UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

DISTRICT H

FINAL REPORT OF MAJOR MINE-EXPLOSION DISASTER
CANE CREEK MINE, POTASH DIVISION
TEXAS GULF SULPHUR COMPANY
GRAND COUNTY, UTAH
(Mine development under contract with
HARRISON INTERNATIONAL, INCORPORATED)

August 27, 1963

by

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INTRODUCTION

This report is based on an investigation made by the writers, who through the Director of the Bureau of Mines were assigned by the Assistant Secretary--Mineral Resources, Department of the Interior to undertake a full scale investigation of the explosion. As part of the investigation, survivors, many employees, and officials were interrogated informally to secure information on the explosion, to ascertain events prior to the explosion, and to learn of practices which might have set the stage for the disaster. This hearing was conducted as a result of a request to the Honorable George Dewey Clyde, Governor of Utah, from Assistant Secretary John M. Kelly, Department of the Interior (see Appendices A, B, and C).

A gas explosion occurred in the Cane Creek mine about 4:40 p.m., Tuesday, August 27, 1963. Twenty-five men were underground at the time; 18 died from the flame, forces, or asphyxiation. Three men erected a barricade near the face of 2 south and died behind it. The other 7 men erected a barricade in 3U drift; 2 of these men left the barricade and traveled to the shaft station where they were met by a rescue crew and brought to the surface at 11:55 a.m., August 28, about 19 hours after the explosion occurred. The other 5 men remained behind the barricade until a recovery crew contacted them and they reached the surface without assistance at 6:30 p.m., August 29, about 50 hours after the explosion. A surface employee received minor injuries and was hospitalized.

The names of the victims, survivors, and the injured surface employee, their ages, marital status, occupations, and number of dependents are listed in Appendices D and E of this report.

Bureau of Mines investigators believe the explosion originated in the shop area where an explosive mixture of combustible gases was ignited by electrical arcs or sparks, open flame, or heated metal surfaces. Forces of the explosion extended to the shaft station, up the shaft to the surface, and throughout the greater part of 2 south and 3U drifts.

GENERAL INFORMATION

The Cane Creek mine, Potash Division of the Texas Gulf Sulphur Company is in Grand County about 20 miles southwest of Moab, Utah, by road, and is reached by paved State Highway 279. The mine is served by the Denver and Rio Grande Western Railroad, and is being developed on State and Federal land.

Officials of the Texas Gulf Sulphur Company are:

Claude O. Stephens	President and Chief Executive Officer, New York, New York
Dr. Charles F. Fogarty	Senior Vice President, New York, New York
Frank E. Tippie	General Manager, Moab, Utah
J. F. Henderson	General Superintendent and Acting Plant Superintendent, Moab, Utah
K. J. Kutz	Mine Superintendent, Moab, Utah
R. J. Ferranti	Assistant Plant Superintendent, Moab, Utah

Officials for Harrison International, Incorporated dealing with the Cane Creek project are:

Nathaniel Harrison	Chairman, Miami, Florida
Patrick Harrison	President, Miami, Florida
Norman Harrison	Project Manager, Moab, Utah
George E. Smith	Chief Engineer, Moab, Utah
A. W. Trenfield	Mine Superintendent, Moab, Utah

The mine is in the development stage and production of ore has not been started. A contract for the sinking of the shaft and driving the development drifts in waste to the ore body was given to the Harrison International, Incorporated, of Miami, Florida, and practically all work being done at the time of the explosion was by the contractor. Likewise, most underground employees were the contractor's. The work schedule was 7 days a week, 3 shifts a day. The average underground employment for Harrison International, Incorporated was 80 men, divided approximately into 30 men on day shift and

25 men each on swing and graveyard shifts. Engineering and maintenance of some equipment was provided by Texas Gulf Sulphur Company. There were many occasions for personnel of the Texas Gulf Sulphur Company to enter the mine, such as for ventilation checks, temperature readings, gas testing, and for collecting other pertinent data. Texas Gulf men worked underground in the shop regularly on 2 shifts daily.

The mine is opened by a circular shaft 22 feet in diameter, inside the concrete lining. The shaft is 2,789 feet in depth; the station is 2,712 feet below the surface. Four sinking buckets, equipped with crossheads and rope guides, were used in the shaft sinking operations and are now used to hoist muck and handle men and materials. Two main development drifts, designated 2 south and 3U and paralleling each other, were advanced about 2,080 and 3,170 feet, respectively, from the shaft station. The 2 south drift was driven downgrade 10 percent from the No. 1 crosscut, a short distance from the shaft. The 3U drift driven downgrade 14 percent is offset slightly but is a continuation of 1 south drift driven 10 percent downgrade from the No. 1 crosscut for a distance of about 360 feet, then level for a distance of 800 feet to the start of 3U which was driven downgrade 14 percent. The face of 3U was within one or two rounds of intersecting the potash bed, which averages 11 feet in thickness and dips 15 percent northeasterly as determined by test drilling.

Strata over the potash bed is variable and consists of salt and various clastics. The floor is salt.

A regular Federal inspection of this mine was made November 28-29, 1961, when the shaft was at a depth of 840 feet. In addition, four separate investigations of fatal accidents were made by Bureau of Mines personnel prior to the explosion.

MINING METHODS, CONDITIONS, AND EQUIPMENT

Mining Methods: Mine projections show that a block system of mining will be followed when the potash bed is reached. Development at the time of this occurrence consisted of driving the two aforementioned drifts, 2 south and 3U. In addition, a ventilation drift was used for a temporary shop and drifts for ore bins and conveyor ways were partly developed (see Appendices G, H, and J).

The presently developed drifts, when driven in salt, were 18 feet wide and 6 feet high on the walls and the back was arched so the center was 8 feet high. When driven in other than salt, the drifts were blasted 17 feet wide allowing for a total of 1-foot sloughing on the two walls. Reportedly, the contractor's plans required that in salt formation the face be undercut its full width to a depth of 10 feet. However, the shift or crew leaders used

their judgment concerning depths and widths of the undercuts, rather than follow the stipulated requirements. Undercutting was done only in salt formations.

The salt back was generally self supporting, but rock bolts were used sporadically where necessary. Rock bolts and chain link fencing were installed for support in other than salt back, and steel H-beam arch sets were installed in shales where the back was poor. Rock bolting was as follows: Rock bolt holes, 1½ inch in diameter, were drilled with compressed-air stopers. The bolts were 6 feet in length and 3/4 inch in diameter. Expansion shells were used to anchor the bolts and the bearing plates were 6 inches square by ¼-inch thickness. The bolts were tightened with the stoper. Chain link fence used was 25 feet long by 6 feet wide. The sections of chain link fence were held tight against the back by 3 rows of bolts installed widthwise in the drifts, 7 bolts to the row. The bolts were about 2½ feet apart widthwise and 2 feet apart lengthwise. The chain link fence sections overlapped so that the rows of bolts along the edges caught both sections. Pull tests were not made to test the effectiveness of the bolts nor were torque readings made.

The drifts were developed with mobile loading machines.

Explosives: Blasting was done with 40- and 60-percent dynamite, regular delay detonators, and nonpermissible blasting machines. The detonators were 0 to No. 14 delays with 12-foot long copper leg wires, and the shots were blasted from stations in the drifts. All blast holes were bottom primed, but stemming was not used.

Reportedly, the explosives and detonators were transported from the surface magazines in their original containers to the shaft collar, lowered in the sinking buckets to the shaft station, from where they were transported in Diesel-powered shuttle cars to the storage locations in the various drifts. At times detonators and explosives were transported together.

Explosives and detonators were stored underground in separate recesses along the walls of the drifts, and reportedly underground storage was limited to a 2-day supply. During the investigation, containers of oil and rock bolting materials were stored with the detonators. A wooden detonator box was provided but the lid was open with detonators stacked on the lid. In 3U drift, 2 cases of deteriorated explosives and 3 bags of AN/FO explosives were in the explosives storage area.

According to the contractor's representatives, blasting was about as follows:

When undercutting was done, blast holes were drilled in a pattern about 2½ feet apart horizontally and vertically in the center of the place and

at lesser distances between the center and the walls. Blast holes in places that were not undercut were drilled on about 2-foot and 2½-foot vertical centers at the walls and vertical center line, respectively. Horizontally, the blast holes at the bottom and top were about 4 feet apart. Holes were drilled on about 1-foot centers around the four burn cut holes that were drilled in the center of the face. Blast holes were drilled 10-, 8-, and 6-feet deep depending on whether the strata were considered good, fair, or poor, respectively. Blast holes were fired on shift with men underground.

The cycle of mining called for undercutting (when in salt), drilling, blasting, and loading. However, there were times when the blast holes were charged with explosives while undercutting and drilling were in progress. After the explosion, officials of Harrison International stated that all shots not in salt would be fired from the surface when all men were out of the mine.

Ventilation and Mine Gases: Ventilation of the mine at the time of the explosion was temporary, because only one shaft was available and a dividing partition wall was not yet installed in the single shaft. Intake air was directed into the mine by means of metal tubing. Two sets of 3 Joy Axivane, 40-horsepower fans connected in tandem, were located on the surface near the shaft collar and operated blowing. One set of the fans provided intake air for the 2 south drift, and the other set of fans provided the intake air for 3U drift. The intake air was conducted from the fans through 26-inch diameter spiral steel vent tubing extending from each set of fans down the shaft and along 1 south and 2 south drifts, distances of 200 and 325 feet from the shaft station in 2 south drift and 1 south drift, respectively. At these locations, 36-inch diameter corrugated galvanized metal tubing was connected to the 26-inch tubing and extended into 2 south and 3U drifts.

In an effort to increase the amount of air being delivered to inby ends of the tubing, booster fans of the same size as those on the surface were installed in the 36-inch metal tubing at 900- to 1,050-foot intervals. Such installations are conducive to recirculation of air in the event of damage to and/or leaks in the tubing. Such damage and/or leaks in the tubing would occasionally occur in installation and during movement of shuttle cars in the same drift. Two booster fans were installed in the tubing in 3U drift and one such fan was installed in 2 south drift.

Four 15-horsepower Axivane fans without tubing were installed at electric power load center locations to provide a cooling effect on the load centers by forcing air over or by pulling air past them. Obviously, such installations resulted in recirculation of the air.

In addition, a 15-horsepower Joy Axivane fan without tubing was suspended near the back at the beginning of the return air flow through the 3 south shop area to increase air velocity in the shop. To provide a volume of cool air for this fan, compressed air was fed through a 3/4-inch diameter hose into the fan intake and an additional supply of compressed air was released in the shop area through a second 3/4-inch diameter hose. A check curtain was installed in the shop inby the fan, reportedly to prevent smoke from blasting from entering the shop. This check curtain would have made recirculation of air by the fan in the shop inevitable, although shop employees stated the curtain opened somewhat while the fan was operating.

Air readings recorded on a ventilation map by Texas Gulf Sulphur Company were: On August 16, 1963, 14,500 cfm returning along 2 south as determined by smoke cloud velocity tests made about 475 feet inby No. 1 crosscut. The metal tubing extended into 2 south for 1,350 feet inby this point. The end of the metal tubing was about 60 feet from the face and flexible rubberized tubing extended toward the face from that point. On August 19, 1963, 12,500 cfm of air was returning from 3U as determined by smoke cloud velocity measurements made in 3U drift about 850 feet outby the present working face. On August 20, 1963, 15,900 cfm was returning from 3U drift as determined by smoke cloud velocity tests made in No. 1 south about 550 feet inby No. 1 crosscut. The metal vent line was extended to within 125 feet of the face of 3U; flexible rubberized tubing extended from the end of the metal tubing to within 50 feet of the face. Two booster fans were installed in the metal tubing inby the point of the last air measurement.

The temperature readings, recorded in connection with air readings in 3U drift on August 19 and August 20, 1963, were 104° and 100° Fahrenheit, respectively. Temperature readings were not recorded in connection with the air measurement in 2 south on August 19, 1963. Recorded random mine temperatures in 3U drift on August 27, 1963, ranged from 102 to 105 degrees Fahrenheit. A temperature reading of 98 degrees Fahrenheit in the shop was also recorded the same day.

