FINAL REPORT OF MINE EXPLOSION
BRADFORD MINE, ALABAMA BY-PRODUCTS CORPORATION
DIXIANA, JEFFERSON COUNTY, ALABAMA
MAY 14, 1945

By

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Coal-Mine Inspector

and

H. N. Smith
Coal-Mine Inspector

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D. J. Parker, Supervising Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

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Introduction

On May 14, 1945 at approximately 4:35 p.m., a gas and coal-dust explosion occurred in the Bradford mine of the Alabama By-Products Corporation at Dixiana, Jefferson County, Alabama.

The explosion occurred at the beginning of the second or night shift while 73 men were in the mine. Three of these men were killed by burns, violence, and afterdamp; two were injured by burns and afterdamp, but are expected to recover; and one man was slightly injured when he struck his knee against either a mine car or debris. The remaining 67 men escaped unassisted without suffering any ill effects.

The explosion was caused by an ignition of methane in the 53 right haulage entry, at about 250 feet from the face of 53 right entry, either by smoking or by an electric arc originating from a nonpermissible electric motor operating a blower fan. The accumulation of methane was probably caused by an interruption to the ventilating current.

The explosion was local in character, with little evidence of violence, and was restricted to the 53 right heading and air course which have been driven about 1,000 feet from the junction with the main-slope haulageway, and about 100 feet in the 46 left heading which is almost directly opposite the 53 right entry.

Rock dust is used to neutralize explosibility of the coal dust in the dry places of the mine, but neither water nor a wetting solution is used to allay coal dust.

Word of the explosion was received by Mr. D. J. Parker, Supervising Engineer, District D., Bureau of Mines about 6:40 p.m., May 14, 1945. Mr. Parker immediately notified Messrs. Jas. B. Benson and H. N. Smith, Federal coal-mine inspectors. Mr. Benson arrived at the mine about 8:25 p.m. with the Bureau of Mines rescue truck and equipment. Mr. Smith accompanied Mr. Benson. In the meantime, Messrs. J. L. Nelson and McKinley Braden of the U. S. Bureau of Mines Safety Division had arrived at the mine. Messrs. D. J. Parker, Norman C. King, and John H. Eggers, of the Bureau of Mines, arrived about 9:00 p.m.

General Information

The Bradford mine is at Dixiana, Jefferson County, Alabama and is served by a branch of the Louisville and Nashville Railroad. The mine is owned and operated by the Alabama By-Products Corporation.

The principal officers and their addresses are:

J. W. Porter	President	Birmingham, Alabama
P. H. Haskell, Jr.	General Manager	Birmingham, Alabama
W. C. Chase	General Superintendent	Birmingham, Alabama
M. E. Haworth	Chief Engineer	Birmingham, Alabama
B. E. Patterson	Superintendent	Dixiana, Alabama

The Bradford mine employed an average of 445 men, of which number 405 were underground employees. The mine is worked two shifts a day, six days a week. The average daily production is 1,000 tons of coal.

The mine is opened by four slopes, 350 to 1,200 feet in length, on a pitch of from 0 to 30 degrees. The mine is worked in the Black Creek coal bed, which varies in thickness from 0 to 35 inches and averages 22-1/2 inches in thickness in this mine. The maximum cover over the coal bed at this mine is about 300 feet. The coal bed is of bituminous rank, free from partings, and dips about 1 percent in a westerly direction. The immediate roof consists of sandy shale which is overlain with hard gray sandstone. The floor is fire clay which varies from soft to hard, and it is smooth.

A composite sample (Lab. No. 82096) collected in this mine in 1921 and analyzed in the Bureau of Mines coal laboratory, Pittsburgh, Pennsylvania, shows the following:

	Percent
Moisture	3.0
Volatile matter	31.8
Fixed carbon	62.1
Ash	3.1
Total	100.0

The ratio of volatile matter to total combustible matter, which is an index to the explosibility of coal dust, is shown by the following formula:

$$\frac{\text{Volatile matter}}{\text{Volatile matter} + \text{fixed carbon}} = \frac{31.8}{31.8 + 62.1} = 0.34.$$

Bureau of Mines tests and experiments have shown that coal dust having a volatile-matter to total combustible-matter ratio in excess of 0.12 is explosive. The explosibility of coal dust increases as this ratio increases. It is obvious, therefore, that the coal dust in this mine is highly explosive and would readily propagate an explosion.

Mining Methods, Conditions, and Equipment

The room-and-pillar system of mining is used, pillars are not recovered, and the total recovery is said to be about 60 percent.

