Report

March 24, 1922

Sopris #2 Mine

REPORT

ON

EXPLOSION AT SOPRIS #2 MINE, SOPRIS, COLORADO,

MARCH 24, 1922. BY D. HARRINGTON.

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I N D E X

R E P O R T

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GENERAL STATEMENT

At about 3:40 P.M. March 24, 1922, there occurred an explosion in the Sopris #2 Mine of the Colorado Fuel and Iron Company, near Trinidad, Colorado, and 17 lives were lost. The day shift of about 125 miners and 50 day men were supposed to come off at 3:30 P.M., and all but eight of the day shift had reached the surface, some of them only a fraction of a minute before the accident, one or two men being slightly injured near the manway portal, and four bodies were found near the air shaft only a few hundred feet from the mouth of the mine. By using the system of checking men into and out of the mine, it was soon established that 18 men were missing, one of these appearing later on as he had failed to go into the mine after having taken his check.

The main fan off-set from the top of the shaft about 50 feet and provided with explosion doors immediately over the shaft, continued to run during and after the explosion, though the explosion doors were blown off and the coke-breeze concrete walls of the fan approach were partially wrecked. The damage to the fan approach was quickly repaired by boards and brattice, and within 40 minutes of the occurrence of the explosion the fan was again pulling air from the mine.

General manager Stout, who happened to be in the vicinity, division superintendent Thomas, mine superintendent Deldossa, company mine inspector McAlister, and others, together with state mine inspector Dalrymple, who was at Aguilar about 20 miles away when the disaster happened, and deputy state inspectors Lawrie and Machin, as well as numerous others aided in the recovery work which was prosecuted with much rapidity, utilizing the air currents by bratticing ahead,much of this being necessary as practically all the stoppings, overcasts and undercasts in the mine near the Main slopes were blown out. Although Mr. George Parker, in charge of mine rescue equipment and rescue work for the Colorado Fuel & Iron Company, was present with the C. F. & I. Co. Rescue Car and numerous men trained in apparatus work, and all assisted in the work, the oxygen apparatus were not used. The entire 17 bodies were recovered within 30 hours of the time of the explosion.

LOCATION

Sopris is one of the oldest coal mining camps in Colorado, and is located about seven miles southwest of Trinidad on the C. & S. and C. & W. railroads. It is also reached by the electric interurban from Trinidad. The Piedmont Mine is about one mile distant, and the Cokedale Mine is in a nearby canon about two miles to the northwest. The Sopris Mine is about 215 miles south of Denver.

OWNERSHIP, OFFICIALS AND TONNAGE.

The Mine is owned and operated by the Colorado Fuel and Iron Company, of which Mr. J. F. Welborn, Denver, is president; Mr. E. H. Weitzel, Pueblo, general manager; Mr. D. A. Stout, Pueblo, manager of fuel department; Mr. J. P. Thomas, Trinidad, district superintendent; and Mr. John Deldossa, Sopris, mine superintendent. Mr. Deldossa has charge of both No. 1 and No. 2 mines at Sopris, the combined tonnage of the two properties in 1920 being 358,239, of which No. 2 mine produced about two-thirds, Sopris being one of the largest producing camps of the Colorado Fuel & Iron Company.

GEOLOGY

The coal in Sopris #2 mine is in the Laramie formation in lower portion of the known coal measures of the Trinidad region, and not very far above the Trinidad sandstone. It is about 150 feet below the seam worked in #1 mine, and is said to be in essentially the same stratigraphic position as the Starkville Mine. The coal is bituminous and of good coking quality; is bright black, hard and rather brittle, and has fairly well defined "faces" which are about 70° inclination to the roof and floor. The immediate roof is a consolidated fine-grained shale, practically a sandstone, and resembles gray lime. There is a small gaseous seam of coal a few feet above the regular seam, yet the rock roof remains in place remarkably well and notwithstanding the blowing out of considerable numbers of timbers and props by the explosion,

there were comparatively few serious rock falls. The floor is of consolidated shale, somewhat hard, practically a sandstone, and about three feet below the coal seam worked in #2 mine is another small seam which also gives off considerable gas. Numerous rolls and faults and some dykes are found, faulting being responsible for driving of rock tunnels and interruption of systematic plan of laying out workings, as well as the source of large quantities of explosive gas. Coal thickness varies from three to seven feet. The dip of the coal seam varies in connection with faults, but is in general very light (probably less than 2 per cent) and the mine workings are comparatively level.

QUALITY OF COAL.

The coal has numerous bands of impurities and is so dirty as to require crushing and washing before coking. Formerly it was coked in beehive ovens at Sopris but at present is sent to Pueblo and coked in by-product ovens at that point. Below is analysis of a sample of coal from the face of the 3rd East entry by J. J. Forbes in May, 1919.

Air-dry loss.. 1.4	Coal (Air dried)	Coal (As recd.)	Coal (Moisture free)	Coal (Moisture & ash free)
(Proximate analysis)				
Moisture	.70	2.10		
Volatile matter	28.70	28.30	28.91	35.30
Fixed carbon	52.62	51.87	52.98	64.70
Ash	17.98	17.73	18.11	
	100.00	100.00	100.00	100.00
(Ultimate analysis)				
Hydrogen	4.66	4.75	4.62	5.64
Carbon	70.32	69.33	70.82	86.49
Nitrogen	1.27	1.25	1.28	1.56
Oxygen	5.03	6.21	4.42	5.39
Sulphur	.74	.73	.75	.92
Ash	17.98	17.73	18.11	
	100.00	100.00	100.00	100.00
Calorific value determined,				
Calories	6962	6864	7012	8563
British thermal units	12532	12355	12622	15413
Calorific value calculated from ultimate analysis,				
Calories		6986		
British thermal units		12575		

Date, June 9, 1919.

(Signed) W.A.Selvig,
Asst. Chemist.

It will be noted that practically 20 per cent of the coal as mined is inert matter (moisture plus ash), nevertheless it has the comparatively high heating value of 12356 B.T.U.

While some advancing entry faces are moist or wet, comparatively few roof drippers are found, and holes drilled for blasting are usually dry; moreover, the roadways are in general free of water, though occasionally pools are found near faulted regions and water kept down by pumping. Rooms, in general, are dry.

LAY-OUT OF MINE WORKINGS.

The mine is operated on the room and pillar system, the main slope from the surface being about 15 per cent for a distance of about 700 feet to the coal, then on a light grade about 1-1/2 to 2 per cent to the dip. There is a substantial pillar between main slope and its air course with a heavy protecting pillar between rooms and the main slope and main air course. Level entries, with about 50-foot pillars between, are turned off the main slope to the right and to the left at intervals of about 500 to 700 feet and from these levels rooms are turned, room length being about 250 feet up to 400 feet. Entries are 8 to 12 feet wide except where coal is low and floor brushed and "gob" stored on the rib, in which case the original entry width is 16 to 18 feet, and after "gobbing" is completed about 8 to 10 feet. Room width is about 22 to 24 feet with room pillars about the same.

In the region of the 8th West faulting has intervened and rooms 14 and 15 off the 7th West were utilized as entries to attack the 8th West region driving entries both east and west; the region of the 8th West to the east or "left", encountered faults necessitating driving rooms off rooms to extract the coal, and on the other hand, the 8th West entries going west encountered low coal necessitating the use of "gob" entries and also room brushing.

In the driving of the main slope (which actually has a very light grade, except the first 700 feet from the mine portal), the faults encountered in the 8th West were also encountered and a rock tunnel was driven for a distance of a few hundred feet, the lower end of the rock tunnel being about 500 feet from the location of the slope faces at the time of the explosion.

In order to increase the total quantity of air for the mine, it was decided somewhat over a year ago to drive a third or left slope, and this third slope was being driven at several places in the lower part of the mine with intent ultimately to extend it back to a point opposite the air shaft, giving a three-entry system for the slopes practically thruout.

OPERATING METHODS.