Early during shaft sinking operations, crude oil was encountered, and about 11:00 p.m., on July 31, 1963, four men were burned when combustible gas was ignited in 3U drift. These occurrences were not reported to the Bureau of Mines, but were reported to a state mine inspector. The combustible gas emitted from a rock bolt hole and was ignited when one of the workmen attempted to light a cigarette with the flame from a cigarette lighter; flame flashed throughout the area and flame continued to burn in crevices and the muck pile until the next day. The gas emitting from the hole and muck pile burned until 5:00 a.m., August 1, when the flame was extinguished. It was extremely hot while the gas burned. Following this ignition, examinations for combustible gas were increased, and a "No Smoking" rule was put into effect underground.

Following the July 31 explosion, additional flame safety lamps were issued, but questioning of employees revealed that some had not been properly instructed in the use of these lamps.

Also, tests for combustible gas were made by personnel of the Texas Gulf Sulphur Company, using permissible electric methane testers and permissible flame safety lamps. The results of tests were included in memoranda on the subject "Shift Summary" starting on August 5, 1963. Following are examples of "Methane Reading" notations included in the memoranda:

August 5, 1963 - Methane in 3U: 0.2%
August 6, 1963 - Sequence of methane readings in 3U:

Day shift	0.1%
Swing shift	Blast face at 5:30 p.m.
6:00 p.m.	4.0%
7:30 p.m.	2.0%
10:30 p.m.	0.8%
11:00 p.m.	Nil

During the period August 7 through August 26 gas in amounts ranging from 0.1 to 5.0 percent was found at various locations.

During the recovery work and investigation, tests made for combustible gases by a company official and State and Federal investigators, using permissible flame safety lamps and permissible methane detectors, showed combustible gases ranging from 0.2 percent along 2 south at No. 4 crosscut to an explosive mixture at the face. Combustible gas in the amount 0.2 to 1.5 percent was detected along 3U from its entrance to within about 600 feet of the face. Following the explosion, ventilation was eventually provided by increasing the compressed airflow into 3U and proving compressed airflow into 2 south. This was the only means by which these areas could be ventilated sufficiently to dilute and remove the combustible gases from the mine until such time as the fan ventilating system could be restored and improved (see Table 1, Composition of Mine Air Samples Taken At the Cane Creek Mine After Explosion on August 27, 1963, and Table 2, Representative Composition of Hydrocarbon Gases Reported as Total Hydrocarbons in Table 1).

Permissible flame safety lamps were carried by the shift leaders (walkers) of Harrison International, Incorporated after the ignition of July 31, 1963. Tests for combustible gases were made by personnel of Texas Gulf Sulphur Company during and after drilling blast holes. Prior to the July 31, 1963 ignition, a representative of the U. S. Geological Survey had recommended that drill holes 10 to 14 feet in depth be drilled ahead of the face to release gas from the strata or give indications that gas might be encountered, and this recommendation was followed. In addition, a diamond drill test hole 110 feet long had been drilled recently in the face of 3U drift. This test hole was 35 feet ahead of the face of 3U at the time of the explosion. It was stated that on occasions gas released during drilling was of sufficient

pressure to blow water out of the hole and on one occasion the gas pressure was strong enough to eject the drill steel--throwing the drilling machine and driller 20 feet up the drift. At times gas was released from fractures in the strata during mining operations. Reportedly, a lighted permissible flame safety lamp was hung in each drift close to the face and was observed occasionally. Apparently, the casual observing of the hanging lamp was considered proper gas testing, and the necessary usual type of gas tests were not made with regularity. Also, a flame safety lamp was suspended in the shop, and the flame of this lamp was observed occasionally and considered a gas test. There were occasions when a flame safety lamp was passed from one crew to another as the shifts changed in the shop and thus was not properly cleaned and serviced.

A broken flame safety lamp found in the shop during the investigation was sent to the Bureau of Mines laboratories in Pittsburgh, Pennsylvania for examination. Part of the findings were: The wick had been turned down to a point where a flame could not be initiated or supported. There was no evidence of charring such as would be expected when the fuel was exhausted in burning. Fuel was available and seemed to be of normal quality as indicated by the appearance of a 1-inch flame when the wick was extended to permit lighting with a match. Flame could not be established with the ignitor. The flame was extinguished when the wick was turned down to the position as found. The conclusions reached on the tests were: From the generally dirty conditions of the lamp and rusty gauzes, the safety lamp maintenance program was poor or the lamp had been abandoned and left in the mine. The position of the wick, the lack of normal combustion deposit on the gauzes, and the amount of gauze rust suggest that this lamp was not in use or burning just prior to the explosion.

Water and Dust: The mine development areas were dry. Water under pressure was piped to the working faces, and reportedly, all drilling when not in salt was done wet.

Transportation: Hoisting of muck and water was accomplished by 4 sinking buckets that ranged in capacity from 71 to 117 cubic feet. Two double-drum hoists were used to hoist the sinking buckets. Each hoist was equipped with Lilly hoist control systems and overwind safety switches. Two sinking buckets, operated in counterbalance by each hoist, were equipped with crossheads which traveled in rope guides. The 1-1/8-inch diameter hoisting ropes were attached properly to the sinking buckets. Compressed-air operated shaft doors and dump doors were provided.

Transportation of muck and materials between the shaft station and working faces was accomplished with Diesel driven shuttle cars. Men were also transported in the shuttle cars. Each car was powered by a Diesel engine rated at 110 brake horsepower at 2,000 rpm and equipped with a 24-volt

electrical battery system and starter. The Diesel shuttle cars bore Bureau of Mines Approval Plates 2414. These Approval Plates, as issued, signify that the Diesel equipment had been tested and approved by the Bureau of Mines for operation in nongassy, noncoal mines, as defined in Bureau of Mines Schedule 24; the ventilation requirement stamped on each Approval Plate was 17,100 cfm. The Diesel shuttle cars were not approved for safe use in a gassy mine, as such cars are capable of igniting gas from the electrical components or heating of the exhaust manifold.

Following the explosion, four of these Diesel shuttle cars, Nos. 1, 2, 3, and 5, were inspected as to condition of intake, exhaust, fuel, electrical and crankcase engine systems, and of overall unit condition. Diesel shuttle car No. 4 was inspected for damage to the crankcase only. All Diesel shuttle cars were empty of muck. Exhaust gas conditioners on all cars contained sufficient water for normal operation. Only Nos. 3, 4, and 5 shuttle cars were in the immediate explosion area.

The No. 1 shuttle car, Serial No. 841, was found at the junction of 2U and 3U drifts and appeared to have been parked here as all controls were in "off" positions. All engine systems of this car were normal and the car appeared to be undamaged.

The No. 2 shuttle car, Serial No. 842, was found parked in 3U drift just over the start of the 14 percent grade, approximately 60 feet inby the junction of 2U and 3U drifts. This car was used for transportation by survivors of the explosion before they barricaded themselves and left parked at this location. The car was not damaged and all engine systems were normal.

The No. 3 shuttle car, Serial No. 843, was found on the downslope, 25 feet inby the junction of No. 2 south right and No. 2 south left. The right rear corner of the car was jammed against the east rib, blocking movement down the drift. The directional gear lever was in "low reverse" position and the traveling gear and conveyor levers were in "zero" or neutral position. The emergency brake lever was in "off" position. The light switch, found in the "off" position by the Diesel engineers, was turned off after the explosion by rescue team members. From the position of the front wheels and various objects around the car, it seemed likely that the car drifted against the east rib after the explosion, and from the position of the traveling gear, it seems unlikely that this car was moving under power at the time of the explosion. The engine intake system, exhaust piping, and exhaust conditioner appeared normal and undamaged. The exhaust conditioner contained water although the "make-up" tank was dry. The fill cap of the "make-up" tank was missing and the fill cap cover plate hinge was ajar, a condition that probably existed prior to the explosion. The engine fuel system, crankcase, radiator, and transmission appeared to be in normal condition.

The No. 5 shuttle car, Serial No. 880, was located in No. 3 south, 120 feet west of the shaft, the front or operator's end facing the shaft. This shuttle car had been driven to this location and parked at the beginning of swing shift; overall damage to this shuttle car was extensive; it appeared that most of the damage was caused by the explosion.

The No. 4 Diesel shuttle car, Serial No. 844, was found at the north end of the shop area in No. 3 south. Since this car was in the shop for general overhauling and was not in operating condition, a general inspection of its condition was not made.

Electricity and Compressed Air: Three-phase, 60-cycle power was received at the main substation at 69,000 volts and was reduced to 12,470 volts for distribution to the secondary substations. A delta-wye connected transformer reduced the 12,470-volt power to 4,160 volts for delivery underground.

The primary underground power was received through the shaft to the No. 1 crosscut load center from where it was dispatched to the 2 south, bin area, and 3U load centers. Proper overload and ground fault protection were provided. Secondary power at 480 volts was supplied to the face equipment, fans, and the shop. Multiple conductors and three conductor type G cables were used for secondary power distribution. Power for lights in the shop and shaft area at 110 volts was provided by dry type transformers.

Extensive damage on the cables was not observed except in the shop and shaft area and in the primary feeder to No. 4 crosscut load center, which was dislodged from the back and was on the floor for about 350 feet in 2 south. The No. 1 crosscut load center equipment was completely destroyed.

The frame-grounding conductors of the secondary and primary system were interconnected through the load centers and were carried out to the surface plant grounding medium. Ground fault relays deenergized the equipment in case of ground faults and regular checks were made on the face equipment to ensure the proper operation of the ground fault relays.

Power for the shaft pumps on the 1330 level was received from the surface at 2,300 volts which was also the operating voltage of the pumping equipment on that level; it was reduced on the 1330 level to 440 volts and transmitted to the 1760 and 2200 level pumping equipment. The 1760 and 2200 level pumping equipment was not in use. Power at 110 volts for the shaft signal system was also supplied from the surface to junction boxes on each level to which 4 signal bell knockers were connected.

The electric face equipment in the 3U section was of the permissible type and consisted of one 15RU Joy mining machine, one CD-43 Joy drill, and one 967-LC Goodman loader. In addition, two National Mine Service 60-ED Diesel shuttle cars were provided. Fire-resistant trailing cables, (Type G), were used on the loader, cutter, and drill and were provided with suitable overload protection through circuit breakers installed in face distribution

boxes. Examination of this equipment showed one bolt missing from the starter compartment and two bolts missing from the main breaker compartment on the cutter; three bolts missing from the starter compartment of the drill; and an opening in excess of .004 inch in the left headlight between the headlight cover and lens of the loader. The two shuttle cars were examined; however, there was no indication of electrical arcing or burning. Similar face equipment was used in 2 south. Examination disclosed one bolt broken and an opening in excess of .004 inch in the main breaker cover of the cutter; three missing bolts, one broken bolt, one loose bolt and an opening in excess of .004 in the controller cover and openings in excess of .004 inch between the headlight cover and lens on both headlights of the drill; and two bolts broken, two bolts missing and one bolt loose on the starter compartment of the loader.

Permissible type 15-horsepower fans were used to ventilate the load center installations and shop. Nonpermissible type 25- and 40-horsepower booster fans were installed in the vent tubing. Nonapproved type magnetic starters and push buttons were used on the nonpermissible type fans. Permissibility defects were not observed on any of the permissible type fans.

In the underground shop area a permissible type loader and two shuttle cars were being repaired at the time of the explosion. Examination showed that three bolts were broken, one bolt was missing, and there was an opening in excess of .004 inch in the starter compartment of the loader. The No. 4 shuttle car was under major repairs. It was observed that the ground cable for the electric welder was equipped with a piece of reenforcing steel instead of a standard ground clamp.

The forces of the explosion had sheared the bolts in the metal shield that protected the 24-volt batteries of No. 5 shuttle car and it was torn loose. The batteries were electrically connected; however, the top battery was destroyed.