The coal bed is worked by a tripple entry system from which cross entries, driven in pairs, are turned to the right and to the left at intervals varying from 200 to 500 feet. Room entries, 7 to 12 feet in width on 25-foot centers, are driven to predetermined distances which vary from 1,000 to 12,000 feet. Rooms are driven 30 to 35 feet wide with a 10- to 15-foot pillar between them. Rooms are turned from both the entry and air course, and where possible are driven through to the rooms of the adjacent entry. Want areas are encountered occasionally; therefore, rooms are not worked where the coal is less than 15 inches in thickness.

All coal is undercut before blasting and is hand loaded onto either shaker or chain-type conveyors.

The ventilating current is induced by means of a well-installed propeller-type fan located on the surface. The air is coursed through the main haulageway, the right and left air courses, and through old worked-out and abandoned areas on the right and left of the main haulage-way. The fan exhausts about 95,000 cubic feet of air a minute from the mine. A split system of ventilation is used, but separate splits are not provided for each active section. Auxiliary fans or blowers equipped with tubing, and operated by nonpermissible electrical equipment, are used to ventilate rooms. These fans are not installed to prevent recirculation of air, and the surroundings are neither fire-resistant nor fireproof. Stoppings in cross-cuts between the intake and return air courses are constructed of gob and are plastered on one side; they are maintained in good condition along the main-slope haulageway, but most room-entry stoppings are not plastered or maintained as airtight as possible.

Room crosscuts are not closed as the faces are advanced and new openings made, and line brattice is not used to conduct the air from the last open crosscuts to the faces. Wooden doors are used, but they are not installed in pairs to

form air locks, nor are auxiliary doors or check curtains provided at the single doors for emergency use; thus, whenever a door is damaged or opened, the air current is short-circuited from all points on the split inby the door.

The mine is classed as gassy by the State of Alabama, Department of Industrial Relations, Division of Safety and Inspection. Preshift inspections and tests for methane are made by certified fire bosses before the day shift enters the mine; methane is reported infrequently; and the fire bosses record the results of their findings on forms provided by the company. Certified section bosses, mining-machine operators, and shot firers test for methane with permissible flame safety lamps during each shift, and, reportedly, the section bosses on the first or day shift make preshift examinations for methane in the working places before the succeeding shift enters the section in which work is to be performed.

Monthly tests for methane are made in the return airways, in the last open crosscuts of working entries, and at the return of each split with a permissible methane detector by the company safety inspector. Air measurements are made at these points, and a copy of the record of measurements and tests is filed with the State agency governing coal mining. This mine is free from the hazards of oil and gas wells.

Table 1 shows the analyses of five air samples taken during the investigation before normal ventilation was completely restored in the 53 right entry and about 20 hours after the explosion occurred. Sample bottle No. 675- X contained 0.03 percent methane and was taken in air returning from the right side of the slope inby the 53 right. Duplicate samples (Bottles Nos. 269 and 270) taken in virtually still air near a small gas feeder in the roof of 53 right haulageway at room 15 about 20 hours after the explosion contained 6.66 and 6.08 percent methane, respectively.

TABLE 1. ANALYSES OF AIR SAMPLES. COLLECTED May 1945

MINE Bradford COMPANY Alabama By-Products Corp. COLLECTED BY H. N. Smith

BOTTLE NO.	LABORATORY NO.	LOCATION IN MINE	PERCENT BY VOLUME						CUBIC FEET AIR PER MINUTE	CUBIC FEET METHANE IN 24 HOURS
			CARBON DIOXIDE	OXYGEN	METHANE	CARBON MONOXIDE	NITROGEN			
675-X	116793	Return, from R side slope and intake to 53 R in R. slope A.C.	0.11	20.84	0.03		79.02		10,925	4,720
632-G	116794	Return, at room 1 in 53 R.	0.17	20.77	0.18		78.88			
631-Q	116795	Return, in 53 R. aircourse inby door	0.13	20.77	0.06		79.04		3,300	2,851
270	116796	53 rt. opposite 15 room Sta. 6 + 36	0.13	19.31	6.08		74.48			
269	116797	53 rt. hdg. at 15 room Sta. 6 + 36	0.18	19.21	6.66		73.95			

The mine is damp to wet in most of the haulageways where the bottom is brushed; however, dry conditions prevail in most of the working places. Thirty-two centrifugal and plunger-type pumps, equipped with nonpermissible motors, are installed in crosscuts in both intake and return air to unwater the mine.

The most prolific sources of coal dust are the operations of mining machines, blasting, hand-loading onto conveyors, transportation, and the discharge of coal from the conveyors into mine cars. Considerable fine coal dust was present along conveyor pan lines and on the floor in rooms. Coal is not topped above the sides of cars, and spillage along the haulageways is not excessive.

