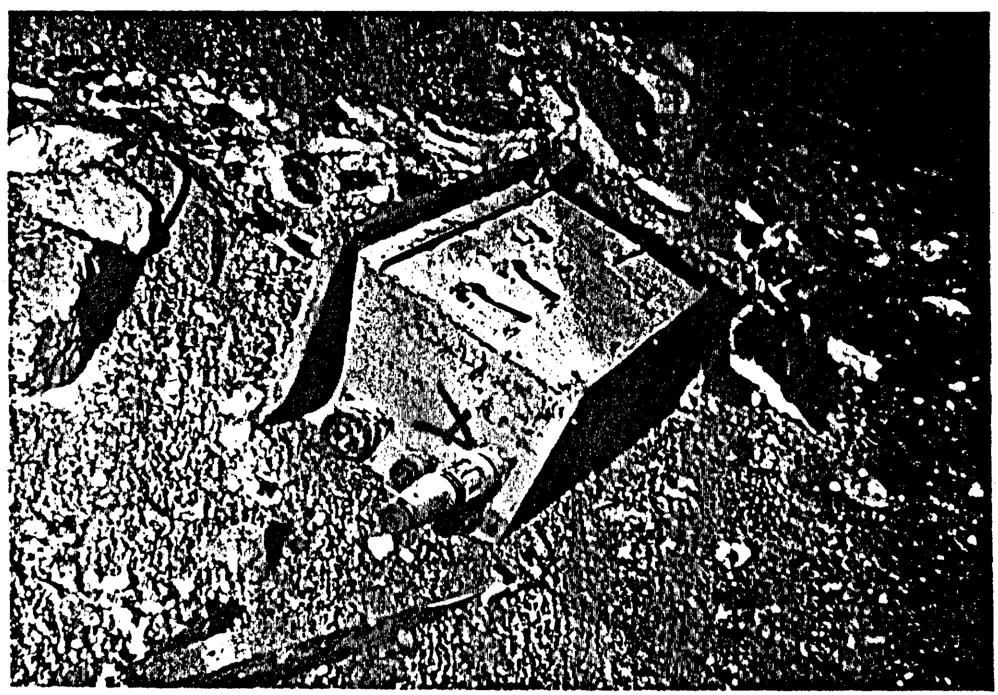
Entangled electric cables blown from the roof at 7 Main Entry East Room 13.



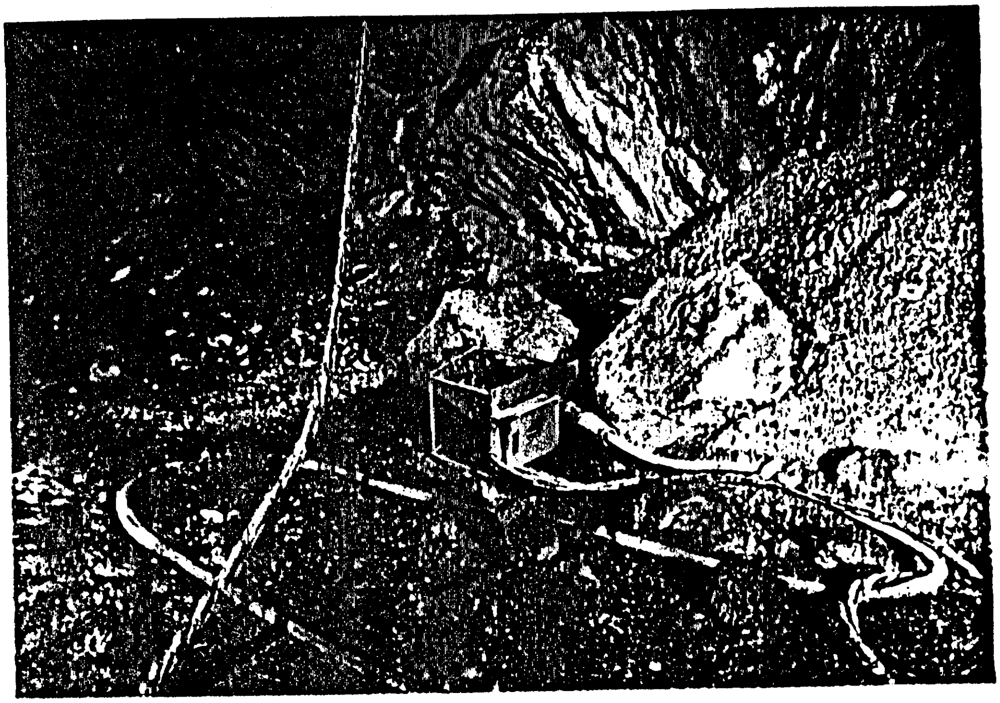
Burned wires at base of turned over face drill at 7X Entry and Room 13.



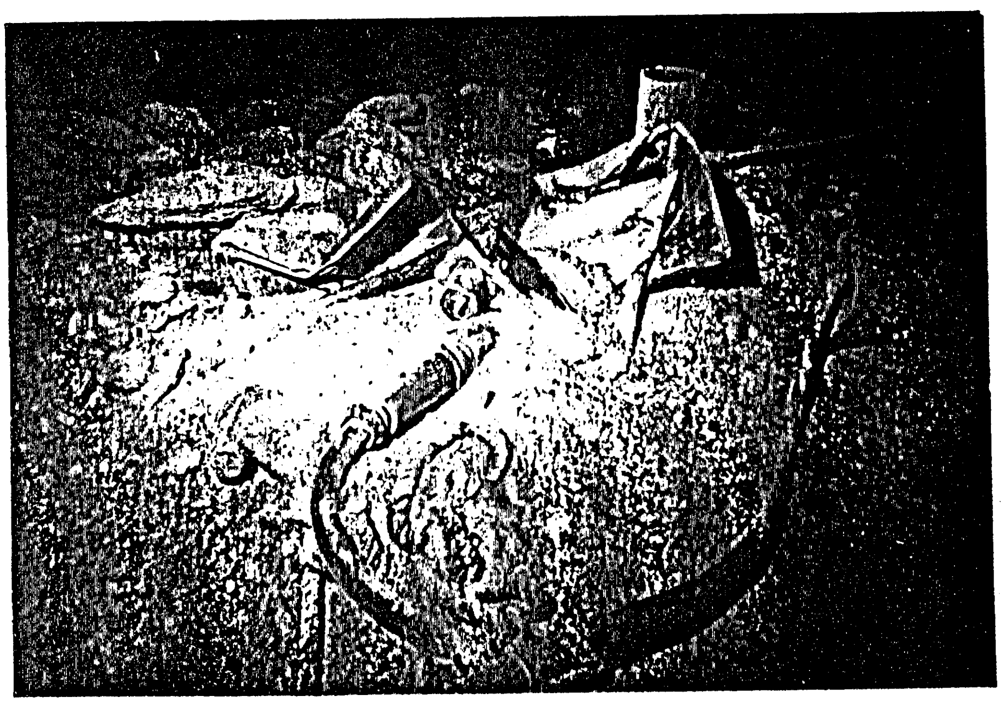
Damaged distribution box at 7X Entry and Room 12.



Damaged distribution box at northeast corner of 7 Main Entry East and Room 14.



Junction box at North rib line of 8 Main Entry East near Room 11. Ty S.E. cable from roof had badly burned insulation.



Joy coupler destroyed by fall of ground on lower level at 7X East and Room 8.