An electric hand-held drill, grinder, several shop tools, including a 50-foot section of oxygen and acetylene hose taken out of service, and parts of the shop panel and battery charger were scattered throughout the shop area.

The shop area had been illuminated with 8 incandescent light bulbs in weatherproof sockets and two outlets had been provided for connecting power tools and extension cords.

During the inspection of the distribution system and equipment, it was noted that the distribution equipment was well installed and that the face equipment, except for the few defects mentioned, was generally well maintained.

Compressed-air for operating stopers, jackleg drills, sump pumps, and air driven fans was provided by compressors located on the surface. These included an Ingersoll-Rand 750 cfm, an Ingersoll-Rand 1,000 cfm, and a Babcock-Wilcox 2,700 cfm. A mobile 600 cfm compressor was used as standby. The compressed air was taken down the shaft through a 6-inch pipe line, and 3-inch pipe lines extended to the face areas in 3U and 2 south.

Oxygen-Acetylene Cylinders and Cutting Torch: Acetylene and oxygen cylinders were found in the shop with gages still attached but damaged. The hoses leading to the cutting torch were torn away at the gages and found at the outby end of the No. 4 shuttle car stretched out under debris. The valves of the cutting torch were found open 2½ quarter turns. The valve wheel on the acetylene cylinder had been blown off, but the valve on the oxygen cylinder was intact. Later when tested on the surface, the acetylene cylinder was empty and the oxygen cylinder contained 1,100 pounds pressure. A small acetylene cylinder with the valve closed and two oxy-acetylene torch ignitors were also found in the area along with other scattered tools. Short sections were cut off the ends of the acetylene and oxygen hoses where they were broken off the gages and these with the damaged acetylene and oxygen gages were sent to the Bureau of Mines laboratories in Pittsburgh for examination. The broken ends of the hoses made reasonable fits with the portion of hoses in the ferrules on the gages. The reports on the tests were summarized thusly: None of the exhibits showed evidence of damage from internal disruptive forces or from overheating by local persistant flame.

Samples of residue scraped from the outside of the oxygen and acetylene cylinders and samples of fine solid material collected in the shop area were sent to the Pittsburgh, Pennsylvania laboratories for tests. The summary of the tests was as follows: Examinations of thirteen samples of materials, brushed or scraped from various locations and equipment in the underground shop area, and two from a flame safety lamp recovered from the mine, were made by chemical, X-ray diffraction, emission spectrographic, infrared absorption, and microscopic methods.

1. The samples principally were a mineral mixture of halite, silicon dioxide (alpha quartz), calcium carbonate, dolomite, and calcium sulphate. Small amounts of magnetic metallic particles and wood splinters were present.

2. All samples contained oil; in amounts ranging from approximately 1 to 21 weight percent.

3. The oil, acetone-extracted and filtered from the solid material, was dark brown-black in color, very viscous, and resembled heavy, oxidized lubricating oil.

4. No evidence was obtained that adsorbed acetylene was contained in two samples of deposits from the acetylene cylinders or in two other samples tested.

5. No evidence was obtained that soot or low density carbon particles were present in the acetone-insoluble residues from any of the samples.

Another oxygen cylinder and another acetylene cylinder were found on the shaft station on the west side of the shaft. The gages were blown off and the valves on each cylinder were found in the shut-off position. The hoses leading to the torch were strung out toward the shaft.

These tests indicate that the combustible gas involved in this explosion was not acetylene.

Illumination and Smoking: The shaft station and shop were illuminated by 110-volt incandescent light bulbs in weather proof sockets. Each underground workman carried a permissible electric cap lamp. Mobile equipment was equipped with headlights.

Prior to July 31, 1963, smoking was practiced freely in the mine; the flame from a cigarette lighter set off the ignition which occurred on this date. Following the ignition, the Industrial Commission of Utah required that smoking in the mine be prohibited and that "No Smoking" signs be posted. Although the "No Smoking" signs were posted, employees were not searched to see that smoking materials were not carried into the mine, and it was quite evident that smoking underground was continued by some persons. Numerous cigarette butts, empty cigarette packages, a book of matches, and other empty match books were found during the investigation in areas driven after the July 31 ignition.

Mine Rescue: The Texas Gulf Sulphur Company maintains a mine rescue station at the mine. Before the explosion, the equipment included 6 McCaa self-contained 2-hour breathing apparatus and spare parts, an electrically driven oxygen pump, 6 Chemox self-generating oxygen breathing apparatus, one permissible mine rescue communication system, a 1,000 foot life line, 6 permissible flame safety lamps, 48 self-rescuers, and 10 first-aid kits. Following the explosion, 10 Universal gas masks and 6 additional permissible flame safety lamps were purchased and used in the rescue and recovery operations. Employees had not been trained as a rescue team.

STORY OF EXPLOSION AND RECOVERY OPERATIONS

Participating Organizations: These included the Texas Gulf Sulphur Company; Harrison International, Incorporated; Columbia and Geneva coal mines, Columbia-Geneva Steel Corporation, United States Steel Corporation; Sunnyside coal mines, Kaiser Steel Company; Industrial Commission of Utah; United States Geological Survey, and United States Bureau of Mines. Mine rescue personnel who assisted in recovery operations are listed in Appendix F.

Activities of Bureau of Mines Personnel: About 7:30 p.m., Tuesday, August 27, 1963, James Cassano, superintendent, Geneva mine, Columbia-Geneva Steel Division, United States Steel Corporation, Horse Canyon, Emery County, Utah, advised Joe Freeman, coal-mine inspector stationed at Price, Utah, by telephone that an explosion had occurred in the Cane Creek mine, Potash Division, Texas Gulf Sulphur Company. Cassano was not positive of the number of men underground in the Cane Creek mine at the time of the explosion. Freeman immediately advised supervisory personnel of the district and subdistrict offices of the Bureau of Mines situated in Denver, Colorado and Salt Lake City, Utah, respectively. Freeman was instructed to proceed to the Cane Creek mine where he arrived at 11:30 p.m. the same day. J. Howard Bird, district supervisor, telephoned Frank E. Tippie, general manager, Texas Gulf Sulphur Company, seeking more direct information. L. D. Knill, supervisor, and W. E. Burleson, mining health and safety engineer, Salt Lake City, Utah subdistrict office, arrived at the mine about 4:10 a.m. Wednesday, August 28; James Westfield, assistant director--Health and Safety Activities, Washington, D. C., and A. C. Moschetti, technical assistant, district headquarters office, Denver, Colorado, arrived at the mine at 11:00 p.m. Wednesday, August 28. Arrival time at the mine for additional Bureau of Mines personnel was as follows:

D. E. Martin, safety representative, Wednesday, August 28, about 1:45 p.m. Thomas C. Lukins, mining health and safety engineer, Friday, August 30, about 11:35 p.m. William C. Gardner, mining health and safety engineer, Saturday, August 31, about 7:30 a.m. Maurice S. Childers, coal-mine inspector (electrical), Rogers F. Davis, chief, diesel test and research section; A. Z. Dimitroff, supervising mining health and safety engineer (electrical engineer), and Albert Maxian, supervisory chemist, about 7:30 a.m., Monday, September 2, 1963.

Bureau of Mines personnel who assisted in the recovery operations and/or subsequent investigations and hearing were:

Walter E. Burleson	L. D. Knill
Maurice S. Childers	T. C. Lukins
Rogers F. Davis	D. E. Martin
A. Z. Dimitroff	Albert Maxian
J. Freeman	A. C. Moschetti
William C. Gardner	James Westfield

Mine Conditions Immediately Prior to Explosion: The mine operated normally on the 7:30 a.m. to 3:30 p.m. day shift. The barometer pressures and temperature readings recorded at the Moab, Utah, airport approximately 12 miles direct from the mine for the periods 8:00 a.m. to 4:00 p.m., August 25, 26, 27, and 28, 1963, were:

	August 25		August 26		August 27		August 28	
Time	Bar.	Temp.	Bar.	Temp.	Bar.	Temp.	Bar.	Temp.
8:00 a.m.	30.11	72°	30.20	67°	30.17	72°	30.19	69°
9:00 a.m.	30.10	73°	30.23	67°	30.18	73°	30.19	72°
10:00 a.m.	30.10	77°	30.24	64°	30.17	75°	30.18	75°
11:00 a.m.	30.09	81°	30.22	65°	30.17	77°	30.15	75°
12 noon	30.06	84°	30.31	67°	30.13	79°	30.30	80°
1:00 p.m.	30.04	84°	30.19	68°	30.11	80°	30.11	83°
2:00 p.m.	30.03	85°	30.14	72°	30.09	83°	30.19	84°
3:00 p.m.	30.02	86°	30.11	71°	30.07	82°	30.07	86°
4:00 p.m.	29.99	87°	30.10	72°	30.07	81°	30.05	86°

Barometric pressure readings and temperature readings are not made at the Moab, Utah, airport for the periods after 4:00 p.m. one day to 8:00 a.m. the next day.

It is the opinion of the Bureau investigators that the slight variation in atmospheric pressure had no bearing on the explosion.

Workmen on the day shift of August 27 performed their work in a normal manner and without incident. The crew in 3U drift loaded 2 shuttle cars of muck, drilled 56 holes, charged them with explosives, and blasted. They loaded 9 more shuttle cars of muck from the nearby blasted round, then drilled 12 holes for rock bolts.

The day shift crew in 2 south loaded 4 shuttle cars of muck and installed chain link fencing in the rock-bolting cycle. Reportedly, this crew drilled 42 rock bolt holes on this shift. They also loaded another car of muck then drilled a round of shots for the oncoming shift. In all, 43 blast holes were drilled. The face was not undercut in this instance since the formation was dolomite and was approaching shale. Reportedly, the drilling pattern was thus:

Four holes 2-1/4 inches in diameter and 8 feet deep were drilled in a diamond shape to form a burn cut in the center of the face. The blast holes were drilled 1-1/2 inches in diameter and 6 feet deep in this particular round owing to poor ground conditions.

Evidence of Activities and Story of Explosion: The swing-shift (3:30 p.m. to 11:30 p.m.) workmen entered the mine at 3:30 p.m., as the day shift was going off shift. The swing-shift employees proceeded to their various working

areas shortly after reaching the shaft station. Grant Eslick, Jr., mine foreman for Texas Gulf Sulphur Company, entered the mine about 3:10 p.m. and after greeting Harrison International, Incorporated day-shift employees at the shaft station, proceeded to the shop area to check the equipment undergoing repairs. Tests were not made for gas in the shop area at the time. Eslick left the shop area after the swing shift entered the mine and proceeded toward 3U drift face following the 3U crew. Eslick stated he spent 10 to 15 minutes taking temperature readings along 3U drift before arriving at the face. The crew was drilling rock bolt holes when Eslick reached the face, and he took temperature readings and made tests for methane with his methane tester as it was opportune. When some of the workmen began installing a section of chain link fencing and rock bolts, other workmen removed the flexible tubing from the vent line and were extending the steel vent tubing toward the face.

The crew in 2 south proceeded to the face and presumably the first work accomplished was the charging of the 43 blast holes drilled by the day-shift crew. The charged boreholes were detonated at 4:20 p.m. The outby end of the blasting cable was about 450 feet from the face near the power distribution center. The blasting unit and galvonometer were found at this location, and it is assumed that the shots were fired from this location. The time of the blast was attested to by statements of Eslick who was in 3U drift at the time. The explosion occurred at approximately 4:40 p.m. It is assumed that the ventilation to 2 south was normal at the time. It is believed the 2-south crew had not returned to the face when the explosion occurred, but they may have been on their way as normally the smoke and fumes would have cleared sufficiently in 20 minutes to permit resumption of operations. The mobile loading machine was parked about 125 feet back from the muck pile with the controls in the "off" position.