Water was not used in any manner to allay coal dust, and although rock dust was being used, analyses of dust samples indicate that it was not used in such quantity as to maintain an incombustible content of 65 percent. Rock dust is applied by hand in the working places, and with a low-pressure rock-dusting machine in the haulageways; trackless places are not redusted; and rock dust is not kept to within 40 feet of the active working faces. Rock-dust barriers are not used; periodic sampling of dust is not done; and the need for additional applications is determined only by observation. Fourteen mine-dust samples were collected in the affected area during the investigation. The samples were analyzed at the coal laboratory of the Bureau of Mines, Pittsburgh, Pennsylvania, and the results of the analyses are shown in table 2. The locations at which these samples were collected are shown on the map in Appendix A.

The analytical results of the samples indicate that from 51.1 to 75.0 percent of the dust passed through a 20-mesh screen and would enter into and propagate an explosion. Twelve of the fourteen samples contained coal particles in amounts ranging between a trace to a large amount. The combustible content of samples taken from gob and timbers ranged between 7[illegible] and 85[illegible] percent, and samples taken from the gob and floor ranged between 37.6 and 78.7 percent combustible. None of the dust samples collected contained sufficient inert material to prevent the dust from entering into an explosion.

TABLE 2. - Analyses of Dust Samples Collected May 15, 1945

Can No.	Location in mine	Kind of sample	Percent			Coked particles present
			Combustible, V.M. + F.C.	Incombustible, moisture + ash	Through 20-mesh	
U-914	46 lt. hdg. 100 ft. inby main slope opposite outby rib 2nd wall.	Gob & timber	87.2	12.8	59.7	Trace
K-689	Opposite inby rib of 2nd wall 46 left hdg.	Gob & timber	85.4	14.6	51.1	None
K-558	In 2nd wall of 46 left, 71 ft. from "C" of 46 left hdg.	Floor and timber	89.6	10.4	68.6	None
K-986	1st wall 46 left, 30 ft. from 46 left hdg.	Timbers	79.2	20.8	75.0	Large amount
K-576	do.	Floor	71.9	28.1	72.1	Medium amount
U-687	Main slope hdg. 75 ft. inby 53 rt. switch frog	Gob & floor	51.1	48.9	56.4	Small amount
K-990	Main slope rt. air course 65 ft. outby 53 rt.	Gob & floor	62.3	37.7	56.8	Medium Amount
U-942	53 rt. hdg. 10 ft. inby 19 wall conveyor loading point	Gob & floor	75.6	24.4	79.0	Large amount
K-999	53 rt. hdg. 20 ft. outby 1st loaded car	Gob & floor	68.0	32.0	68.2	Small amount
U-968	53 rt. hdg. at neck of No. 20 wall	Floor	78.7	21.3	59.1	Medium amount
U-929	53 rt. hdg. 75 ft. outby face	Gob & floor	61.2	38.8	53.5	Small amount

TABEL 2 (Contd.) - Analyses of Dust Samples Collected
May 15, 1945

Can No.	Location in mine	Kind of sample	Percent			Coked particles present
			Combustible, V.M. & F.C.	Incombustible, moisture & ash	Through 20-mesh	
K-902	53 rt. air course opposite 7th crosscut from face	Gob & floor	56.5	43.5	52.7	Small amount
K-935	53 rt. hdg. 655 ft. from main slope	Gob & floor	62.1	37.9	73.3	Medium amount
U-950	53 rt. air course 50 ft. inby door	Gob & floor	37.6	62.4	60.1	Trace

A rope haulage system is used on the main slope. Trips consisting of twelve to sixteen cars are hoisted and lowered by a 1-1/4-inch rope motivated by the main hoist on the surface. Main haulage underground is accomplished with five 13-ton trolley locomotives. Numerous trolley locomotives are used in secondary and gathering haulage, and nonpermissible room hoists are used to move cars at conveyor discharge points. Main haulageways are in intake air, but most secondary haulage is in return air. Roadbeds are composed of rock obtained from brushing, and excessive grades, dips, and curves are not encountered on the main or secondary haulageways.

Incandescent electric lights are not provided along haulageways except at some of the main-line switches, and where they are used, the wires are not properly supported by insulators,and clamps are not provided for connections to the source of power.

All underground employees use permissible electric cap lamps, and fire bosses and section bosses carry permissible flame safety lamps to test for gas.

Although this mine is classified gassy by the State of Alabama, Department of Industrial Relations, Division of Safety and Inspection, and gas is occasionally reported found by tests made with a flame safety lamp, smoking is permitted in the mine.

All electrical equipment used underground is nonpermissible type. Face electrical equipment, pumps, and locomotives operate on 250 volts direct current. Three underground substations convert the 2,300-volt alternating current to 250-volt direct current for mine use. The 2,300-volt transmission lines are taken into the mine through boreholes and the return airway slope to the underground substations. Oil and enclosed circuit-breaker-type switches are used to control the alternating current power circuits. Trolley frogs and cut-out switches with insulated handles are provided at branch roads. Haulage tracks are used for the return power circuit, but only one rail in cross-entry tracks is bonded. Nonpermissible telephones are used underground, and these are connected to the surface telephone system. They are maintained in good operating condition and are equipped with fuses. The signaling system on the main slope consists of two bare wires, well supported by insulators. Signals are given by push-button switches, and 22 volts are used in the system.