Mining and Shooting:

The coal in the first north region was undermined by pick miners, while the rest of the mine was undercut by electrically driven short-wall machines, most of the undercutting being done on the night shift, the machine men going on shift at 2:30 P.M. while the day shift went off at 3:30 P.M. The three slopes were driven on the day shift by four men who had a contract cutting and loading using electrically driven short-wall machines to do the cutting, this machine being the only one operated during the full day shift at the time of the explosion.

All holes are drilled by miners (about two holes to an entry face, and three or four to a room face), using breast auger, the miner supplying the one to two, or three sticks of Mohobel #4 permissible explosive per hole, and also providing the adobe dummies. The miner carries the explosive into the mine in a fiber container holding about eight sticks. Also where brushing is done (generally in the floor to a width of about seven feet in entries and five feet in rooms), Monobel #4 is used (about one to three sticks in the one hole drilled). All shots are fired by shotfirers who enter the mine at 11:00 P.M. (after all others are out of the mine) and shoot by electric battery. No shots are supposed to be fired during either day or afternoon shafts, or between them, and no exception to this rule was made as far as can be ascertained.

Haulage:

Gathering in rooms is done by mules, and on main levels there are 500 volt D.C. trolley locomotives. About 700 feet from mouth of the main slope is the main parting from which a surface hoist pulls the coal by rope up the approximately 700 feet of 15 to 20 per cent grade.m Heavy steel rails are laid on haulage roads where mechanical hauling is done, and lighter steel rails are laid on mule hauls in entries and rooms. Haulage tracks are generally dirt ballasted. Some of the cars are of steel and some of wood with iron bands; all have end doors, hence have leakage of slack along roads and have capacity of about 3000 pounds of coal.

Electrical Equipment:

The mine is equipped with both 440 volt A.C. and 500 volt D.C. current, power wires going down the air shaft and the return air course to the 1st North and to the 7th West, thence into 7th and 8th West; one line also goes down the main west slope air course to the face. The 500 volt D.C. is used on electric locomotives in the 1st North, Main slope from 7th West to main parting 700 feet from mouth of slope, and in the 7th West also for one pump. nThe 440 volt A.C. is used for electric cutting machines and three small pumps in the 7th and 8th West, and in the Main slopes. The mine was not thought to be sufficiently gaseous to require power wires kept on intakes, but after the explosion wires are to be removed from returns.

There were four electric cutting machines manufactured by the Sullivan Machinery Company, all being in use about three years and described as CE-7, 440 volt A.C., 42 amperes, 60 cycles, 30 H.P., and said to be flame-proof, originally carrying Bureau of Mines permissibility plate, the latter not being found on the machines in the mine after the explosion. The machine in the 8th West air course was #5969, the one in the Main slope #5970, and the one in room 3 off room 8, 8th left, #5968, the machine in the 7th West not being seen because of water. The power wires serving the machines were well insulated triplex cables, each of the three parts being about #6 copper wire or strand. At points available to places in which the machines were to be used, the three wires of the insulated cables were separated for a few feet and bared for a few inches to provide for connection with the machine cables to give power to the machines. Ordinary flexible machine cables were used on the machine reel. The connectors on the machine cable to be attached to the mine power wires were home-made and of #6 copper wire, bent to form prongs; contacts were made by pushing this prong over the bared places on the power lines.

Ventilation:

The main fan is steam-driven, belt-connected, substantially housed with fan location offset about 50 feet from top of air shaft, and fan well protected by suitable explosion doors which were blown out by the explosion and the fan left uninjured. Ordinarily, the fan pulled 70,000 to 80,000 cubic feet of air per minute from the mine, with water gage of 2.6 to 3.1 inches and on the day after the explosion the water gage was 5.0 inches.

Air samples taken by J. J. Forbes on May 19, 1919, were as follows:

	3rd East Entry Return from East Side of Mine.	4th West Return from Entire Mine.
Quantity (Cu.Ft.per min.)	7680	74,400
Wet Bulb Temperature	61	61
Dry Bulb "	63	62
Relative Humidity	89½	94½
CO_2	0.13	0.09
O_2	20.57	20.56
CO	0.00	0.00
CH_4	0.56	0.44
N_2	78.74	78.91

From the above it will be noted that the main return had 0.44 per cent methane for 74,400 cubic feet of air per minute, this agreeing fairly closely to the 500,000 cubic feet of methane per 24 hours said to be removed from the mine before the explosion by the 75,000 cubic feet of air being handled.

Underground workers used only permissible electric cap lamps of the Wico make and were prohibited from carrying matches, smoking material, etc., though from evidence at the coroner's inquest search for the latter was not made very systematically. Flame safety lamps were used only by officials, such as shotfirers, fire bosses, foremen, etc., and these lamps were of magnetically locked type as required by an order of the state coal mine inspector, applying to all coal mines of Colorado. Below is data as to air quantities splits, etc., as given at the coroner's inquest from report by deputy state coal mine inspector Lawrie of his last inspection of Sopris #2 mine, January 30, 31 and February 1, 1922.

Location	No. Men	Area (sq.ft.)	Velocity (Lineal ft. per min.)	Quantity (Cu.Ft. per min.)
Main slope intake	--	68	800	54,400
Manway intake	--	--	--	21,000
Main return	--	48	1600	76,800
7th West entry	12	42	200	8,400
8th West entry	40	45	60	2,700
5th East entry	21	40	140	5,600
4th East entry	31	50	160	8,000
3rd East entry	11	40	100	4,000
4th North entry	25	40	300	12,000
Main slope faces	4	60	140	8,400

(Fan Revolutions 200 - Water gage 3 inches)

Overcasts were constructed of brick or concrete, or both, and main entry stoppings generally of coke breeze-concrete of about 8-inch thickness. Doors were of wood, generally with door jamb of 8 by 8 or 10 by 10 timber, set in concrete frame. Line brattices were used to some extent to carry air from last crosscut to the working face; and room crosscuts driven approximately 60 feet apart.

Methane issued from roof, coal and floor and in region of the main slope could be heard bubbling through the water at points several hundred feet from the working face. Holes drilled in the coal in face of the West main slope before the explosion forced out methane at sufficient velocity on April 4, 1922, to turn an anemometer, and on that date while making the mine examination, one of the state inspectors secured a 3/8-inch gas cap on a Koehler safety lamp at a point about 100 feet from the face of the West main slope in a separate split of 8,400 cubic feet of air per minute, supposed to be ventilating only the three advancing slope faces, though the air may have been contaminated by leakage as permanent stoppings had not been placed after the explosion. Drill hole in the face of the 8th West air course drilled before the explosion, gave off methane at considerable velocity on April 4, 1922, and as ventilation had not been completely restored, a heavy gas cap was readily obtained in this entry face. At the coroner's inquest it was brought out that room 10 off the 8th West (left) entry was one of the most gaseous places in the mine and, in general, it was brought out that gas accumulations could be

expected in almost any part of the mine upon interruption of ventilation, and probably dangerous accumulation at face of main slope upon interruption of ventilation for as short a period as quarter of an hour.

Safety Practices:

This mine, known to be gaseous and to have an easily ignited and explosive dust, had adopted numerous safeguards against possible explosion. Since 1911, it has been equipped with a system of humidifying intake air, and it is said that rarely, if ever, did air of the mine workings have relative humidity less than 90 per cent. (This humidification system is described in Appendix #1). Roadways were sprinkled by water car and in places by hose. No open lights of any kind were used, all underground workers having Wico electric cap lamps and only the mine officials used flame safety lamps, and these were magnetic locked.

A well equipped and housed fan was provided and the mine divided into splits with substantial concrete or brick overcasts, stoppings, etc. While electricity was used underground, trolley wires and pumps were generally located on intake air courses, though main power wires were on the return. The electric cutting machines were of flame-proof type and all coal was undercut by machine or by pick; shooting was done by battery by shotfirers after all but the shotfirers were out of the mine, and nothing but permissible explosive (Monobel #4) was used, and the amount of explosive per hole held within the permissible limit and holes tamped with clay.