The approximate cross-sectional area of 2 south drift is 160 square feet. The quantity of return air flowing along 2 south drift was reported as 14,500 cfm on August 16, 1963. Dividing 14,500 by 160 shows an approximate return air velocity in 2 south of 90 feet a minute. The entrance to the shop off 2 south right is about 1,800 feet from the face of 2 south. This indicates the smoke and fumes from blasting and a sudden release of combustible gas in the face of 2 south would reach the shop area in about 20 minutes, or about 4:40 p.m., the time of the explosion.

Theoretically, most of this return air from 2 south would have travelled the less circuitous route through 2 south left and 2 south right to the shaft. However, with the fan (without tubing) operating in the shop area near its junction with 2 south right some of the return air would be circulated through the shop regardless of the loosely installed curtain inby the shop fan. The fan installed as it was, would cause recirculation of a combustible gas-air mixture in the shop area. The shop was at an elevation slightly higher than the surrounding area; moreover, the back had been taken down to provide

room for a steel beam to support a chain block thus making the height in the critical area about 11 feet from sill to back. The high place extended for several feet along the shop drift and created a natural cavity for collection of gases (see Appendix I - profile). Reportedly, tests for combustible gases were made in the shop area by an employee of the Texas Gulf Sulphur Company at 3:00 p.m. on August 27, 1963, using a permissible methane tester, but none was found. These tests were made only at heights that could be reached by the man standing on the floor. Inasmuch as gas tests were made in the shop area as indicated above, it is possible that combustible gas accumulated in the high spot in the shop and was not detected.

It was common practice to keep a lighted permissible flame safety lamp in the shop for gas-testing purposes. It was not determined whose responsibility it was to use the lamp for gas-testing purposes, but there apparently was some misconception that the lighted lamp would indicate the presence of gas by just keeping it suspended in the area and the flame burning. There were occasions when the lamp was left hanging from one shift to another without being taken to the surface for refueling, cleaning, and checking. This was the case on the day of the explosion.

The forces and concussion from the explosion were felt by the crew in 3U drift, and the men in that area knew something out of the ordinary had happened. Two men in 3U were knocked down by the forces; the first impression of at least one of the men was that a large quantity of explosives had been accidentally detonated. Seven contractor's employees were at or near 3U face, as was Mr. Eslick, mine foreman of Texas Gulf Sulphur Company. The eight men attempted to make their way to the shaft station, riding in a shuttle car part way; however, they encountered dense smoke. It was stated it was "white smoke". The "white smoke" possibly was formation of fog following the explosion in conjunction with fine salt and shale dust in suspension. Two additional men were encountered at the top of 3U. These two men had been building a bridge across a raise. The 10 men attempted to travel to the shaft station by way of 1 south and 2U drifts, but dense smoke prevented travel in each drift. The two men building the bridge across the raise immediately after the explosion heard a man screaming, "I can't see". The man was at or near the bottom of the raise, 1U north. The two men attempted to assist the man in the 1U north raise but were unable to locate him. When the 10 men were unable to travel to the shaft station, visibility became so poor they could not see each other, so they retreated groping their way back to 3U accounting for each other along the way. In the returning of the 10 men toward the face of 3U drift, only seven employees traveled to the transformer station, about 950 feet outby the face. At this location they erected a barricade by ripping open a length of flexible tubing.

This barricade was in an area where it was difficult to make it airtight, also, smoke was present in the area while the barricade was being erected, so the men decided to move inby toward the face and erect a second barricade in a better location under chain link fencing secured to the back by rock bolts. The second barricade was less difficult to erect and prevented the smoke, which was reported to be shoulder high, from moving further inby. Shortly thereafter, a third barricade made of opened-out flexible tubing was erected about 25 feet inby the second barricade. This was a more airtight barricade; it was fastened to the chain link fencing at the back, held tight against the ribs with pieces of 2- by 2-inch wood and a short piece of pipe. The opened end of the vent tubing within the barricade was sealed off with a piece of flexible tubing. Two of the 7 men left the barricade after about 15 hours and eventually reached the surface. The other 5 remained inby the barricade and were rescued about 50 hours after the explosion.

While the first barricade was being erected, the lead miner (Donald B. Hanna) went back up the drift and separated the compressed air line, hoping the escaping air would hold back the smoke; however, there was no pressure in the line and it was later learned that the compressed air line was broken near the shaft station. When Hanna, who separated the compressed air line, returned to the barricade, he found that the other men had retreated farther down the drift and were erecting a second barricade. The lead miner on this trip found three men lying on the floor with their heads near the vent pipe near the top of 3U drift. Hanna asked them to move enough for him to get in the air at the vent pipe but he was informed there was no air there. He then advised the three men that a barricade was being erected inby and they were to move inby to the barricade. Hanna was in poor condition physically and he returned to the barricade; however, the other three men remained at the vent tubing and died at this location. Later, about midnight Hanna and Paul McKinney left the barricade to repair the separated compressed air line so that if air pressure was restored it would reach within the barricade. In making the repairs, the men worked in smoke, and they could find only one bolt to replace the clamp coupling; a poor connection was made. After the two men returned to the barricade the blow hose was removed from the compressed air line and all valves were opened. This was done to relieve undue pressure on the poor connection outby the barricade in the event compressed air pressure was restored.

The barricaded men spread opened-out flexible tubing on the floor just inside the third barricade, but later moved down the drift about 220 feet from the barricade. They rested and awaited rescue on the spread out tubing. When the men retreated to the inby end of 3U drift they took with them a 10-gallon container about 1/4 full of water. This water was supplemented by breaking the 1-inch water line and draining water from it into the container. The water in the water line was treated but was muddied, nevertheless, the men drank it. A water manifold with four outlets was connected to the air line at the "resting place" and hoses were attached to the manifold's four outlets. Later this proved to be valuable when some air reached the men through the compressed air line after temporary repairs were made outside the barricade.

Each man had his permissible electric cap lamp and the lead miner had his permissible flame safety lamp. Only one cap lamp was kept lighted so that the lights could be conserved. There was little or no moving about in the barricade.

About 15 hours after the explosion, Hanna was of the opinion that rescue operations, which all the barricaded men believed were underway, should have at least progressed to the point where compressed-air flow was restored. Because compressed-air pressure was not present in the lines inby the barricade, Hanna thought that the shaft was inaccessible to rescue crews and he wanted to leave the barricade and check the compressed air lines.

Another man (Paul McKinney) agreed to accompany him and the two men left the barricade, one carrying the lighted flame safety lamp. It was stated the flame was yellow when the lamp was held at face level, but would get reddish when lowered toward the floor. Tests were made as the men travelled. Along the way they made some repairs to the compressed-air line and finally reached the shaft station where they found compressed-air being delivered from the surface. About 100 feet of the air line was missing, and the two men searched the area and the shop for pipe and other material to repair the section of 3-inch compressed-air line to 3U drift. They were successful in this attempt to the point where only a short span (12 to 18 inches) remained to be connected. (The compressed-air line was later made continuous by a rescue crew about 30 hours after the men were in the barricade and although other leaks developed some air reached the barricaded men.) The two men attempted to attract attention on the surface by beating on the intact compressed-air line in the shaft with a piece of steel. In this they were not successful, but were found by the next rescue team that was lowered in the shaft. Shortly thereafter they were hoisted to the surface.

There was no way to determine the actions or movements of the 2-south crew members after they fired the blast in the 2 south face at 4:20 p.m. Location of the face equipment and examination of the shot face indicated that no work was done at the face after the blast. Following the explosion, some of the 2-south crew members erected a barricade about 75 feet outby the face of 2 south; this barricade erected of the ripped-open flexible tubing was not airtight. Three victims, who had died of asphyxiation, were found inby the barricade by the recovery parties. The bodies of two other members of the 2-south crew were found 725 feet outby the face of 2 south and they had been killed by violence. One of the three victims found in the 2 south barricade was the employee who had been heard screaming at the bottom of the raise, 1U north shortly after the explosion. Footsteps in the settled dust showed that the man traveled from 2 south drift into 1U north and back to 2 south drift.

Whether men were actually in or working within the shop area could not be determined definitely. Bodies of two men were found at the inby junction of

2 south right and 2 south left. These two men were the master mechanic and a mechanic who normally worked on the surface but had traveled underground with a part for the inoperative loading machine under repair in the shop. Bodies of two additional men were found at the outby junction of 2 south right and 2 south left. These were the bodies of the shift walker and a shuttle-car operator. The body of a shuttle-car operator from 3U drift was found on the east side of the shaft station; he had traveled to the station with his shuttle car to charge the car batteries. The body in the shaft was that of the skip loader; the four bodies found on the west side of the shaft station were those of two underground shop mechanics, an underground electrician, and a miner. Examination of the bodies and the immediate areas in these locations showed that the explosion had been most violent in the vicinity. All of the 10 bodies showed that they had been picked-up, tossed about, or blown some distance by the explosion forces. One man had been dismembered, others were blown out of their shoes or boots, and the torn boots and shoes as well as evidence on the bodies showed clearly that the bodies were tossed or blown some distances (see Appendices G and H).

Examination of the entire mine after the disaster showed that the explosion originated in the shop area. All evidence indicated that the combustible gas ignited in the shop area was released at the face of 2 south drift when the round of shots were fired therein at 4:20 p.m. As mentioned previously, the velocity of the air moving from 2 south drift to the shaft would move the combustible gas from the face of 2 south to the shop area at a suitable rate of flow to initiate the explosion in the shop area at 4:40 p.m. Ignition of the combustible gas in the shop area might have and easily could have been from an electric arc or spark, an open flame, or a heated exhaust manifold on a shuttle car. Some of the more likely ignition sources were:

1. Arcs or sparks from the battery-charging clamps being placed on or removed from the battery terminals on the No. 5 shuttle car, the switch on the power panel in the shop being opened or closed, the power cable to the battery charger being placed in the power outlet, or an electric circuit on a shuttle car or from equipment or circuits in the shop area.

2. An open flame such as from a match or cigarette lighter or from a cutting torch.

3. Heated surfaces such as the filaments in electric light bulbs or an exhaust manifold on a shuttle car.

The possibility that the combustible gas that was ignited could have come from a source other than liberation from the strata after blasting in 2 south drift was recognized. All such sources were investigated thoroughly, including the possibility that acetylene was the combustible gas, but there was no evidence found to support such possibilities, and analyses of dusts

and residues after the explosion indicated that the combustible gas ignited had not been acetylene.

Damage was confined generally to the shaft, shaft structures on the surface, and the immediate areas of the shaft station and shop areas. Elsewhere, underground damage was slight.

Recovery Operations: Shortly after the explosion forces reached the surface, Messrs. Tippie and Harrison, as well as other officials and employees of the two companies, examined part of the shaft, the shaft structure on the surface and the hoisting ropes, sheaves, and surface dump bin doors, and continuoue efforts were made to enter the mine. After these examinations, recovery plans were discussed and about 6:00 p.m., members of The Industrial Commission of Utah were advised of the disaster. Later, officials of coal mines near Price, Utah, and owned by the United States Steel Corporation and Kaiser Steel Corporation, were informed of the explosion, and these officials were asked to send their mine rescue teams to Cane Creek mine. Officials and mine rescue teams from both companies responded and began arriving at the Cane Creek mine the same evening. In addition, the Independent Coal and Coke Company and Deseret Coal Mines each sent two supervisors to the mine.

Only one shaft had thus far been opened, which necessitated that ingress and egress to and from the mine be through this shaft. Furthermore, as intake air traveled underground from the surface through vent tubing extended down the shaft, return air from the underground workings and contaminated with afterdamps of the explosion flowed through the open areas of the shaft. These conditions required that extreme care and caution be exercised in initial recovery operations. Several attemps were made to lower the buckets to the shaft station and then return the buckets to the surface. These trips were made with the empty buckets. The first of the coal company officials and mine rescue teams from near Price, Utah, arrived at the Cane Creek mine about 9:00 p.m., August 27, and the others arrived shortly thereafter. During conferences with coal company officials, members of the mine rescue teams, and local mine officials, it was decided that four men should travel to the shaft station in the Nordberg No. 1 bucket and attempt to ascertain how much fresh air was in the vent tubing in the shaft station. The four men wearing self-contained oxygen breathing apparatus left the surface about 11:00 p.m. in the bucket and traveled to the shaft station; they returned to the surface at 11:40 p.m., August 27. This trip and others made by the mine rescue and recovery crews were in the buckets without the crossheads. Two of the four buckets could not be lowered to the shaft station because the dislodged vent pipe partially blocked the particular bucket hoisting lanes.