Face electrical equipment consists of 22 nonpermissible shortwall mining machines, 18 shaker and chain-type conveyors, and 22 hand-held nonpermissible electric drills. Two-conductor, rubber-covered cables are used with portable and

semiportable electrical equipment. Bare wire nips are used for making connections to the source of power; cables are not provided with suitable taps equipped with fuses; and the metal frames of mining machines, conveyors, and hand-held drills are not frame-grounded.

Temporary splices in cables are made with metal rings; the conductors are reinsulated with rubber tape and covered with P and B tape. Cables with numerous temporary splices are used an indefinite period of time before they are repaired by vulcanizing or replaced by new cables.

Gas-ignition hazards, from an electrical standpoint, are prevalent throughout this mine because of the arcing of open-type electrical equipment, which is used in face regions and return air currents.

None of the permanent electrical equipment, except one substation, is in rooms of fireproof construction. The electrical equipment is inspected regularly by assistant electricians, but a record of inspections is not kept.

Explosives are transported in an insulated car from the surface to underground operations boxes, and detonators are carried underground in closed leather bags by designated employees who walk. The underground storage boxes are placed in crosscuts or abandoned room necks at an adequate distance from working faces, but they are not at least 25 feet from haulage tracks and power wires. Detonators are placed in separate wooden boxes which are stored in a manner similar to the explosives.

Permissible explosives in 1-1/8- by 6-inch cartridges and No. 6 electric detonators are used for blasting. Rock dust is used for stemming. Shot holes about 1-3/4 inches in diameter are drilled at least 6 inches less than the depth of the cut by members of the conveyor crews, and the shots are fired simultaneously on shift with a nonpermissible shot-firing unit by the crew leaders who are designated locally as shot firers. The average quantity of explosives used in each hole is less than one pound. Blasting cables are duplex rubber covered, are 100 feet or more in length, and are wound up after each shot.

Twelve men were trained in mine rescue and recovery work by a Bureau of Mines representative in May 1945, and additional mine rescue training is conducted semiannually by a representative of the Bureau of Mines. One-hundred-percent first-aid training has been conducted at this mine for the past 14 years.

A central mine rescue station is under construction at the Praco plant of this company; ten 2-hour oxygen breathing apparatus have been purchased and are being repaired by the

manufacturer, and gas masks, self-rescuers, and an adequate supply of parts and tools will be provided when the station is put into service.

An adequate supply of water is available on the surface for fire-fighting use. Water mains, 4 inches in diameter, traverse the plant yard, and single-outlet 2-inch hydrants and hose are well spaced and marked. Numerous soda-acid and carbon tetrachloride fire-extinguishers are conveniently placed in the various surface buildings. A fire-fighting organization is maintained; fire drills are held at least twice each year; and, reportedly, the fire-fighting equipment is tested at least once each 90 days and a record of inspections is kept.

Water pipe lines and hose are not available in all the working entries in the mine. A supply of rock dust and fire extinguishers are provided near the entrance to each permanent electrical installation, but rock dust is not kept at the wooden doors. Portable electrical machines are not equipped with fire extinguishers, and the underground fire-fighting equipment provided is not marked plainly.

Previous Explosions in This or Nearby Mines & Their Probable Cause

According to records of the United States Bureau of Mines, three explosions have occurred in the Birmingham, Alabama district in mines which were operated in the Black Creek coal bed. These are listed as follows:

Date	Mine	Type	Cause	Number Killed
4/29/19	Majestic	Gas-Dust	Open light	22
6/10/26	Majestic	Gas	Open light	4
12/19/26	Dixiana	Gas	Open light	1

Mine Conditions Immediately Prior to Disaster

The weather was clear on the day of the explosion. A recording barometer at the official weather bureau in Birmingham, Alabama, about 28 miles from the mine indicated only a small change in atmospheric pressure from 29.22 inches of mercury at 6:00 a.m. May 13 to 29.14 inches of mercury at 4:00 p.m. May 14, 1945. Thus it is obvious that this drop in atmospheric pressure (0.08 inches of mercury) did not have any appreciable effect on the liberation of explosive gas into the mine workings.

The mine was in normal operation, and the fan was operated continuously on the day of the explosion. The report of the fire boss on May 14, 1945 showed the 53 right entries were clear of gas, but gas was reported found in the old workings in 52 right on the same date.