In addition to having a foreman and assistant foreman for the day shift, there was a night boss and there were three fire bosses and three shotfirers, all of whom were expected to take part in detecting and removing dangerous conditions, such as accumulations of gas and dust. There was also a company mine inspector who made periodical examinations with especial respect to dust and ventilating conditions, and at intervals samples of air together with air quantity were taken at each ventilation split and at the fan, and the air analyzed as to methane content by the company's chemist. A system was in operation checking all employees into and out of the mine, and all persons were supposed to be searched before going into the mine for matches, smoking tobacco, etc.

In addition, the company had numerous men trained in the use of oxygen breathing apparatus, had a readily available mine rescue car thoroughly equipped with oxygen apparatus, stretchers, etc., and various kinds of emergency equipment, such as telephones, telephone wire, power wire, etc.; and while the oxygen apparatus was not used, much of the emergency equipment on the car proved of material aid in effecting the prompt removal of the bodies after the disaster.

THE MINE INVESTIGATION AFTER THE EXPLOSION

General Statement:

As before stated, the fan was uninjured by the explosion and it required but about 40 minutes to repair the fan approach to a sufficient extent to start pulling fumes out of the mine. Before the time the fan approach was repaired there was a reversal of air, the air shaft becoming downcast instead of upcast and forcing explosive gases out of the manway and Main slope. By utilizing the ordinary air currents, together with emergency equipment such as telephones, telephone wire, brattice cloth, etc., which were quickly available, many of the bodies were recovered within three hours of the explosion though at least six overcasts and more than fifteen doors and sixty main concrete stoppings had been blown out.

Main Slope and Main Return Air Course:

While there was sufficient force at the mouth of the Main slope to partly dislodge about 30 feet of the roof of the concrete approach, still there was little destruction along the slopes until the 4th West was reached, though some props were dislodged, and just outbye the 4th West two doors on the return air course deflecting the return air to the air shaft were blown outbye and two bodies found near these doors; two bodies having previously been found in the manway, one about 260 feet and the other 320 feet from the manway portal.

The first blown-out overcast was at the 4th West about 1700 feet from slope mouth, and the first-blown-out stopping at the 5th West or about 2200 feet from slope mouth; between this point and the slope face, a distance of 2500 feet, twenty-nine concrete stoppings each about eight inches thick were blown out and in every instance blown westerly or towards the return air course. From the 5th West to the face of the slope but two stoppings were left standing, one at the 5th West back, and one in the 5th crosscut from the face of the slope. In addition to the destruction of stoppings, the overcasts along the slopes at the 4th West, 2nd East, 6th West, 7th West, and 4th East were wrecked and doors in slant crosscuts near the face of the slopes destroyed.

While exposed posts and other supports for the trolley wire, as well as posts for other purposes on the main slope were swept out practically completely from the main parting through to the face of the slope, there were remarkably few serious rock falls on the main slope; exposed posts in the main return were also swept out and there were some bad falls, especially outbye the 7th West, these falls partly choking the air course and compelling some of the return air to go through the rooms to the north of the 7th West.

Until the 7th West was reached, all forces pointed towards mouth of the slopes, but from the 7th West to the face of the slopes there was ample evidence of forces in opposite directions, with the main force going towards slope mouth. A solid triangular-shaped concrete pier on the southwest corner of the intersection of the 7th West

West and Main slope was moved slightly but definitely towards the west, indicating a powerful force going into the 7th West from the Main slope, and probably also headed out towards the slope mouth. On the parting on the Main slope near the 5th East, 12 cars were pretty badly smashed, and there was ample evidence of two distinct forces one (probably the most powerful as well as the first) going out towards mouth of slope forced the cars north and west, and tore off doors, ends, etc., and otherwise wrecked the cars; the other went inbye and carried the loosened doors, ends, etc., towards the face of the slope but apparently was not sufficiently powerful to carry the cars themselves. This second force threw much debris on the outbye end of cars, and it seems almost certain that on this parting the last direction of material violence was towards slope face.

The main slope track was raised by a force coming from the Left or East slope at the point where the 6th crosscut from the face between Main slope and East slope enters the Main slope. In the 4th crosscut from slope face between slope and West or Right air course was a concrete stopping not blown out, the only one below the 6th West. A small pump in the crosscut, located practically at the line of the rib of the Main slope, was apparently unharmed and starter, wires, pipe, etc., were - even after the explosion - probably in condition to operate; a brattice curtain had lodged against the pump, showing a force going towards the face of the slope, and a pile of debris on outbye side of pump indicated a practically spent force also towards face of slope. At a point about 50 feet inbye the pump and in the mouth of a slant crosscut to the left

or east slope was a car with end bulged in, showing a force towards face of slope, this conclusion being helped by a pile of debris on outbye end of car and by the fact that the car was driven southeast.

Immediately inbye the above mentioned slant crosscut to the left and just outbye a slant crosscut to the right (the fourth from the face), and on the Main slope, was found the mining machine thought to be responsible for the explosion. The machine had evidently just finished cutting at the face of the right Main slope and had been run on its own power up the Main slope to the slant above mentioned, then through the slant to the Main slope, and had just gotten onto the Main slope straight track and was being taken down the Main slope towards the face to the next crosscut, in which there was a short track used to store the machine when not in use. The flexible machine feed cable was "strung out" through the slant crosscut to the Right slope and the "nips", or connectors, were apparently connected to the mine power wires on the East rib of the Right slope at a point a few feet inbye the intersection of the slant with the Right slope. After the explosion the power wires, as well as machine cable end and door from the slant, were found blown against the West rib of the Right slope by a force which came from the Main slope. It is not definitely known whether the controller on the machine motor was in a starting position.

One machine man was found near the machine, and one at a point about 20 feet outbye the machine; both suffered from violence and one

had a broken leg; it is said that both were burned badly around the face, though not about hands or lower part of body. The machine was off the track slightly and some bits and a sheet-iron cover were found slightly inbye the machine, indicating a force towards slope face; and debris on outbye end of machine and truck corroborate this indication as to direction of force.

Between point where the machine was found and the face of the Main slope were some rock falls, and there was conflicting evidence as to forces, though it appears that the last force went through the crosscuts near slope face towards the right or West slope. At the face of the Main slope, the coal had been shot down and floor brushing also shot, the shotfirer testifying at coroner's inquest that these shots had been fired the night before the explosion. The crosscut near face of Main slope towards left slope was caved fairly badly. The face of the right or West slope had been undercut and a hole drilled on the right rib, from which gas was issuing very freely. There was a "step off" of about two feet at a point about 10 feet from the face, this constituting the floor to be brushed, and in this was also a hole drilled about opposite the center of the track. A man (partner with the machine men in driving the three slopes on a contract) who apparently had been drilling at the face, was found dead in the pool of water about 15 feet from the face, his drill being in the hole at the face.

Gas issued freely from the faces of all three slopes, but particularly from the Right slope, not only from the face but also

through the water pools on the floor for several hundred feet from the face, and on the day of the mine examination (about 10 days after the explosion) a 3/8-inch cap was obtained on safety lamp in current of 8,400 cubic feet per minute, at a point in the Right slope about 200 feet from the face; the impression being that this air had passed only the three slope faces and had accumulated its methane from them, but it was stated afterwards that this air split probably had also obtained some methane from the 5th East region. Nevertheless, the slope faces were in a region of faults and dykes and certainly "made" a large quantity of methane.

In taking the coal-cutting machine from the right slope through the slant crosscut to the Main slope, it was necessary to go through a door in the slant which, when open, would short-circuit air away from the face of the Main slope and from the right or West slope; and it was generally admitted that if the door were left open 15 to 20 minutes, or more, there would be a dangerous accumulation of gas at the two slope faces and in the right or return slope inbye the slant. Moreover, in going on the switch from the slant to the Main slope the machine would also pass through a curtain across the Main slope, which deflected air to the left slope, and if this curtain were open at the same time as the door in the slant (which might readily be the case, as the doors in this mine usually had hooks by which they may be held open indefinitely), there would be short-circuiting of air from all three slope faces.