Compressed air pipe lines extending from the surface into the shaft were not damaged and the four compressors located on the surface were operated at full capacity. About 3:00 a.m., Wednesday, August 28, a crew of mine rescue workers wearing self-contained oxygen breathing apparatus were lowered from the surface to the shaft station where tests made with carbon monoxide indicators and methane testers showed 0.1 percent carbon monoxide and 0.2 percent combustible gas.

Rescue crews thereafter at irregular intervals and wearing self-generating oxygen breathing apparatus and gas masks, and operating from fresh-air bases at the shaft collar and shaft station continued checking the mine atmosphere, examining the mine workings, and locating bodies of the victims. The times rescued men reached the shaft collar and the times bodies were hoisted to the surface are in sequence as follows:

Date	Day	Time	Remarks
August 28	Wednesday	11:55 a.m.	2 men walked from the barricade to the shaft and were hoisted to the surface when found by a rescue team at the shaft station
August 29	Thursday	2:35 a.m.	1 body recovered
August 29	Thursday	6:30 p.m.	5 men rescued by crews and walked from barricade in 3U drift to the shaft station
August 29	Thursday	8:00 p.m.	4 bodies recovered
August 29	Thursday	8:16 p.m.	2 bodies recovered
August 29	Thursday	8:59 p.m.	2 bodies recovered
August 29	Thursday	9:28 p.m.	3 bodies recovered
August 29	Thursday	10:37 p.m.	1 body recovered
August 29	Thursday	10:49 p.m.	1 body recovered
August 29	Thursday	11:27 p.m.	1 body recovered
August 29	Thursday	11:54 p.m.	2 bodies recovered
August 31	Saturday	6:30 p.m.	1 body recovered

A rescue crew equipped with, but not wearing self-contained oxygen breathing apparatus and all-service gas masks, reached the barricaded men about 5:30 p.m., Thursday, August 29. The crew and the five rescued men walked from the barricade site to the shaft station where they were hoisted to the surface.

The early stages of the recovery operations were lead by supervisory officials from Kaiser Steel Company and United States Steel Corporation's Utah coal mine facilities with continuous assistance from personnel of the Texas Gulf Sulphur Company, Harrison International, Incorporated, The Industrial Commission of Utah, and the United States Bureau of Mines.

INVESTIGATION OF CAUSE OF EXPLOSION

Investigation Committee:

Texas Gulf Sulphur Company

Dr. C. F. Fogarty	Senior Vice President
T. L. Wilson	Assistant Mine Superintendent
Jack Marshall	Supervisor, Maintenance Department
E. Ziolkowski	Mining Engineer
Wiley Brooks	General Mine Foreman

Harrison International, Incorporated

Nathaniel Harrison	Chairman
Patrick Harrison	President
Norman Harrison	Project Manager
George E. Smith	Chief Engineer
Albert Trenfield	Mine Superintendent

The Industrial Commission - State of Utah

Casper A. Nelson	Commissioner
Steve Hatsis	Mine Inspector
John Holmes	Mine Inspector

United States Geological Survey
Branch of Mining Operations

Ernest Blessing	Regional Mining Supervisor, Western Region
Harvey McCann	Mining Engineer

The Travelers Insurance Companies

Sterling Tolby	Agent
Ralph Tuck	Agent

United States Bureau of Mines

James Westfield	Assistant Director--Health and Safety
A. C. Moschetti	Technical Assistant
L. D. Knill	Subdistrict Supervisor
Rogers F. Davis	Chief, Diesel Test and Research Center
A. Z. Dimitroff	Supervising Mining Health and Safety Engineer
Albert Maxian	Supervisory Chemist
Maurice S. Childers	Coal-Mine Inspector (Electrical)
Joseph Freeman	Coal-Mine Inspector
T. C. Lukins	Mining Health and Safety Engineer
W. C. Gardner	Mining Health and Safety Engineer
W. E. Burleson	Mining Health and Safety Engineer
D. E. Martin	Safety Representative

A detailed examination of the underground areas was carefully made by the entire investigating committee. To expedite the work, the committee was divided into three groups, each composed of representatives of the respective agencies. The electrical equipment was studied by electrical inspectors, and the Diesel equipment was studied by Diesel engineers; the findings of the electrical inspectors and Diesel engineers have been recorded heretofore in this report.

Survivors of this explosion and many of the mine employees and officials were interrogated September 5 and 6, 1963, by representatives of The Industrial Commission - State of Utah, United States Bureau of Mines, Texas Gulf Sulphur Company, and Harrison International, Incorporated. This interrogation was to secure information on the explosion and learn of events prior to the explosion or practices which might have helped set the stage for the disaster.

Combustible Gas as a Factor in the Explosion: The following evidence shows that combustible gas was liberated in the Cane Creek mine:

1. A gas ignition occurred in 3U drift on July 31, 1963, and the gas emitting from a rock bolt hole continued to burn for several hours until extinguished.

2. Records of gas tests made by a Texas Gulf Sulphur Company employee after the July 31 ignition showed gas was found on many occasions.

3. Air samples collected in 2 south drift on August 31, 1963, following the explosion contained total hydrocarbons (combustible gas) ranging from 1.31 to 6.7 percent. All other samples collected in other locations in the mine following the explosion contained total hydrocarbons in lesser amounts.

4. Sample X-1289 collected in the 2 south drift on August 31, 1963, had the following composition:

	Concentration, volume percent	
	(1)	(2)
Component	"As received"	"Air-free"
Carbon dioxide	0.3	3.3
Oxygen	19.0	
Methane	4.74	51.4
Ethane	1.1	11.9
Propane	0.5	5.4
Butane	0.24	2.6
Pentane	0.12	1.3
Nitrogen	74.00	24.1

The data in column (1) show the concentrations of the individual components of the atmosphere when the sample was collected. The data in column (2) show the actual composition of the gases issuing from the strata. The calculated lower and upper flammable limits, respectively, for the "air-free" mixture are 5.3 and 16.4 volume percent.

5. The quantity of combustible gas liberated at the face of 2 south drift when mixed with air was capable of forming an explosive mixture.

6. This disaster resulted from an ignition of combustible gas that was liberated in 2 south drift and carried by air currents into the shop area where it was recirculated and formed an explosive mixture with air.

7. After the explosion, with ventilation totally disrupted, combustible gas and air accumulated in the inby portion of 2 south drift to form an explosive mixture.

8. Records of prospect holes that have been drilled, and are being drilled in the Moab, Utah area show that combustible gas has been encountered in the clastics, particularly in the shales. The gas is under considerable pressure but bleeds off in a short time indicating relatively small quantities. The analysis of gas encountered in the prospect holes is similar to the gas found in the Cane Creek mine.

Flame: Flame was confined to the shaft station and shop area and for short distances inby the shop area. Scorched pages from a torn-apart equipment manual were found at the junction of the 3 south shop area and 2 south right, but probably these were carried to this point by forces of the explosion as presumably the manual would have been in the shop. Soot was not discernible, but in general, material scraped or brushed from various locations and equipment in the shop area were dark brown-black in color and were oily and greasy. Some material was lighter colored and contained little oil. Samples of the above materials were analyzed in the Bureau of Mines laboratories in Pittsburgh, Pennsylvania. Soot was not present in the samples.

Forces: The explosion forces radiated from the shop area and then traveled in all directions. The forces traveled all the way up the shaft to the 7th floor of the concrete headframe. A small wooden house constructed of 3/4-inch plywood on ground level near the shaft and a 3/4-inch plywood wall closing an opening in the headframe behind the wooden shelter house were blown out and the nearby corrugated fiber glass enclosure to a beltway was damaged. Other pieces of 3/4-inch plywood used to cover the steel grill around the bucket openings at the shaft collar were blown some distance away. A man in the wooden shelter house near the shaft was blown into the air and landed about 15 feet away; the roof of the small wooden house came to rest on him. The forces extended to the face of 3U drift and likely the face of 2 south drift; survivors from 3U drift stated forces knocked two of them down.

Torn up vent tubing and explosives and detonators were scattered from their storage areas.

Probable Point of Origin: Bureau of Mines investigators believe that the explosion originated in the shop area.

Factors Preventing Spread of Explosion: This disaster was strictly a gas explosion, and all available fuel (mixture of combustible gas and air) was ignited. Mine dusts are not explosive and other materials, such as oils and explosives, that might have propagated the explosion were not ignited.

Summary of Evidence: Conditions observed in the mine during recovery operations and the investigation that followed, together with information made available during interrogation and discussions with officials and employees of the Texas Gulf Sulphur Company and Harrison International, Incorporated provided evidence as to cause and origin of explosion. The evidence from which the conclusions of the Bureau of Mines investigators are drawn are summarized as follows:

1. One explosion occurred in which only combustible gas was involved.

2. The explosion occurred at 4:40 p.m., August 27, 1963. This time was given by an underground official of the Texas Gulf Sulphur Company, who survived the explosion and was corroborated by an employee of Harrison International, Incorporated, who was on the surface at the time.

3. All victims in the vicinity of the shop and shaft station and two victims in 2 south drift were killed instantly. Three men in the 2 south face area and three others in 3U drift died later of asphyxiation.

4. The 2 south face was blasted 20 minutes prior to the explosion.

5. Combustible gas was liberated from the 2 south face. Sample No. 1289, collected August 31, 1963 in the face of 2 south after the explosion, contained 6.7 percent total hydrocarbons composed of 4.74 percent methane, 1.1 percent ethane, 0.5 percent propane, 0.24 percent butanes, and 0.12 percent pentanes.

6. Gas had been emitted with sufficient pressure during blast hole drilling in shale to eject the drill with force and push the drill and operator back 20 feet from the face. Also, gas was released occasionally from fractures encountered in the strata during mining operations.

7. The calculated velocity of return air current in 2 south was adequate to carry combustible gas released at 2 south face after blasting at 4:20 p.m. to the shop at the time of explosion.

8. A fan, operated openly in the shop area, was capable of drawing some of the return air from 2 south and recirculating it within the shop.

9. Failure to find soot or low density carbon particles during comprehensive tests made of samples of fine solid materials collected in the shop indicates that acetylene did not enter into the explosion.

10. There was no electrical face equipment in use at the time of the explosion. Rock bolting with compressed-air stopers was in progress in the face of 3U drift, and the mobile loader was parked about 125 feet from the face in 2 south; no blasted rock had been loaded out.

11. Power circuits and the 110-volt lighting system in the shop were energized.

12. A permissible flame safety lamp was left hanging (between shifts) in the shop area. Laboratory examination of this lamp indicates that the lamp was not lighted at the time of the explosion.

13. Some persons using the permissible flame safety lamps had not been trained adequately in their use as gas-testing instruments.

14. Some smoking continued in the mine regardless of the "No Smoking" rule instituted following the July 31, 1963, gas ignition. A search program to dissuade persons from carrying smoker's articles underground had not been instituted.

15. Not all the permissible electric face equipment was maintained in permissible condition..

16. Diesel shuttle cars approved for use in nongassy noncoal mines were used in the mine.

Cause of Explosion: The disaster was caused by the ignition of combustible gas in the shop area by electric arcs or sparks, open flame, or heated metal surfaces. The gas was liberated from blasting in the face of 2 south drift, and was carried by return air toward the shop. The fan, operated openly in the shop area, drew some of the gas-laden return air from 2 south into the shop and then recirculated it.

RECOMMENDATIONS

The following recommendations are made to prevent similar disasters, and they include recommendations that would add to the safety of the operation:

1. The mine should be operated as a gassy mine.

2. Positive ventilation of all underground workings should be provided before raises or drifts are advanced. Until such positive ventilation is established, work underground should be restricted to that necessary to restore the mine to normal and provide positive ventilation. This is not intended to prevent the development of necessary connecting crosscuts between drifts.