However, during the investigation the section boss in charge of this area testified that the gas in 52 right was removed. Testimony and evidence also revealed that some roof movement was in progress in Nos. 14 and 15 rooms in 53 right, and a large fall of roof in No. 15 room 53 right was noted during the investigation.

Story of Explosion and Recovery Operations

On the evening of the explosion, the day-shift crew had returned to the surface, and the second shift, consisting of 73 men, had entered the mine and were on their way to the active working sections. However, a mining-machine operator, who normally starts to work about one hour earlier than the regular second shift, had arrived at 44 left without a helper so he decided to get the mining machine, which was parked in 53 right air course just off the main-slope right air course, and tram it to 44 left turn-out and wait for the night boss to assign some one to help him. The mining-machine operator proceeded alone to where the mining machine was parked. A single wooden door, erected in the main-slope right air course between 53 right entry and air course, deflected the air current into 53 right air course. Since this door opened toward the parked machine, it was necessary for the mining-machine operator to block the door in the open position in order to tram the machine onto the main slope. The mining-machine operator stated that upon tramming the machine to 53 right entry to a point just outby the air course switch, he stopped the machine, realined the switch for 53 right entry, and closed the door to the air course. He further stated that the door to the entrance of 53 right entry was pushed open by the machine; however, after passing through this door, he stopped the machine to make certain that the door closed of its own accord before proceeding to 44 left turn-out where he awaited the arrival of the regular second-shift man-trip.

Upon the arrival of the man-trip, the night boss assigned an employee to work with the machine operator. The newly assigned employee did not have knee pads; consequently, he was instructed to go to where the machine had been parked to get a pair which had been left by the day-shift mining-machine operator. As the helper went to get the knee pads, he was followed by Alonzo Tubbs, newly assigned to the 53 right wall, and as the helper started to open the door between 53 right entry and air course, Tubbs asked the direction to 53 right wall, the helper told him to follow the two men (Cobb and Coleman) who were going up 53 right entry as they too worked on 53 right wall. The helper stated that both doors in 53 right were closed when he arrived, and that he closed the doors after passing through them. The explosion occurred about 5 minutes after the helper had returned to 44 left turn-out.

In the meantime, four night-shift men entered 46 left, three of whom went to No. 3 room 46 left and one (Suddeth) to the explosives-storage box in the main-slope left air course just inby 46 left door and about 30 feet from 46 left roadway. Four men, Nash, Cobb, Coleman, and Tubbs, entered 53 right. Nash, for reasons of his own, went into the main-slope right air course for a distance of about 75 feet outby 53 right entry. Cobb and Coleman proceeded toward the wall (No. 19 room) in 53 right followed closely by Tubbs. The explosion occurred about the time the three men, who were walking up 53 right entry, reached a point opposite 18 room 53 right. Nash was returning to 53 right entry and had almost reached the intersection of the main-slope right air course with the 53 right entry when the explosion occurred. He received third-degree burns on the face, neck, hands, and arms, but was able to proceed to the main-slope entry into fresh air unassisted. The three men who were at No. 3 room 46 left also escaped unassisted to the main-slope entry into fresh air, although one received a slight knee injury, probably from striking a mine car or debris. Suddeth, who was in the main-slope left air course near the explosives box, received third-degree burns on the back, neck, hands, and arms and had to be assisted to the main-slope entry.

The night foreman who was at the 50th yard when the blast occurred proceeded to the affected area, and with the assistance of a night section foreman and an electrician proceeded to the rescue and aid of the injured vicitms. Officials on the surface were notified immediately by telephone, and all men in the unaffected sections of the mine were ordered to return to the surface.

Upon the arrival of officials and additional employees from the surface, the rescue party proceeded in fresh air to the 53 right air course. By replacing the blown-out stopping and damaged doors with brattice cloth, the ventilation was restored partly to the 53 right section. The rescue party traveled with the air current up 53 right air course, thence to 53 right entry, thence to the main slope. The dead bodies of three workmen were found in 53 right entry near the entrance to No. 18 room. The bodies were recovered and removed from the affected area by 8:00 p.m. The recovery operations were conducted without the use of respiratory equipment; however, numerous tests were made for carbon monoxide and methane during recovery operations. During this time no carbon monoxide was detected and only a small amount of methane was reported found. After the bodies were recovered and removed from

the mine, all persons except those necessary to repair the damaged doors were withdrawn from the mine, and the investigation was postponed until the following day.

The participation of the Bureau of Mines personnel was limited to the investigation, because recovery operations had been completed by the local mine officials and employees soon after the Bureau of Mines representatives arrived at the mine.