At any rate it is supposed that there was a gas accumulation in the Right slope, especially near the roof, and that when the machine was going onto the Main slope track, the machine cable was in tension to a slight extent and the home-made "nips", or connectors, attached to the power wires in the Right slope inbye the slant were pulled off with attendant arcing and ignition of surrounding gas, as the "nips" were connected at points within 18 inches of the roof.

The region of the Main slope near the machine, as well as inbye from the slant in both Main and Right slopes shows intense heat, both in charring of bark on timbers, etc., and in coking. However, about five feet from the face of the Right slope are some timbers which certainly were not charred, and at the face itself there is no evidence of heat, yet ten feet from the face, posts, caps, etc., are charred and there are spots of coke around entire circumference of posts, this coking being particularly true as to the region around the intersection of Right slope with last crosscut to the Main slope.

The Right slope is wet for a distance of several hundred feet from the face, serving as a sump for the face region. On the other hand, the Main slope is dry and probably was dusty for several hundred feet from the face, hence assuming that the original ignition took place as above described, the flame from gas would be unable to get additional fuel from dust in the right slope, but could get an abundance from the Main slope and from the left slope, hence it proceeded out via these two slopes forcing stoppings towards the right slope.

7th and 8th West:

The 8th West was not connected directly to the slopes and was on a separate air split off the 7th West, with overcast at Room 15 to the south of the 7th West, coal being hauled out of the 8th West through Room 14, the latter also acting, together with Room 6, as intake for the 8th West.

The 7th West near the Main slope showed distinct evidence of a violent force going inbye from Main slope, this being manifest in the moving of the heavy triangular concrete pier at intersection of 7th West and Main slope in a direction towards 7th West; moreover, the ribs showed scouring in the 7th West near the slope, indicating a heavy force going inbye and a later, almost equally heavy force, going outbye, the scouring showing inbye force being partly dust covered in places. Some timber piled in the mouth of partly caved rooms 1 and 2, south of the 7th West, were forced into the rooms, indicating a force going into the 7th West; and some sheave wheels piled before the explosion in the first crosscut to the north inbye the 7th West overcast were found both inbye and outbye their original place.

The first twelve concrete stoppings in the crosscuts between the 7th West entries were all blown violently north or towards slope mouth, there being apparently no reversal of forces here, or, at any rate, all forces acting here had strong component towards the north or towards mouth of slope. There was comparatively little coking in the 7th entries, though on a cap in the concrete of the overcast in the 7th West, just inbye the slope, was copious coking on the inbye or west side of the cap.

While there was some evidence of force going into rooms 6 to 14 inclusive, south of the 7th West, apparently the last force was one out of those rooms, forcing material northward or towards mouth of slope. Similarly in Room 14, which acted as a haulage entry from the 8th West, the last force was northward, but the crosscuts between #13 and #14 apparently emptied themselves westward into Room 14. At the intersection of Room 14 with the 8th West, there was ample evidence of forces going westwards, though a trip of cars on the parting in Room 14 was not much harmed and few, if any, timbers on this parting were blown down.

In the part of the 8th West, left or east of Room 14, there was much evidence of forces going in conflicting directions, and there was also much evidence of intense heat in heavy coking and charring, yet there was not very great violence probably due to openness of the workings of the region, which was cut by faults, dykes, etc., causing much irregularity in working and resulting in poor ventilation control. In Room 3 off Room 8 was a mining machine off the truck and with "nose" within a few inches of the right rib ready to start cutting, though it had not yet done any cutting. Whether the controller was "on" or "off" is uncertain, but it was said to be in the "off" position when found. There was no violence at the machine and two props about 8 or 10 feet from the face on opposite sides of the room, and about opposite the controller, showed no signs of charring, coking, etc., though some props about five feet farther out showed coking and charring on all sides from roof to

floor; and there was evidence of charring of exposed ends of insulation fabric on the machine cable on the reel about 25 feet from the room face. The flexible machine cable was carefully strung out and "nips", or connectors, were apparently attached to the mine power wires opposite Room 10. The "nips" were home-made and when tried on the power wire after the explosion remained attached only a short time. The region showed intense charring and coking from roof to floor, and while there were some falls, blown-down timber, etc., in general there was little disturbance, even the power lines remaining in place. The machine men, Romero and son, were found about 100 feet from the machine in Room 8 apparently trying to escape, as they were together and fell head forward; they were burned little, if at all, yet where they were found the entire region shows intense heat. It is probable they were at the machine near the face of Room 3 off Room 8 when the explosion occurred, and were not burned or killed as there wasn't much violence, and at the face of Room 3 there wasn't much heat. However, they probably tried to get out and were overcome before they had gone 100 feet. Many people think this point the origin of the explosion due to intense heat indications and lack of violence, and to the fact that the machine cable "nips" were apparently attached to the power wires and the men working on the machine at the time, yet apparently not killed outright. Moreover, it was brought out that the power for the 7th and 8th West regions had been turned off about 3:00 P.M. while mules were going out, and again turned on about 3:25 P.M., and the explosion occurred about 3:40 P.M. or fifteen minutes

later. It is also pointed out that Room 10 opposite which the "nips", or connectors, were attached to the power wires, was the most gaseous room in this region; and the air supply for the region (testified to by Deputy Coal Mine Inspector Lawrie as 2700 cubic feet per minute) was very small, and it was brought out that if any one of three doors (each provided with hook to hold it open) were held open, this entire region would be deprived of air circulation.

At mouth of Room 5, north of the 8th West and east of Room 14, was a fall carrying the three alternating current power wires together, and the theory was advanced that part of this fall might have occurred before the explosion and in falling simultaneously stir a cloud of dust, and by breaking wire insulation and bringing wires together cause an arc which would ignite the dust above mentioned. However, the circuit breaker at the surface was not thrown, and upon removing the fall it was found that there was no evidence of blistering of wires by arcing, though it was also found that the fall was at a place where the power wires were bared for the "nips". It was found that coking was intense in this locality, yet it took place on both sides of caps, and there was the usual conflict of direction of forces. The region near the machine in Room 3 off Room 8 indicates that both gas and dust entered materially into the making of heat and flame.

In the region of the intersection of Rooms 14 and 15 (south of 7th West) with the 8th West entries were again seen evidences of forces going in opposite directions, but apparently the last force had its direction towards mouth of slope. A door in the extension of Room 14 just south of the 8th West air course, showed force going outwards, or north, and also one going inwards, or south. A door in the 8th West air course just west of the extension of Room 15 was blown inbye or westerly, leaving the strap iron hinges to show they had been blown inbye though the door ordinarily opened outbye, and then the hinges had been later on forced outbye; here the maximum force was undoubtedly inbye, yet there were numerous indications in this region that the latest force had been in outbye. A door in a slant crosscut from 8th West air course to 8th West main, just inbye above discussed door, was blown inbye or north-westerly. These three doors, located close together, were all destroyed, yet the door jambs were scarcely scarred. The last force evidently went into the face of the 8th West (going west) then through the last crosscut and out the air course.

About 20 feet from face of the 8th West air course, just inbye the last crosscut, was a coal-cutting machine of the same type as those previously discussed. This machine was on its truck and evidently had just been pulled into the entry on its own power, as the flexible machine cable was unreeled and strung along the 8th West air course and the loose end with the "nips", or connectors, (home-made) found near the bare spot on the power wires about 200 feet from the machine.

The socket end of the machine cable at the machine was disconnected from the machine when found, and it was thought that possibly the machine men (Covi and Adamo) had pulled out the cable socket at the machine, and with "nips" attached to power wire at opposite end of cable and controller in running position, this resulting in a flash which would ignite gas which might be present, as the nearby coal face was distinctly gaseous. However, it is said that the controller was in the "off" position when the machine was first seen after the explosion, and there is no evidence that the "nips" were actually attached, even though they were found in a place indicating that they had either been attached or soon would be; (it was also stated that there was a down-grade towards face and the machine could be "spragged in" without use of power, if the machine men desired to do this).