3. A suitable dividing partition should be installed in the shaft, and the main fan proposed for use in ventilating the mine should be installed on the surface and put into operation.

4. A second opening to the underground workings should be provided as soon as possible, so that sufficient airways and a second escapeway are available.

5. If it is necessary to drive crosscuts or drifts to provide adequate positive ventilation, at least 40,000 cubic feet of air a minute should be provided at each working face to properly dilute sudden gas releases and provide adequate ventilation for Diesel shuttle cars.

6. Underground shops should be ventilated with a separate split of air, and air returning from the shop should be directed into the main return.

7. Preshift examinations of the entire mine should be made by certified persons before each shift enters the mine. Suitable records of such examinations should be kept in a book on the surface provided for that purpose.

8. Foreman, crew leaders, and other supervisors should have in their possession at all times while underground a permissible flame safety lamp and/or an approved methane tester. Such lamps or methane testers should be used to make gas tests frequently throughout the working shift at working faces and in other locations where combustible gas might be found.

9. Tests for gas should be made immediately before and after blasting, and gas tests should be made in face areas before electrical equipment is taken into or operated at working faces. Gas tests should also be made at frequent intervals while electric equipment is operated at working faces.

10. A capping flame should be used when making gas tests with a flame safety lamp.

11. Examinations for gas in face workings should be made at intervals sufficiently frequent to detect the presence of gas before it reaches dangerous proportions. The location in which foreman and men are required to make tests for gas should be clear to all and the required testing practices should be strictly enforced.

12. Shots should not be fired and electrical equipment and Diesel shuttle cars should not be taken into or operated in a working place when 1.0 percent or more combustible gas is detected in the place.

13. Permissible equipment should be maintained in permissible condition at all times.

14. The rule prohibiting smoking in the mine should be strictly enforced.

15. All officials and employees should be searched at sufficiently frequent intervals so as to prevent matches, cigarettes, and other smoker's articles from being taken into the mine.

16. Oxygen-acetylene cutting torches and electric arc welders should be used underground only when necessary.

17. When it is necessary to use oxygen-acetylene torch and/or electric arc welders in the mine, persons qualified in the use of gas detecting instruments should be assigned to test for gas before and during cutting and welding. Cutting torches and welders should not be used when 1.0 percent or more combustible gas is detected.

18. All valves on oxygen-acetylene equipment should be kept closed except when the equipment is actually in use.

19. Diesel equipment used in face regions should be of a type approved as permissible for gassy noncoal mines.

20. Electric equipment taken into or operated in face regions should be permissible.

21. Incandescent lights should be used only in areas that are ventilated with intake air.

22. If blasting is done on shift or with men in the mine, only permissible explosives and millisecond delay detonators should be used. Blast holes should be stemmed with water stemming or incombustible material and fired with permissible blasting units.

23. Explosives and detonators taken underground should be placed in nonconductive containers and transported separately in the buckets and shuttle cars.

24. Explosives and detonators underground should be stored separately in closed boxes constructed of wood or other nonconductive material.

25. Extraneous materials, such as containers of oil and rock bolting materials, should not be kept in explosives or detonator storage areas.

26. Deteriorated explosives should not be left underground; these should be returned to the surface and proper disposal made.

27. Boreholes should not be charged at the same time drilling or undercutting operations are in progress. Charging of blast holes should be done only when other work in the face area such as undercutting and drilling is completed.

28. Pull tests and torque readings of installed rock bolts should be made periodically to determine their effectiveness as ground support.

29. A positive means of identifying each person underground should be established, and a positive check-in-and-out system should be adopted.

Following the completion of the investigation, employees of Texas Gulf Sulphur Company and the Harrison International, Incorporated were trained in the proper maintenance and use of the permissible flame safety lamp and suitable gas-testing procedures. Also, employees have begun attending classes on maintenance and wearing of oxygen breathing apparatus.

ACKNOWLEDGMENT

The writers acknowledge the courtesies, cooperation, and assistance extended by officials and employees of the Texas Gulf Sulphur Company, Harrison International, Incorporated and representatives of the Industrial Commission of Utah.

Respectfully submitted,

James Westfield

L. D. Knill

A. C. Moschetti

Table 1. Composition[1/] [2/] Of Mine Air Samples Taken At the Cane Creek Mine After Explosion on August 27, 1963

Bottle No.	Date	Time	Location	Carbon Dioxide	Oxygen	Carbon Monoxide	Total Hydrocarbons[3/]	Nitrogen
X-1750	8/28/63	12:45 a.m.	Return air, collar of shaft	0.06	20.86	0.01	0.06	79.01
X-1751	8/28/63	12:45 a.m.	Return air, collar of shaft	0.11	20.61	0.01	0.07	79.20
X-1702	8/28/63	5:45 a.m.	Return air, near bottom of shaft	0.27	20.44	0.04	0.29	78.96
X-1761	8/29/63	7:00 p.m.	East drift, about 1000 ft. inby shaft	0.06	20.85	0.005	0.36	78.73
X-1738	8/29/63	7:30 p.m.	East drift near crosscut at 3U	0.13	20.85	0.005	0.28	78.74
X-1512	8/30/63	12:25 p.m.	No. 2 south, 50 feet inby No. 4 crosscut	0.07	20.71	0.00	0.80	78.42
X-1511	8/30/63	12:35 p.m.	No. 2 south, about 100 feet inby No. 4 crosscut	0.10	20.74	0.00	0.56	78.60
X-1672	8/30/63	12:40 p.m.	No. 2 south, about 175 feet inby No. 4 crosscut	0.09	20.46	0.00	0.98	78.47
X-1671	8/30/63	12:45 p.m.	No. 2 south, near station 68	0.09	20.54	0.00	1.31	78.06
X-1700	8/30/63	12:55 p.m.	No. 2 south, about 30 feet outby face	0.12	20.38	0.00	1.79	77.71
X-1289	8/30/63	12:58 p.m.	No. 2 south over muck pile at face	0.3	19.0	0.00	6.7	74.00
X-302	9/1/63	11:25 a.m.	No. 2 south, 350 feet outby face	0.15	20.59	0.005	0.73	78.53
X-297	9/1/63	11:40 a.m.	No. 2 south, on muck pile at face	0.07	20.78	0.00	0.69	78.46
X-916	9/1/63	12:05 p.m.	Face, No. 1 U south drift, inby ore pass raise	0.10	20.74	0.00	0.42	78.74
X-910	9/1/63	12:20 p.m.	Face, No. 1 U north drift, inby No. 2 ore bin	0.13	20.82	0.005	0.14	78.91
X-1748	9/1/63	3:10 p.m.	No. 3 U drift, 775 feet from face, at outby end of steel sets	0.13	20.37	0.00	1.32	78.18
X-1749	9/1/63	3:10 p.m.	Face of No. 3 U drift	0.06	20.90	0.00	0.07	78.97
X-993	9/4/63	8:45 a.m.	Station 20 plus 25 feet, close to back	0.10	20.79	--- [4/]	0.15	78.96
X-992	9/4/63	8:55 a.m.	Station 12 plus 67 feet, close to back	0.07	20.70	--- [4/]	0.15	79.08
X-1648	9/4/63	9:05 a.m.	Station 12 plus 57 feet, close to back	0.06	20.72	--- [4/]	0.11	79.11
X-997	9/4/63	9:12 a.m.	Station 12 plus 15 feet, close to back	0.05	20.86	--- [4/]	0.14	78.95
X-1704	9/4/63	9:15 a.m.	Station 12 plus 35 feet, close to back	0.10	20.89	--- [4/]	0.13	78.88
X-1705	9/4/63	9:25 a.m.	Station 8, close to back	0.09	20.82	--- [4/]	0.15	78.94

1/ Concentrations of gases expressed in percent by volume.

2/ Acetylene is not listed in Tables 1 and 2 as none was detected in samples analyzed by infrared absorption spectroscopy.

3/ Total hydrocarbons include all hydrocarbons. See Table 2 for representative composition of total hydrocarbons found in bottles X-1289, X-1671, X-1700, and X-1748.

4/ Not analyzed for carbon monoxide.

Table 2. Representative Composition[1/] of Hydrocarbon Gases Reported As Total Hydrocarbons in Table 1

Bottle No.	Date	Time	Location	Total[2/] Hydro-carbons	Methane	Ethane	Propane	Butanes	Pentanes
X-1671	8/30/63	12:45 p.m.	No. 2 south, near station 68	1.31	0.87	0.24	0.12	0.05	0.03
X-1700	8/30/63	12:55 p.m.	No. 2 south, about 30 feet outby face	1.79	1.24	0.28	0.17	0.07	0.03
X-1289	8/30/63	12:58 p.m.	No. 2 south, over muck pile at face	6.7	4.74	1.1	0.5	0.24	0.12
X-1748	9/1/63	3:10 p.m.	No. 3 U drift, 775 feet from face, at outby end of steel sets	1.32	0.85	0.28	0.12	0.05	0.02

1/ Concentrations of gases expressed as percent by volume.

2/ Total hydrocarbons as reported in Table 1.

APPENDIX A

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON 25, D. C.

August 30, 1963

Memorandum

To : Director, Bureau of Mines

From : Assistant Secretary--Mineral Resources

Subject: Mine disaster at Moab, Utah

In connection with the recent disaster at Cane Creek Shaft, Texas Gulf Sulphur Company, Moab, Grand County, Utah, I hereby direct you to authorize personnel of your Bureau whom you select to conduct an investigation of the disaster and participate at official hearings thereon.

The designation of James Westfield, Assistant Director--Health and Safety, as principal representative, along with assistants Lester D. Knill and Anthony C. Moschetti, Subdistrict Supervisor and Technical Assistant, respectively, Health and Safety District H, as suggested by you is satisfactory.

(SGD) John M. Kelly

APPENDIX B

HCT BUREAU OF MINES 41.3178.1

JAMES WESTFIELD
C/O UTAH MOTEL
MOAB, UTAH

YOU ARE HEREBY AUTHORIZED AND DIRECTED TO CONDUCT A THOROUGH GOING INVESTIGATION OF THE RECENT MINE DISASTER AT THE CANE CREEK POTASH MINE FOR THE DEPARTMENT OF THE INTERIOR.

MARLING J. ANKENY

MARLING J. ANKENY
DIRECTOR, BUREAU OF MINES

S E N T

AUG 30 1963

Clerical Service Section

BA

APPENDIX C

HCQ

BUREAU OF MINES 41.3178.1
WASHINGTON, D.C.
AUGUST 30, 1963

HON. GEORGE DEWEY CLYDE
GOVERNOR OF UTAH
SALT LAKE CITY, UTAH

IN REFERENCE TO INVESTIGATION OF RECENT DISASTER CANE CREEK POTASH MINE, IT IS RESPECTFULLY REQUESTED THAT THE INDUSTRIAL COMMISSION OF UTAH CONDUCT A HEARING IN WHICH ESSENTIAL WITNESSES WILL BE CALLED FOR QUESTIONING AND THAT A REPRESENTATIVE OF THIS DEPARTMENT BE PRIVILEGED TO QUESTION THE WITNESSES. JAMES WESTFIELD IS HEREBY DESIGNATED AS THIS DEPARTMENT'S REPRESENTATIVE.