Investigation of Cause of Explosion

An investigation of the explosion was made on May 15, 1945 by the following: H. J. Gentry, chief inspector, and J. H. Chapman, J. R. Wilson, and O. H. Youngblood, inspectors, State of Alabama, Department of Industrial Relations, Division of Safety and Inspection; W. C. Chase, general superintendent, B. E. Patterson, superintendent, Edwin Dorricott, mining engineer, and R. L. Hall, mine foreman, for the Alabama By-Products Corporation; James B. Benson and H. N. Smith, coal-mine inspectors, for the United States Bureau of Mines. Mr. Troy L. Back, Mines Safety Representative, Bureau of Mines, Washington, D. C., accompanied the investigating party.

During the questioning of witnesses, the mining-machine operator, who has a reputation for reliability, stated that he was positive that he closed the doors immediately after he passed through them. However, during subsequent questioning by Superintendent Patterson, the mining-machine operator is alleged to have made a statement somewhat as follows: "Suppose Mr. Patterson, but I am sure I closed the doors, but suppose I did leave the door between 53 right entry and air course open, would enough gas accumulate in 53 right in that length of time to cause an explosion? I am sure I closed the doors, but would like to know this for my own information." The machine helper, one of four persons who was probably in a position to know whether the doors were open or closed and the only one of the four to survive the explosion, stated that both doors were closed when he obtained the knee pads. Will Nash, the leader of the 53 right crew, stated that upon entering 53 right he immediately went into the main-slope right air course and did not notice whether the 53 right air course door was open or closed. The explosion occurred just as he returned to the 53 right entry. Nash received third-degree burns, from which he will recover.

Parts of the 53 right air course door, which was blown down and badly broken by the forces of the explosion, were moved during the rescue and recovery operations and the restoring of ventilation, thereby making it impossible to ascertain, during the investigation and subsequent interrogation of members of the rescue crew, in just which direction the door was blown.

The investigation further revealed that the explosion was initiated by the ignition of a body of methane which had accumulated in 53 right entry as the result of a short circuit in the ventilating current. The short circuit could have occurred by the opening of any one of the single doors on the split which ventilates the right side of the main slope. However, had any of the doors outby 53 right been left open, the air current would have been short-circuited from 52 right and all points on the split inby 52 right. In which event, methane would probably have accumulated in 52 right, and since the explosion did not extend to 52 right, it is reasonable to assume that the short circuit occurred inby 52 right. Had any of the doors inby 53 right been left open, the resulting short circuit would not have affected the ventilating current in any of the entries outby the short circuit, unless an accumulation of methane occurred inby the short circuit. In such a case, whenever the short circuit was removed and normal ventilation restored, the accumulation of methane would be coursed through the airways to 53 right thence through the remainder of the split and to the fan. It is believed that, had any such short circuit and accumulation of methane occurred, the methane would have been diluted below the lower explosive limit before reaching 53 right because of leakage of intake air through the stoppings and single doors.

After carefully considering the statements of the mining-machine operator and other information and evidence, it is believed that the accumulation of methane in 53 right entry occurred as the result of the door in the main-slope right air course between 53 right entry and air course being left open from the time the mining machine was removed from the parking stall until closed by the mining-machine helper about 30 minutes later.

As previously stated smoking is permitted in this gassy mine, and although smoking is said to be prohibited in face regions, numerous burned and unburned matches and empty cigarette packages were found in face regions, near the bodies of the victims, and in the pockets of clothing worn by two of the victims. Such evidence indicates that smoking is common practice in all parts of the mine. The deceased victims, while enroute to No. 19 room, apparently stopped for a few minutes at the entrance to No. 18 room to remove their jackets and leave their lunch pails. It is quite possible that one or two of the victims attempted to smoke while on the entry and before going to work under the low top in No. 19 room.

The force of the explosion broke three doors, two in 53 right and one in 46 left, and slightly damaged several

others in the affected area. Sixteen of 22 unplastered gob-wall stoppings in 53 right were blown out, and three small falls of roof occurred. Following the investigation, arrangements were made to replace the damaged stoppings and complete other necessary work which was estimated to require two days.

The forces of the explosion, as shown on the map in Appendix A, radiated inby and outby from a point just outby the bodies of the victims, and traversed the entire area in 53 right entry and air course, and extended across the main slope entry for about 100 feet into the 46 left entry and about 65 feet in No. 1 room, 46 left, where the forces began to dissipate as there was no evidence of disturbance inby this point.

The conditions of the parts of the mine where the explosion died out were dry, and although some rock dust had been applied, the analyses of dust samples collected show the combustible content was between 62.3 and 87.2 percent. Although the roof in some of the rooms in 53 right had fallen, it is the opinion of the investigators that the large cross-sectional area of the openings in the explosion area permitted dissipation of the forces.