The machine men were found in the entry about 100 feet from the machine, both badly burned and battered; apparently at least one had been at the machine when the explosion occurred, as an electric lamp with belt and cap was found near the machine. The entire region of the machine and for at least 200 feet outbye, was thoroughly charred, and heavy deposits of coke were found on props, on the machine cable and reel, etc., and a spike keg near the machine had heavy coking around its entire surface. The machine tools were still on the truck, showing no attempt had been made to unload; some Monobel #4 permissible explosive was found on a ledge on the rib near the machine with its paper wrapping thoroughly scorched (permissible explosive was found in several places with paper scorched, but no evidence of any explosion from it).

On the 7th West entry inbye Rooms 14 and 15, the violence died out comparatively quickly. The floor was blown out of the overcast over the 7th West at Room 15, and the stoppings in Rooms 16, 17, 18 and 19 were forced out into the 7th West. Some cars on a parting on the 7th West inbye Room 19 were but slightly affected, the force going inbye. A door between the 7th West entries just inbye Room 30 was forced northerly.

At a point on the 7th West about 100 feet inbye Room 30, the bodies of the Valencich brothers were found lying face downwards in a pool of water, each with an undergarment wrapped around his head. They had been working on a machine in a room near the face of the 7th West, and apparently had travelled over 800 feet after the explosion and were overcome by the afterdamp. It is said they had cut about two-thirds the distance across the face of a room and apparently heard the explosion, disconnected the "nips", and pulled out the socket connecting the machine cable to the machine and started out. The 7th west face region was inaccessible to examination because of water.

The 7th West entry was distinctly wet inbye the parting and this undoubtedly prevented the explosion from travelling to the face, as it had done in the regions where water was absent.

4th and 5th East:

These regions were not accessible for examination due to lack of ventilation, but those who entered them immediately after the explosion state that there were conflicting evidences but the main forces in the 4th East had a direction into the 4th East and southerly to the 5th East, thence out of the 5th East to the Main slope, seemingly indicating that the last and strongest force came from the 7th West into the 4th East. In the 2nd and 3rd East the forces were all outbye, corroborating the situation as to the Main slope that from the 7th West all forces were going outbye.

5th and 6th West:

There was comparatively little violence in these parts of the mine, seemingly indicating that the room for expansion in the rooms northerly off the 7th West caused the pressure to die away.

1st East and 1st North:

This region had no electricity and the coal was pick-mined. The explosion came into the 1st East entry from the Main slope, destroying three doors in the 1st East entries and two concrete stoppings and a door in the 1st north. At a point in the 1st North at the intersection with a slant from the 1st East, four bodies were found. Two of the men had apparently been killed by violence, while the other two apparently had walked out from the face region several hundred feet after the explosion, (as their footprints were found in the dust which settled after the explosion), and were overcome by poisonous gases at the point where the

first two men were lying dead. These bodies were all found within three hours after the explosion, and as the explosion died out at a point about 400 feet inside of the location of the bodies, leaving large quantities of fresh air in the regions of the 3rd and 4th East and 3rd and 4th West off the 1st North, the two men who walked out would have been saved had they remained in their working places. A door in a crosscut between the 1st North entries opposite the 1st East off the 1st North was blown easterly into the 1st East off 1st North, but a nearby door between 1st and 2nd East in one of the 1st North entries was unharmed. The explosion died out at about this point, probably because of the damp (wet) condition of the region of the 1st North outbye the 1st and 2nd East off 1st North.

Probable Origin:

There were at least four places at which it was presumed the explosion started: (1) Near the face of the slopes with electrical arc from machine wires as ignition agency, and gas accumulation as the original material to ignite and explode; (2) In neighborhood of Room 3 off Room 8 8th West (left) entry, also with electric sparking from machine wires as ignition agency and gas accumulation; (3) Region of 8th West (left) at Room 5 (north) with rock fall forcing machine power wires together, possibly destroying insulation with attendant arc to ignite dust also thrown into the air by the fall; (4) Region of 8th West air course where there was a machine where there was gas present, and where there could be sparking from machine wires.

Each hypothesis could be supported by valid arguments based on observed data, and each has its weak point as the evidences were very conflicting. The theory of rock fall causing arcing of machine power wires with dust ignition was proven untenable by removal of the rock fall, and failure to find any evidence of such arcing; moreover, arcing would probably have thrown the circuit-breaker at the surface, and this was not done, and there was no consistent evidence of radiation of forces from this point though the point was in a region of prolific coking.

State Coal Mine Inspector Dalrymple and assistant coal mine inspectors Lawrie, Machin and James fixed the origin at the point of fastening the "nips", or connectors to the mine power wires in the right

slope. It is entirely probable that this conclusion is correct, though there is also much reason to place the responsibility on the region of Room 3 off 8th West (left), with less reason to place it in the region of face of 8th West air course.

There is much evidence of a heavy force going out the Main slope, forcing stoppings westerly and dividing at the 7th West, part going out towards the surface, and the other part going into the 7th and 8th West, again igniting gas and dust in the 8th West and returning, part going north through the 6th West and possibly the slopes towards the surface, part going out the 7th West and inbye on the slope and across the slope expanding into the 4th East, and going south, or inbye, into the 5th East, forcing stoppings south and dying in the 5th East and region of slope faces. It seems certain that there were at least two forces on the Main slope between 7th West and the face, one outbye, one inbye, and almost equally certain that the last force was inbye. This, together with fact that the slope faces were giving off much gas; that the mining machine had just come through the slant door which, when open, would short-circuit air from the most gaseous place (the region of face of right slope); that the machine was apparently moving under electrical power with "nips", or connectors, fastened to bare spots on mine power wire in the right slope inbye the slant, hence in region where gas would quickly collect; and the fact that the "nips" were of home-made variety, easily pulled away from wires and sparking when so pulled away; all indicate that the slope region was the point of origin.

Waiving the fact that there were opposite directional forces on the Main slope inbye the 7th West, and also waiving the fact that the slope faces were the most gaseous parts of the mine, and probably the point at which dangerous accumulations of gas could most easily and quickly be made, there would be many arguments in favor of placing the blame on the region of machine wires near Room 3 off Room 8, 8th West (left). There was the same possibility of arcing of wires by pulling off of "nips"; the "nips" were fastened at mouth of Room 10, said to be the most gaseous room in this region, and open doors near Room 15 would deprive the region of circulation; there was much evidence of gas ignition in charring of timber, power wire insulation, etc., especially near roof; there was intense coking in the region; forces radiated away from this place north and west, yet there was not very great destruction in the region itself; and the machine men were not hurt appreciably by violence/a condition which might be expected at ignition point. However, placing ignition point here fails to leave any good explanation of the fact that there was an outbye, as well as an inbye force on the Main slope below the 7th West, with inbye force subsequent to the one outbye; moreover, if one concedes a sufficient accumulation of gas to be ignited at mouth of Room 10 off 8th West (left), the accumulation would likely have been enormous, as it would have had to partly fill several long rooms and, if so, the destruction in this region would have been much greater than it was.

As to possibility #4, (region of 8th West air course), while the

region was gaseous and circulation could readily be interrupted by neglect to keep any one of several doors closed, and there was present the same danger of arcing from "nips" as at the two other places, yet the most powerful forces came towards rather than away from this region; the controller was "off" when machine was found, and the cable plug at the machine was disconnected and the machine still on the truck, hence probably not using power. Moreover, the machine men were found about 100 feet from the machine pretty badly burned and injured from violence, the latter of which would not be likely to be the case if the men were at or near the point of ignition, unless a second explosion or force occurred.

As heretofore indicated, it is entirely probable that the origin was in the region of face of the slopes, and that additional ignition took place in the dusty, gaseous, comparatively poorly ventilated region of the 8th West; and that the practically spent forces came back (with added momentum) out of the 8th West and went partly up and partly down the slope. That there was no evidence on the surface of a second or secondary explosion was probably due to the fact that the second one was much less violent than the first, and in going out towards slope mouth died quickly in the wide rooms of the region between 7th West and 6th West.