(SGD) JOHN M. KELLY

ASSISTANT SECRETARY OF THE INTERIOR

APPENDIX D

Victims of Explosion

Name	Age	Occupation	Marital status	Dependents (including children under 18)
Wesley J. Barber	35	Miner	Married	Wife and 2 children
Robert W. Bobo	33	Miner	Married	Wife and 2 children
Myrlen H. Christensen, Sr.	44	Lead Mechanic	Married	Wife and 3 children
Myrlen H. Christensen, Jr.	21	Mechanic's Helper	Married	Wife
Lawrence I. Davidson	45	Master Mechanic	Married	Wife and 3 children
Jesse E. Fox	52	Mechanic	Married	Wife and 2 children
James N. Hollinger	33	Miner	Married	Wife and 2 children
William Huzil	41	Lead Miner	Married	Wife and 4 children
Clell Johnson	44	Electrician	Married	Wife
Jesse C. Kassler	38	Skiploader	Married	Wife and 3 children
Emile J. LeBlanc	32	Miner	Married	Wife and 3 children
Kenneth Milton	43	Torkar Operator	Married	Wife and 2 children
Fred D. Rowley	41	Lead Miner	Married	Wife and 3 children
Joseph Rene Roy	40	Walker (Shift foreman)	Married	Wife and 5 children
Lamar C. Rushton	35	Lead Miner	Married	Wife and 2 children
Keith Schear	22	Miner	Married	Wife and 1 child
Peter Sviscsu	42	Miner	Single	None
John B. Tinall	38	Miner	Married	Wife

APPENDIX E

Survivors of Explosion

Name	Age	Occupation	Marital status	Dependents (including children under 18)
Charles W. Byrge	30	Torkar Operator	Married	Wife and 6 children
Charles C. Clark	27	Miner	Married	Wife and 4 children
C. S. Eslick	47	Mine Foreman (Texas Gulf Sulphur Company)	Married	Wife and 2 children
Donald B. Hanna	27	Lead Miner	Married	Wife and 4 children
Robert E. June	36	Miner	Married	Wife and 6 children
Paul D. McKinney	22	Miner	Married	Wife
Thomas J. Trueman	35	Torkar Operator	Single	None

Injured by Explosion

Matt Rauhala	Dumpman

APPENDIX F

Names of Mine Rescue Personnel That Participated in Rescue and Recovery Operations after the Explosion.

Kaiser Steel Corporation

Sunnyside Mines

T. R. McCourt
Sunnyside, Utah

Frank Markosek
Sunnyside, Utah

C. E. Self
Sunnyside, Utah

Nick Tallerico
Sunnyside, Utah

Walter Jones
Dragerton, Utah

M. D. Ross
Sunnyside, Utah

Fred Tatton,
Sunnyside, Utah

John Schmidt
Sunnyside, Utah

William Shumway
Sunnyside, Utah

Bruno DallaCorte
Sunnyside, Utah

Newell Kofford
Castle Dale, Utah

Louis Villegos
Sunnyside, Utah

Howard Kissell
Sunnyside, Utah

Floyd Tucker
Sunnyside, Utah

Don Larsen
Price, Utah

John Westbrook
Sunnyside, Utah

Caratat Olson
Sunnyside, Utah

James Harvey
Dragerton, Utah

Wallace Christman
Price, Utah

Lloyd Jaramillo
Sunnyside, Utah

John Palacios
Sunnyside, Utah

George Ferguson
Sunnyside, Utah

Harry Krebs
Sunnyside, Utah

Clive Peterson
Sunnyside, Utah

John Peperakis
Sunnyside, Utah

APPENDEX F (continued)

Columbia-Geneva Steel Division, United States Steel Corp.

Columbia and Geneva Mines

R. M. von Storch
Dragerton, Utah

Lyle Burdick
Dragerton, Utah

W. J. Poglajen
Columbia, Utah

L. Paul Clark
Dragerton, Utah

George Dunham
Columbia, Utah

Alex Meadlak
Dragerton, Utah

Hugh Behling
Dragerton, Utah

Emery C. Olsen
Dragerton, Utah

Paul W. Butler
Dragerton, Utah

N. Dell Judd
Price, Utah

Ted Self
Price, Utah

Henry J. Colette
Dragerton, Utah

Bert Frandsen
Dragerton, Utah

Guy Hersh
Dragerton, Utah

James Cassano
Dragerton, Utah

R. E. Yourston
Dragerton, Utah

Lloyd R. Miller
Dragerton, Utah

Robert L. Kilcrease
Dragerton, Utah

Med Allred
Dragerton, Utah

J. D. Gray
Dragerton, Utah

Oscar Padgett
Columbia, Utah

Kenneth Walters
Dragerton, Utah

William Ward
Price, Utah

Kenneth Litster
Price, Utah

Alden Swasey
Wellington, Utah

Texas Gulf Sulphur Company

Cane Creek Mine

Wiley Brooks
Moab, Utah

Morris Worley
Moab, Utah

Bob Mashaw
Moab, Utah

APPENDEX F (continued)

Harrison International, Inc.

Lorenzo Boren
Moab, Utah

Norman Harrison
Moab, Utah

L. H. Thomas
Moab, Utah

Orin Green
Moab, Utah

Vernon Martin
Moab, Utah

H. Laviolette
Moab, Utah

Henry Levigne
Moab, Utah

E. Jessome
Moab, Utah

Ray Long
Moab, Utah

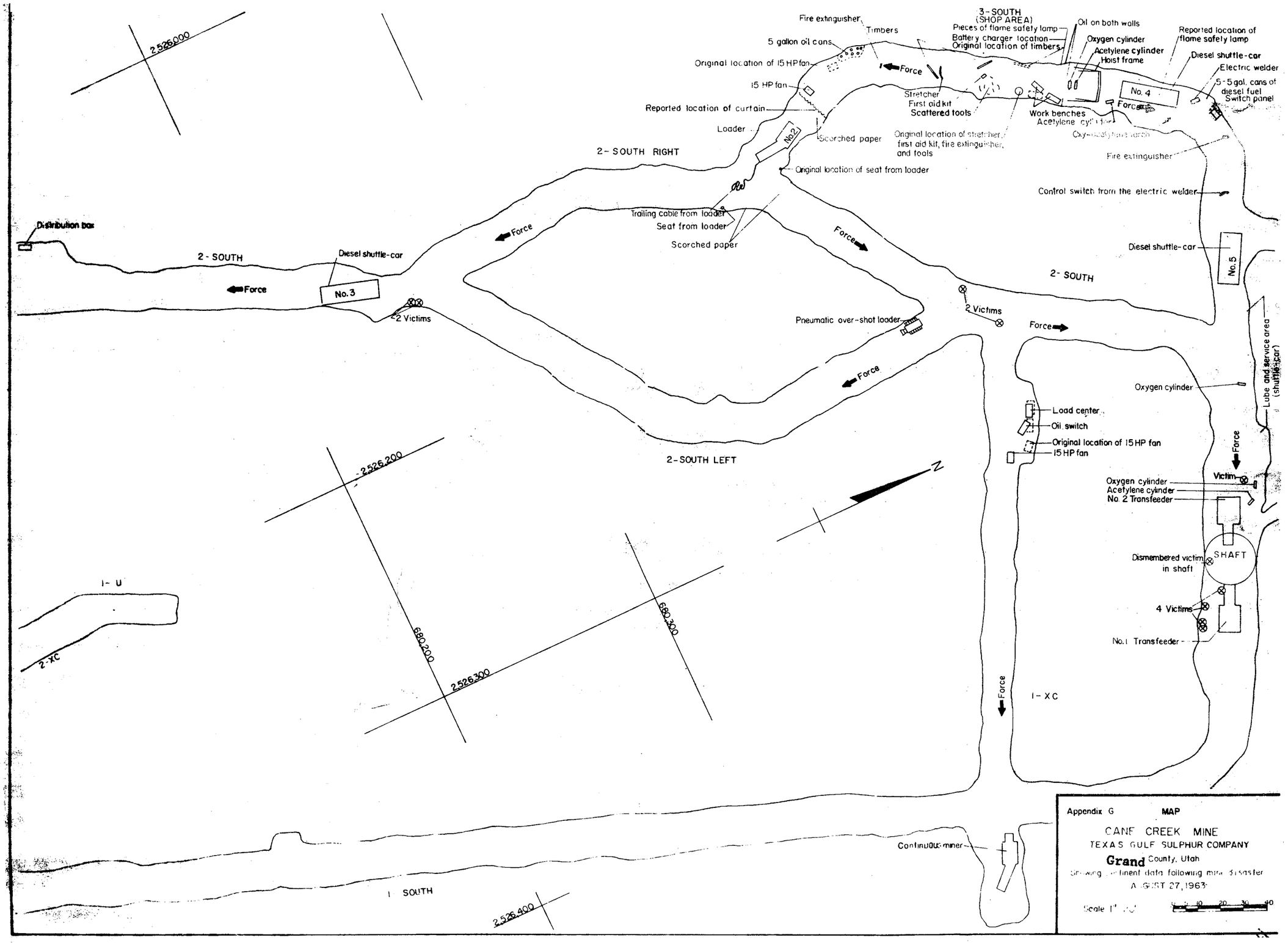
George McCloud
Moab, Utah

Robert Zimmerman
Moab, Utah

Ronald Cressler
Moab, Utah

Armond Roy
Moab, Utah

Bud Pilling
Moab, Utah



Appendix G **MAP**

CANE CREEK MINE

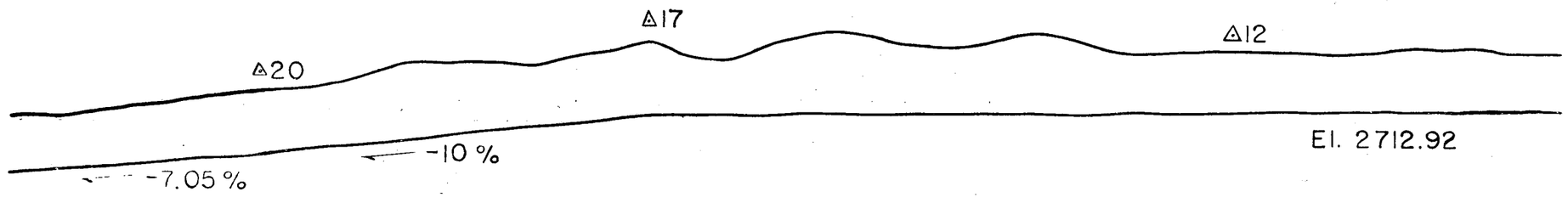
TEXAS GULF SULPHUR COMPANY

Grand County, Utah

Showing pertinent data following mine disaster

AUGUST 27, 1965

Scale 1" = 20'



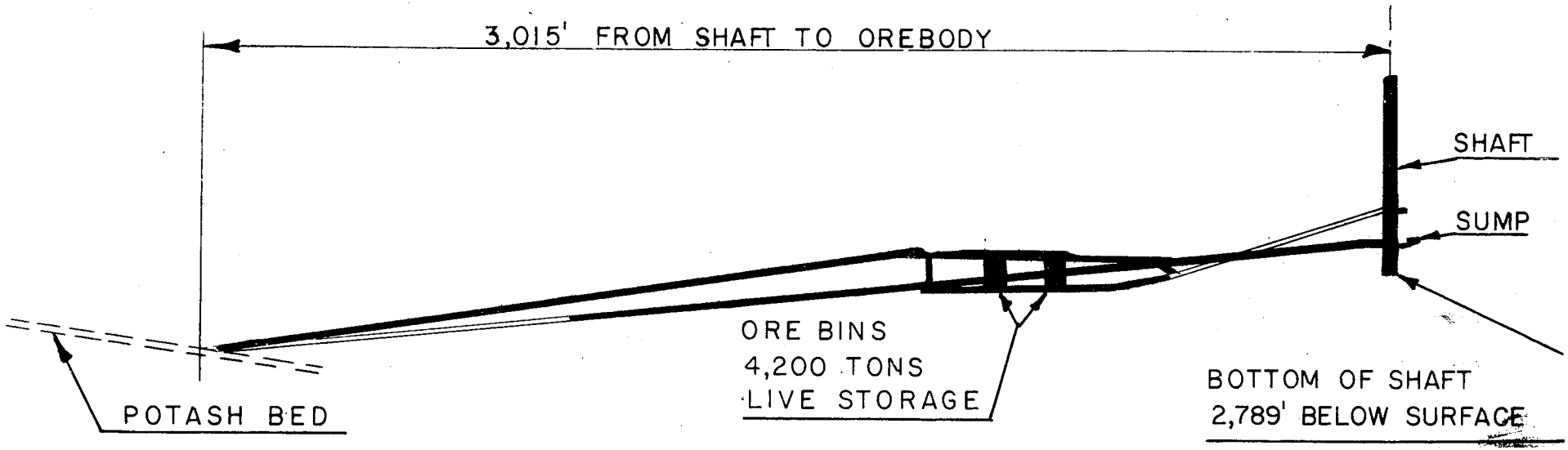
APPENDIX I

VERTICAL CROSS SECTION
SHOP AREA
3 SOUTH

△12 - 50' to △20 +40'