Visible evidence of heat and flame was indicated by the deposition of coke on timbers in the entire area in 53 right entry and air course, in No. 1 room, 46 left, and on the ribs and gob in 46 left 100 feet from the main-slope entry. A large deposit of coke was noted on the motor of the blower fan at No. 20 room neck. Only small amounts of coke were visible on the ribs and timbers at the locations of the bodies and for 100 feet outby the bodies. Explosives were found scattered near a box at No. 16 room, 53 right, but there was no evidence that any had burned or exploded. A thorough examination of electrical equipment by the investigators did not reveal any evidence of short-circuit.

After a careful study of the area and the location of objects moved by the forces of the explosion, it is concluded that gas was ignited either by smoking or an electric arc from a nonpermissible blower motor which was in operation at the mouth of No. 20 room 53 right. The forces seemed to radiate from a point just outby the location of the bodies (No. 17 room) gathering momentum as coal dust was thrown into suspension and ignited. Evidence of travel in all directions from this point is indicated by the direction in which stoppings, doors, and other articles were moved. The forces extended to the worked-out rooms in 53 right and 46 left, and the doors at the entrances to 45 left, 47 left, and 52 right. The forces were not extremely violent, as shown by the fact that heavy objects were not moved, and no timbers were dislodged.

Important Features Concerning the Explosion

1. The explosion was local in character with little evidence of violence and was confined to the 53 right entry and air course, which are about 1,000 feet in length and about 100 feet in the 46 left entry which is almost directly opposite the 53 right entry.

2. An explosive mixture of methane and air accumulated in 53 right entry haulageway which was on return air.

3. Two wooden doors, one at the entrance to 53 right and one in the main-slope right air course, between 53 right entry and air course, were used to conduct the air current in 53 right, and the opening of either door would result in short-circuiting the air current from 53 right heading and air course.

4. Wooden doors erected singly at the entrance to the entries turned to the right off the main-slope entry outby the 53 right were in use, and, if any of these doors were left open, the air current would be short-circuited before reaching 53 right.

5. The Jefferson coal bed is about 40 feet above the coal bed being worked in this mine, and although the Jefferson coal bed is not being worked, it is known to be gassy.

6. Some roof movement was in progress in 53 right in room Nos. 14 and 15 before the explosion occurred.

7. A nonpermissible blower fan with tubing was in operation at the neck of No. 20 room, 53 right, when the explosion occurred.

8. Smoking and the carrying of matches and other flame-making devices were permitted in the mine.

9. Matches and cigarettes were found in the pockets of clothing worn by two of the three deceased victims.

10. A lack of a proper ventilation system existed in the mine.

11. Deposits of coke indicate that coal dust contributed to the extent and violence of the explosion.

After careful consideration of information gathered and testimony given during the investigation, it is the opinion of the Bureau of Mines investigators that an interruption to the ventilating current occurred when a door was left open, thereby short-circuiting the air

current from 53 right entry and air course, thus permitting gas to accumulate in 53 right entry, which was ignited either as a result of smoking by one or more of the victims or by an electric arc from the nonpermissible blower-fan motor which was in operation at No. 20 room neck.

The State mine inspectors and company officials who participated in the investigation concluded that:

1. An interruption in the ventilating current, caused by short-circuiting of the air current when a door was left open, was responsible for an accumulation of explosive gas emanating from the roof in No. 15 room 53 right.

2. The explosion was initiated either by an electric arc at the blower-fan motor which was in operation at No. 20 room neck or by striking a match to light a cigarette or other smokers' articles.

3. The most likely possibility is that the accumulation of gas was caused by the 53 right air course door being left open, because it had been previously propped open by a mining-machine operator.

Some of the lessons to be learned from the conditions as they relate to this explosion are:

1. Sudden and unusual liberations of explosive gas can occur in this coal mine; therefore, this mine should be operated so that ignition sources will not be present when such liberations occur.

2. The importance of continuous positive ventilation properly coursed to all underground workings, so as to properly dilute and remove explosive gas from the mine, was apparently overlooked in this so-called slightly gassy mine.

3. Wooden doors erected singly in coal mines permit interruptions to the ventilating current whenever a door is opened and are a constant source of danger. This danger can be eliminated by dividing the mine into sections or panels in such a manner that each section can be ventilated by a separate air split.

4. It is decidedly poor practice to permit one employee to operate coal-mining equipment when more than one man is required.

5. Smoking is a definite fire and gas-ignition hazard, especially in this gassy mine. Had smoking been prohibited and frequent and rigid searches of employees been made for matches, flame-making devices, and smokers' articles before they entered the mine, it is doubtful if the explosion would have occurred.

Recommendations

The following recommendations, many of which were made following an original and reinspections of the mine by Federal coal-mine inspectors previous to the explosion, are made in the belief that their adoption will materially lessen the probability of an explosion occurring in this mine in the future.