SUMMARY AND CONCLUSIONS

While, in general, the mine has adopted numerous precautions to prevent occurrence of a disaster, the fact that one did occur makes it evident that something was lacking.

The evidence brought out at the coroner's inquest as well as that obtained from examination of the mine after the explosion, seem to remove from possible causes for the explosion such factors as shotfiring, mine fires, use of matches, or any other form of open flame; and even the flame safety lamp, which has been responsible for ignition in several of Colorado's disasters, seems absolved from responsibility in this instance.

Ventilation:

While definite attempt was made to provide adequate ventilation, it is apparent from deputy inspector Lawrie's report, quoted in part on page 12, that some of the splits did not provide sufficient air for a gaseous mine, particularly that of the 8th West region; in fact, it would appear advisable that in a mine as gaseous as Sopris #2 at least 15,000 cubic feet of air should be provided for each split and measures taken to reduce leakage to a minimum, as is apparently done at the Morley mine of the Colorado Fuel & Iron Company. With a total of about 75,000 cubic feet of air per minute being handled by the fan, it would appear that more than 45,000 cubic feet could be accounted for in summing up the separate splits, and this discrepancy of about 30,000 cubic feet between split summation and fan delivery indicates excessive leakage.

It was brought out that failure to close any one of several doors for a comparatively short time might allow of dangerous accumulations of gas by short-circuiting, and in regions in which this might occur, there were in use electric locomotives, electric pumps and electric coal cutting machines, any one of which with its accessories might under certain conditions give off sufficient spark to ignite gas; hence, it would be advisable to take such precautions as may be available to make this short-circuiting difficult, if not improbable.

The practice of having hooks by which ventilation doors are held open is dangerous and, in addition, it appears to violate the spirit of section 126 of the Colorado Coal Mining Law reading as follows: "The doors used in assisting or directing the ventilation of each mine shall be so hung and adjusted that they will close of their own weights".

Dust:

While the mine was provided with a humidifying system by which relative humidity in the working places was held to 85 per cent, or over, and while it is stated sprinkling of haulage roadways was done several times per week, it is apparent from the abundant coking found after the explosion that dust entered very definitely into the explosion.

In May, 1919, Mr. J. J. Forbes, mining engineer of the U. S. Bureau of Mines, made a short study of the humidification system of the Sopris #2 mine (see Appendix #1), and simultaneously took some samples of road dust, rib and roof dust, and sample of coal at a working face (see Appendix #2). He found that while the intake air had relative

humidity in excess of 80 per cent after it had travelled about 1,000 feet from the portal of the mine, and had relative humidity well over 90 per cent in general, yet a sample of rib dust from a point 300 feet from the Main slope on the 3rd East entry had but 6.61 per cent moisture; and its moisture plus ash content was but 30.59 leaving 69.41 per cent combustible matter which would be easily ignited and would readily propagate an explosion, especially since 82.4 per cent of the material went through a 20-mesh sieve, and of this material thru 20-mesh, 53 per cent went thru 200-mesh. A sample of rib and roof dust from a point on the main slope below the 3rd East entry gave 9.03 per cent moisture and 22.94 per cent ash, or 31.97 per cent inert matter, leaving 68.03 per cent combustible, also easily ignited and able to propagate an explosion as 80.7 per cent went thru 20-meah sieve and over one-half of this 20-mesh material went thru 200-mesh.

A sample of road dust taken on the 3rd East entry between rooms 26 and 27 gave 5.78 per cent moisture and 45.16 per cent ash, leaving about 50 per cent combustible matter which would readily propagate an explosion started, for instance, by a pocket of gas. And a road dust sample from the Main slope 3rd East parting gave 3.22 per cent moisture and 27.23 per cent ash, a total of 30.45 per cent ash plus moisture, leaving 69.55 combustible which would readily propagate an explosion as the dust had 21.7 per cent material thru 20-mesh. From the above it will be seen that road, rib and roof dust taken only on the haulage roads, hence with more moisture and less pure coal dust than in the rooms, all gave sufficient combustible to readily propagate

an explosion, indicating that insufficient precautions had been taken to render the dust inert. This does not mean that the humidification system has not been performing a very useful function, as it is undoubtedly true that without the humidification system in operation, the percentage of combustible would have been much higher than the above samples indicate.

In the 1918 Report of the State Coal Mine Inspector of Colorado there was published (pages 91-99) an explosion hazard report of a gaseous mine of the Trinidad coking coal region, having a coal of essentially the character, analysis, etc. of the Sopris #2 mine. A two-ton sample of this coal was sent to the Experimental Mine at Pittsburgh, Pa., and the coal tried out by engineers of the U. S. Bureau of Mines as to its explosibility, samples of road and rib dust having previously been collected in the mine by Bureau of Mines engineers, the analyses of the road and rib dusts being similar to those of the Sopris #2 mine above discussed. The tests at the Experimental Mine indicated that ignition could be obtained when there was 39.2 per cent incombustible matter, but that with 47.8 per cent incombustible no ignition would take place, in both cases there being no explosive gas present. However, it was found that if 2 per cent of gas were present, the dust of the coal of this mine of the Trinidad District would require about 65 per cent incombustible matter to prevent ignition. It was also found that this coal dust would propagate an explosion if it contained 56.3 per cent incombustible even if no gas were present, and it was concluded that if 2 per cent gas were in the surrounding air it would require

80 per cent, or more incombustible matter to prevent propagation of an explosion. This latter statement is of greatest importance, indicating the absolute necessity in mines having this dangerous dust of taking drastic measures to render dust inert near working faces which give off much methane.

Electrical Equipment:

With the elimination of matches, smoking material, open lights, flame safety lamps and mine fires as possible source of igniting agency, there was left practically nothing but electricity on which to place responsibility for furnishing the flame which initiated the disaster. Trolley electric locomotives were on intake air courses and did not operate sufficiently near working faces to be in gaseous region. While electric pumps were fairly close to faces, yet no evidence was found by which the starting point could be fixed as probably due to pump motors or other electrical equipment at pumps. By almost universal consent it was felt that the electrical cutting machines furnished the igniting agency, yet no evidence was found at the machines, or from men who had been associated with operating the machines that any sparking had ever been noticed in the machines themselves, or immediately around them except upon encountering hard material ("sulphur balls", rolls, etc.) by machine bits when cutting. Inasmuch as none of the machines was actually cutting, sparking from bits is eliminated.

This apparently absolves the machines themselves from furnishing the flame, and inspection of the region around the three machines available for inspection after the explosion indicates that ignition probably did not take place immediately at the machine. However, it was readily established that sparking or arcing does take place at the point of connecting the machine cable to the mine power wires when attaching the "nips" or connectors to the power wires, or more probably when detaching them. This sparking is probably the more intense with a home-made "nip", or connector, than with the manufactured connector made probably with specific reference to reduction of sparking or arcing. The probability of responsibility of this method of ignition is enhanced by the fact that the machine cables were strung out and "nips", or connectors, were near bare spots or connecting points of mine power wires in the case of each of three mining machines on which men were working at the time of the explosion; moreover, at each point there might readily be an accumulation of gas by ventilation interruption, and the point of attaching "nips" or connectors to power wires is comparatively close to roof where the gas would probably accumulate first.

Another possible source of flame to start the disaster would be arcing caused by roof fall, causing wires to be brought in contact and wire insulation to be broken. There was a fall at mouth of room 5, 8th West (left) entry with power wires brought together, and it was supposed that this fall might almost simultaneously throw fine dust into the air and cause arcing of exposed power wires with ignition of dust.