Scale 1"=20' 0 5 10 20 30

Appendix J
CANE CREEK MINE
TEXAS GULF SULPHUR COMPANY



VERTICAL SECTION

SCALE 1" = 500'

Completed work

Remaining

NORTH

-10% | LEVEL

3-SOUTH
(SHOP AREA)

20° Force

17° Force

12°

Force

Force

m. return air by
surement

Force

2 SOUTH RIGHT

Force

Force

Force

Force

Force

of flame

Force

36" 26"

Force

2 SOUTH LEFT

End 26" vent pipe and
start of 36" vent pipe

SUMP (above level)

SHAFT

3-40 HP fans in series
in each line at collar
of shaft (6 fans total)
2-26" vent pipes in shaft

Force

1-U

Approximate extent of flame

1 XC

40 HP fan in
vent pipe

2,526,500

680,500

Force

Vent line damaged extensively

36" 26"

-10% | LEVEL

LEVEL | +10%

APPENDIX H
MAP
CANE CREEK MINE

TEXAS GULF SULPHUR COMPANY
GRAND COUNTY, UTAH

Showing pertinent data following mine disaster

AUGUST 27, 1963

SCALE 1"=50'

0 50 100

arette package

re to face

40 HP fan, moved about 100'

Cap lamp, broken

Cigarette butt

Load center

Switch house

15 HP fan

15 HP fan and vent tube

Explosives storage

Explosives and detonators scattered

Vent line badly damaged and stacked up here

Detonator storage, detonators scattered

Extraneous materials, roof bolts etc. here

NORTH

8-16-63
14,500 c.f.m. return air by
smoke measurement

2 SOUTH

Force

Approximate extent of flame

4 XC

Loose detonators

LEVEL +30%

Miners belt

Pneumatic longhole drill

SOUTH

1-U NORTH

1-U

8-20-63
15,900 c.f.m. return air by
smoke measurement
temp. 80°/100°

2-U

Electric delay on air line

Scattered explosives

Pneumatic overshot loader

15 HP fan with vent tubing

1 SOUTH

3 XC

2 XC

Force

Vent line damaged extensively

36"

Vent line bowed but not broken

fan (adapter torn from vent line)

LEVEL +10%

compressed air line

ater can

vent line, safety lamp in end

Cigarette butt

Blasting unit

End of blasting cable

Galvanometer

Distribution box

Cap lamp on rib

1 case of explosives in plastic bag on vent line

Cigarette and empty cigarette package

Vent line intact from here to face

Cigarette butt

Hardhat

Steel sets

Hardhat

Hardhat on rib

Empty cigarette package

Cigarette butt

Steel sets

2 Victims

40 HP fan, moved about 100'

Cap lamp, broken

Cigarette butt

Load center

Switch house

15 HP fan

15 HP fan and vent tube

Explosives storage

4 XC

25 HP fan, not in use

Loose detonators

Load center

Switch house

2 cases deteriorated explosives

2 bags AN/FO

5 cases of explosives

Empty matchbook

Cigarette butts

Diesel shuttle-cars

I-U SOUTH

Miners belt

Pneumatic longhole drill

No. 2

No. 1

1- 5 gallon can of oil

Detonator storage box open (27 boxes of detonators)

Cigarette butts

2 - 5 gallon cans of oil

Empty cigarette package

Empty cigarette package

3 Victims

2 - U

Electric delay on air line

Scattered explosives

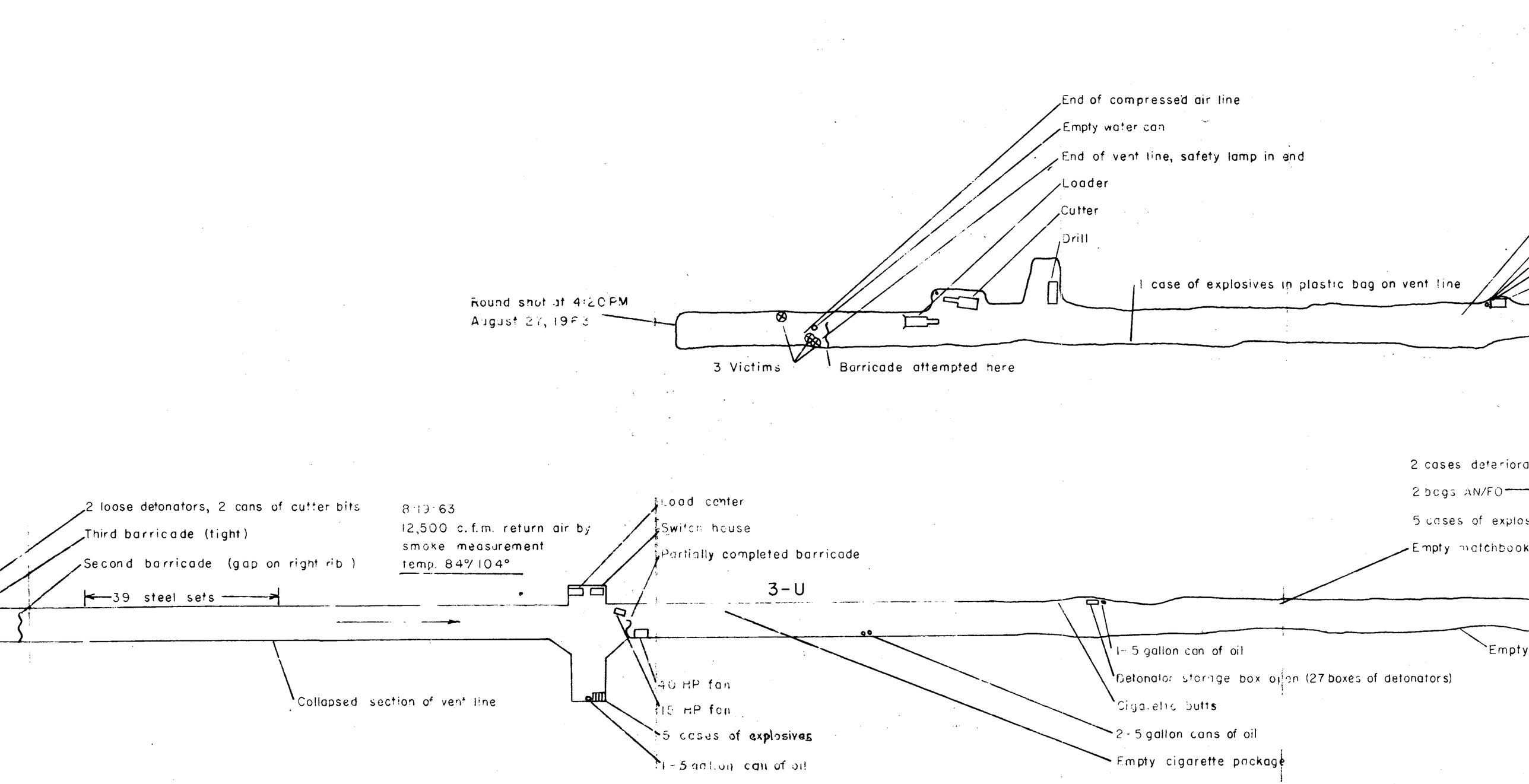
Pneumatic overshot loader

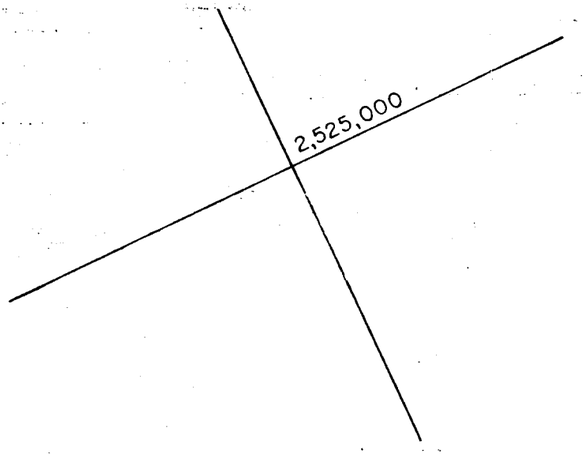
15 HP fan with vent tubing

I SO

40 HP fan (adapter torn from vent line)

-14% LEVEL


End of compressed air line
Empty water can
End of vent line, safety lamp in end
Loader
Cutter
Drill
1 case of explosives in plastic bag on vent line
Round shot at 4:20 PM
August 27, 1963
3 Victims
Barricade attempted here
2 cases deteriora
2 loose detonators, 2 cans of cutter bits
Third barricade (tight)
Second barricade (gap on right rib)
8-19-63
12,500 c.f.m. return air by
smoke measurement
temp. 84°/104°
39 steel sets
Load center
Switch house
Partially completed barricade
3-U
2 bags AN/FO
5 cases of explos
Empty matchbook
1-5 gallon can of oil
Empty
Detonator storage box open (27 boxes of detonators)
Collapsed section of vent line
40 HP fan
15 HP fan
5 cases of explosives
1-5 gallon can of oil
Cigarette butts
2-5 gallon cans of oil
Empty cigarette package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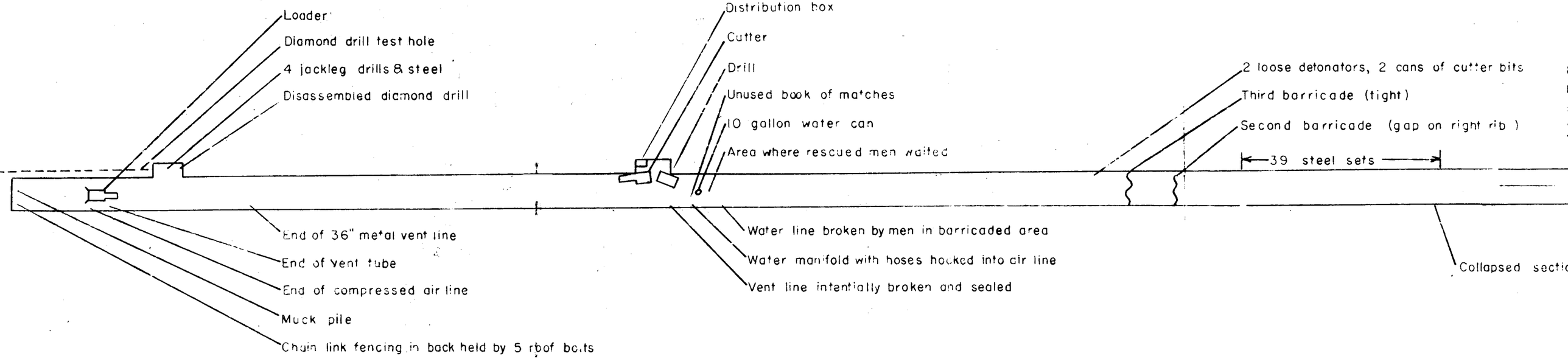
Loader
Diamond drill test hole
4 jackleg drills & steel
Disassembled diamond drill
Distribution box
Cutter
Drill
Unused book of matches
10 gallon water can
Area where rescued men waited
2 loose detonators, 2 cans of cutter bits
Third barricade (tight)
Second barricade (gap on right rib)
39 steel sets
End of 36" metal vent line
End of vent tube
End of compressed air line
Muck pile
Chain link fencing in back held by 5 roof bolts
Water line broken by men in barricaded area
Water manifold with hoses hooked into air line
Vent line intentially broken and sealed
Collapsed sectio