Explosives and Blasting

1. Permissible shot-firing units should be used as soon as they are obtainable. Until such time as permissible multiple shot-firing units can be obtained, extraordinary precautions should be taken to minimize the hazard of gas ignition by arcs during breakage of blasting wires or contacting of wires. These precautions ordinarily include good ventilation, careful testing for gas before blasting, and rock dusting near faces being shot.

Ventilation and Mine Gases

1. The ventilation system should be changed so that each active working section will be ventilated with a separate split of pure intake air.

2. Splitting of the air should be accomplished with overcasts substantially constructed of incombustible material.

3. Each working place should be ventilated by a perceptible air current sufficient in quantity to dilute and carry away any inflammable or harmful gases that may be present.

4. Accumulation of gas should be removed under the direct supervision of a foreman or other competent official, and no men should be permitted to work, or electrical equipment be operated, on the return of the split while gas is being removed.

5. The auxiliary or booster fans should be removed from the mine, and approved methods of regular and continuous coursing of the air to the working places should be used.

6. Room crosscuts, except those nearest the face, should be closed where necessary to obtain a perceptible movement of air at the face.

7. Stoppings between intake and return airways should be constructed substantially and be as airtight as possible.

8. Doors should not be used to control ventilation except where absolutely necessary. Where doors are necessary, they should be erected in pairs to form air locks, so that when one door is open the other having the same affect on the ventilating current can remain closed. The space between air-lock doors should be ventilated adequately to prevent an accumulation of gas. Where space does not permit the installation of air-lock doors, tight check curtains, well maintained, should be hung in connection with single doors.

9. A rigid preshift examination of the mine for methane should be made following completion of the day shift and before the second or night shift is permitted to enter the mine.

10. Air measurements should be made by the mine foreman, his assistants, or other certified officials at least once each week at or near the mouth of the main intake and return of the mine and also in or immediately adjacent to the last crosscut on each air split. Tests should be made with a permissible flame safety lamp or other methane indicator in such splits and in the main return. A record of these measurements and tests should be kept in a book furnished for this purpose.

11. At least 6,000 cubic feet of air a minute should be coursed through the last open crosscut on each pair of working entries or the maximum inby point of a split.

Mine Dusts and Rock Dusting

1. Provisions should be made to apply water on the cutter bars of mining machines or to spray water on the dust as it emerges from the kerf. All working places should be thoroughly wetted in the face regions before and after blasting. Water should be applied on the coal pile as it is being loaded onto conveyors and on the coal at conveyor discharge points. The tops of loaded cars should be thoroughly wetted to avoid distributing coal dust in haulageways. The face region back to the last application of rock dust should be kept wet.

2. The mine should be kept thoroughly rock-dusted in all dry, open, unsealed places to within at least 40 feet of the faces.

3. Where rock dust is applied, it should be distributed upon the top, floor, and sides of all open, unsealed places and maintained in such quantity that the incombustible content will not be less than 65 percent, plus 1 percent additional rock dust for each 0.10 percent of methane present.

4. Sampling should be done with sufficient frequency to determine whether additional rock dust is required.

Electrical Equipment, Accessories, and Hazards

1. Trolley wire, trolley locomotives, or other types of open electrical equipment should not be used in return air.

2. Electrical equipment used in face regions should be of permissible type.

3. In all haulageways, both rails should be well bonded at every joint and cross-bonded at least every 200 feet.

4. Underground electrical stations for permanent installations of pumps, compressors, motor generators, and other electrical equipment should be located in well-ventilated, fireproof rooms equipped with fire doors arranged to close automatically in the event of fire.

5. Telephones should be of a permissible type.

6. Cable splices should be made in a workmanlike manner, mechanically strong, and electrically continuous. When cables become damaged, they should be replaced with stand-by cables, and those defective should be sent to the shop for permanent splicing and, if practicable, vulcanizing.

7. Trailing cables for portable or semiportable electrical equipment should be provided with taps equipped with fuses, or be connected properly to permissible junction or distribution boxes.

8. Where incandescent electric lights are used, the wires of the power circuit should be installed properly on insulators, and the connection to the source of power should be made with clamps that give a firm connection.

Fire Protection Underground

1. Suitable fire extinguishers should be installed on all locomotives, cutting machines, and mechanical loading equipment.

2. A supply of rock dust for fire-fighting use should be kept at all doors.

Miscellaneous

1. Smoking should not be permitted in this mine, and employees should be thoroughly searched at frequent intervals to assure that smoking material, matches, or other flame-making devices are not being carried into the mine.

Acknowledgment

The writers wish to acknowledge the courtesies extended by the officials of the Alabama By-Products Corporation during the investigation. The cooperation of the members of the State of Alabama, Department of Industrial Relations, Division of Safety and Inspection also is gratefully acknowledged.

Respectfully submitted,

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Appendix A