Saving of Life:

There was an impression more or less current, that by greater promptness in the rescue work some lives might have been saved. This is an absurd and unjust conclusion, as the rescue work was certainly done in a quick and efficient manner. It is true that two men in the 7th West entry and two in the 1st North had travelled several hundred feet after the explosion and were killed by the after-damp. However, had these men remained at or near their working places and bratticed themselves off, they would undoubtedly have been saved. The two men in the 1st North above referred to were found less than three hours after the explosion, and while their bodies were warm, they were absolutely dead, as artificial respiration was tried on them without avail.

RECOMMENDATIONS.

Ventilation:

(a) The practice of having hooks for doors to hold doors open, even temporarily, should be abolished. Where region is as gaseous as in the face of the 8th West or at face of Main slopes, it would be advisable to have air lock in slants used as haulageways or manways, the air lock to consist of two doors, one at or near each end of slant, or one door near one end of slant, and a heavy curtain near the other end.

(b) Using Deputy Mine Inspector Lawrie's measurements of air splits, it is evident that at least some sections of the mine were not adequately ventilated, notably the 8th West region with 2700 cubic feet per minute in the last crosscut between the entries. This region not only had 40 men working in it at the time of measuring, but was in broken, faulted territory and giving off much gas and likely at any time to encounter faults or dykes with heavy outpour of gas. It is suggested that this mine should have at least 15,000 cubic feet of air per split, and that each split be kept separate from other splits until the air is discharged into the main return.

(c) If the mine is to continue in operation for many years, it would be advisable to provide for additional air. Temporarily this can be done by enlarging the air shaft (which it is understood is to be done), by removing as far as possible posts, falls, sharp turns, abrupt changes

in direction, etc., from both intake and return air courses, and by elimination of leakage by construction of tight doors with air locks, etc.; and, if necessary, by construction of two stoppings in crosscuts between main return and main slope from 4th West to 7th West where pressure is greatest. It is suggested that where possible to do so, abandoned workings be sealed and air used in ventilating them be diverted to working places; in fact, an effort should be made to extract coal as quickly as possible from each region and seal the region as soon as possible after such extraction. It is understood that the 3rd or East slope will be opened to a point opposite the air shaft, giving a three-entry system; and if the fan is to be retained in its present location it is desirable that this 3rd entry be completed as soon as possible.

However, it would appear to be advisable to sink a shaft ahead of present slopes, say for instance, where the slopes go under Francisco Gulch, depth of shaft being 300 to 400 feet, and while it would probably go through old workings of the #1 mine, the few difficulties encountered could be overcome. A smooth-lined concrete circular cross-section shaft 8 to 10 feet in diameter would readily allow of pulling of 150,000 cubic feet of air from the mine by fan located near the shaft collar and utilizing both of present slopes as intakes; and if this were done it would be unnecessary to drive the proposed East slope outbye the 7th West. The main disadvantage of the shaft scheme would be that it would probably demand an electrically driven fan, which is by no means so satisfactory for a gaseous mine as one driven by steam.

Dust:

(a) In addition to the present humidification system, which is an extremely commendable one, it is suggested that permanent water sprays be placed just inbye the radiators, and also at intervals along the intakes to aid the humidification system and simultaneously aid in wetting the dust along floor and ribs.

(b) An inspection of the results of dust sampling in this mine in 1919 by Mr. Forbes, given in Appendix #2 of this report, together with the data as to ignition and propagation properties of dust from mines around Trinidad as given in the 1918 Report of the State Coal Mine Inspector of Colorado, indicate that humidification alone will not properly prepare the dust against either ignition or propagation of an explosion. And on inspection of Appendix #3, tabulation from State Coal Mine Inspector's Reports as to fatalities in coal mine explosions and fires in Colorado since 1908, shows that out of 490 such fatalities for the coal mines of the State (in itself a very bad record for 13 years, with fewer than 15,000 employed), at least 394 were from mines around Trinidad, and at least an additional 31 from Aguilar and Walsenburg; and in nearly every case dust played a prominent part. It seems evident that coal mining men around Trinidad do not fully appreciate the dangers from coal dust or, at any rate, insufficient precautions have been taken and are being taken against dangers from dust; hence, it is strongly recommended that the Utah system of piping all places (including rooms) with water be installed, and at least one person (probably more than one) be kept constantly sprinkling

ribs, as well as floor, with hose, and also that all rooms be supplied with hose, and room men, as well as machine men, be required to keep region of working faces thoroughly moistened; and it would seem that if coal-cutting machines are continued in use, it would be very advisable to provide water pipe and hose for use in the event of cutting material, which gives off sparks in connection with bit contact. It is a certainty that spasmodic sprinkling of a few places by water car is absolutely inefficient and wholly unable to curb the very definite dangers from dust in the Trinidad region.

(c) The practice of having chemist from time to time sample and analyze air from the mine and from various splits in the mine, is a very commendable one; and, in addition, it is suggested that samples of rib and roof dust, road dust from haulage entries, as well as dust from region of room and entry faces be sampled and analyzed, to show whether there is sufficient inert material (rock dust or ash plus moisture) to prevent ignition and propagation of an explosion. It may also be advisable to have an explosion hazard test of coal from this mine or some other humidified mine of this region made by the U. S. Bureau of Mines, to determine definitely the limits of ignition and propagation of the dust, taking into consideration also the gaseous content of the air.

(d) If it is not feasible to adopt method of intensive daily sprinkling by hose, involving wetting of ribs and roof as well as floor, it would appear advisable to consider rock dusting in mines of the Trinidad region.

Electricity:

(a) It was proven that the home-made "nips", or connectors, of machine cable to power wire are dangerous as to sparking or arcing, and they should not be used. And if the manufacturers' connectors with strong spring also spark or arc when being detached, they too should not be used in a gaseous mine.

(b) If not already available, manufacturers should perfect a type of "nip", or connector, which will not spark or arc, or, if it does, the spark or arc should not be exposed to surrounding air; and this applies also to the plug connecting the machine end of the flexible cable to the cable reel or to the machine. It is foolish to state that if the controller is turned off, there need be no sparking, as men running machines in coal mines forget such cautions; moreover, sometimes there are disconnections for which the runner is not responsible.

(c) Where there is possible danger of gas accumulations and yet electric cutting machines, electric pumps, or other electrical equipment must be used, the point of attaching "nips", or of placing switch, etc., which may spark, should be as far as possible from the roof rather than the usual practice of placing them near the roof.

(d) It would appear that there should be some safer method of preparing power wires for giving power to mining machines than the one of baring the insulation at points where the "nips", or connectors are to be attached.

(e) One of the most dangerous parts in connection with electrical cutting machines is the flexible machine cable, as it quickly loses insulating material, and if run over by machine may cause a very decided arc. Hence, only the most rugged and safest type of cable should be used in a gaseous mine.

(f) It would appear advisable not to operate electric cutting machines during any part of the main working shift in a mine, as gaseous as Sopris #2. In fact, it is a grave question as to whether electric cutting machines should be used at all in a mine as gaseous as some places in Sopris #2. This is especially true as the type of machine runners may not always have the highest order of electrical intelligence. However, pick mining, which generally means that the coal is partly undercut, partly shot off the solid, is but little less dangerous than using electrical cutting machines in gas; and it is probable that if surrounded with all available precautions, the machine mining is to be preferred to pick mining from viewpoint of safety as well as of efficiency.

being used for testing should be hung on a substantial support such as a spike near the top of a prop that has been firmly set against the roof.

(c) Comparatively few fire bosses, mine foremen or mine superintendents are able to interpret height of gas cap on a safety lamp in terms of per cent of gas in the air, yet this is vital. Each person using a flame safety lamp should be given a chart showing that a quarter inch cap on a round wick Wolf lamp, using gasoline as fuel, is equivalent to about 1-1/2 per cent methane in the air; 3/8 inch cap to 2 per cent; 1/2 inch cap to 2-1/2 per cent; 5/8 inch cap to 3 per cent; 1-1/4 inch cap to 4 per cent, etc. These gas caps are correct only when using a round wick Wolf lamp that has its testing flame reduced to 1/10 inch and in which there is no yellow flame. It should also be impressed that while it requires about 5-1/2 per cent of methane to cause an explosion, on the other hand, a much less percentage is dangerous. It would also be advisable to furnish users of flame safety lamp with a scale to be placed back of lamp, by which height of cap may be gauged or the scale may be made to read directly to per cent methane instead of length or height of cap.

GENERAL RECOMMENDATIONS.

(a) This mine and all other mines sufficiently gaseous to require use of closed lights should take rigid measures to exclude matches, smoking materials or anything which might cause an open light to be used underground. Any one found taking any of the above materials underground should be prosecuted vigorously, and in every instance given the heaviest possible penalty, especially when trying to hide such materials from detection. At time of strike every possible precaution should be taken.

(b) Just before taking a coal cutting machine into a working place, or before connecting the power cable that operates the machine, a competent fireboss or other official such as a shot firer or mine foreman, experienced in testing for gas, should test the place for the presence of gas and if gas is found the place should be properly ventilated; and at intervals while a machine is being used, an experienced official should visit the working place and test for the presence of gas.

This is not a duty that should be placed upon the average machine runner unless he has been specially trained in the use of a modern safety lamp and fully appreciates the danger of accumulations of gas.

If flame safety lamps are placed in the hands of machine runners, one of the conditions of their employment should be that they be required to demonstrate to the official fire boss that they can detect gas with the lamp, and some penalty should be assured against them if the fire boss should find them at any time operating the machine when the safety lamp gives a showing of the presence of gas. Flame safety lamps in charge of machine runners should never be set on the floor of the mine, but when not

(d) Care should be taken in choosing officials whose duties demand use of flame safety lamp, that these men be of mentality sufficient to understand the dangers and limitations of the lamp, and also able to interpret quantities from cap and to know when those quantities become dangerous.

(e) After having attended many coroner's inquests in several states after mine disasters, the writer is impressed with the fact that extremely few coal mine officials, including fire bosses, shot firers, foremen or superintendents, are familiar with provisions of State Mining Law, or even of properties of or dangers from gas, dust, electricity, etc. These officials seem to feel that having received a certificate entitling them to act, it is not necessary to know or remember details like the above, or that it is either necessary or desirable to keep informed as to progress in safety in mining. It would appear that all persons acting as such mine officials should be required by the State to take re-examination at intervals of not more than five years, reviewing standard safety data,

as well as taking into consideration new ideas as to safety in mining. It is earnestly suggested to this company operating the Sopris and other mines in the Trinidad region, that all officials be given a night school training to impress upon them essential facts as to State laws, properties of and dangers from gases, dusts, electrical equipment, etc., as well as other up-to-date ventilation and safety practices.

(f) There appeared to be some uncertainty upon whom responsibility for ventilation conditions devolved. This is an extremely dangerous situation, and any uncertainty should be cleared without delay and full responsibility be placed upon some one person.

(g) It would appear advisable to establish a system of panel working in this mine and other mines of the Trinidad region, keeping each panel separate from other panels and with separate ventilation split, instead of connecting all workings, hence almost ensuring that any untoward occurrence in one part of the mine will almost certainly reach nearly all parts of the mine. With panel workings and a system of rock dust barriers at the few places where the panel workings intersect the general workings, there would be practical certainty of restricting within the panel any explosion or fire which might occur; and if ventilation split of about 15,000 cubic feet per minute were kept in tact, and sprinkling by hose maintained efficiently, and other available precautions as to shotfiring, electricity, etc., taken the Trinidad district mines should be kept free of explosions.

ACKNOWLEDGMENTS.

The promptness of recovery of the bodies after this disaster reflects much credit upon the Colorado Fuel and Iron Company and its organization, not only in the good judgment and engineering skill used in placing of fan by which the latter was uninjured by the explosion, but also in the fact that the officials apparently were on hand promptly and had men, material, apparatus, etc., available for all needs; and there was no stint in the use of both men and material to facilitate the recovery work and to do the work safely. The operating company had ample mine rescue equipment and personnel capable of using it, and though the services of the U. S. Bureau of Mines Car 2 were offered the Denver offices of the company, there was no need for outside help.

The writer is indebted to Manager Stout, Mine Inspector McAllister Division Engineer Hair, Superintendent Deldossa, and other Colorado Fuel & Iron Company officials for numerous courtesies and information given. He also wishes to acknowledge the many courtesies and hearty cooperation of State Inspector Dalrymple and Assistant Inspectors Lawrie, Machin and James in connection with the mine examinations to determine the cause of the disaster.

APPROVED:

Chief of Coal Mining
Investigations.

APPENDIX #1.

Humidification System - Sopris #2 Mine.

By J. J. Forbes.

May, 1919.

"Humidity readings collected along the main intake of the Sopris Mine, Colorado Fuel & Iron Co., Sopris, Colo., at intervals of 100 to 300'.

"100' inby from the portal of the Sopris Mine there are steam radiators 150' in length, arranged in two tiers, 9 pipes in each tier, diameter of pipes 1". About 25' inby from end of steam radiators exhaust steam from radiators is injected into the air current. The foregoing curve shows the increase in humidity, commencing 100' below injection of steam into intake. On the day these readings were collected the barometer on the outside registered 23" Hg, dry bulb 63 deg. wet bulb 56 deg. R.H. 64.3. Total quantity of air entering intake was about 53,000 cu. ft. On the same day a reading was taken in the main return from the Sopris Mine, giving a dry bulb of 63 deg. wet bulb 62½ deg. R.H. 98½%., velocity 1350, area 42, quantity of air returning 55,700. It is extremely interesting to note that reading taken opposite radiator was 82 deg. dry, 60 deg. wet, R.H. 26%, indicating a decrease in humidity between the outside of 38.3%. At a distance of 3800' down the main slope the air current was saturated at a temperature of 61 deg. From this point inby the humidities began to drop slightly, as shown by the curve.

"The following table shows all the readings, namely, wet and dry and humidities, taken along the main slope at intervals of 100 to 300'.

"At place along main slope where steam is injected into intake, will be considered as 0 station and all other readings will be based from this point.

Dry	Wet	Station	R.H.%
63	56	Outside Portal	64.3
82	60	Opposite radiators & about 100' from portal.	26
85	67	100' below live steam jets.	42.8
85	70	200	50
83	70	300	55
80	69	400	60
79	69	500	64.6
77	68	600	68.3
76.5	67.5	700	69.3
72	65	800	72
71	65	900	76
70	65	1000	77½
70	65½	1100	80
69	65	1200	81
69	65	1300	81
68	64½	1400	82.5
66	63	1500	85
65½	62½	1600	85
65	62½	1700	87.5
64½	62½	1800	87.5
64	62	1900	89.5
64	62	2000	89.5
63¾	62	2100	91.5
63	61½	2400	92.5
62½	61	2700	93
62	61	3000	94.5
61½	61	3300	97.5
61½	61	3600	97.5
61	61	3900	100
61	60½	4200, outside of parting	97.5
62	61	4700, inside parting.	95.0

Note: At the time of the explosion in March, 1922, there were 23 one-inch steam pipes, each one inch diameter and 75 feet long at the mouth of the Main slope (intake), and 27 one-inch diameter pipes, each 36 feet long at the mouth of the manway (intake), the total quantity of intake air being normally about 75,000 cubic feet per minute.

APPENDIX #2.

Road, Rib and Roof Dust Sample Analyses, Sopris #2 Mine,

Sampled May 13 and 14, 1919 by J. J. Forbes.

Analysis by W. A. Selvig, Asst. Chemist.

	MATERIAL SAMPLED & PLACE OF SAMPLING				
	Rib dust. 3rd E. entry 300' in by Main slope	Rib & roof. Main slope below 3rd E. entry.	Road. 3rd E. entry between Rooms 26&27	Road. 3rd E. parting on Main slope.	Road. 4th W. Entry.
Date sampled 5/14/19 & 5/13/19	5/14	5/14	5/13	5/13	5/14
Total weight of sample (grams)	505.2	246.3	-----	-----	1277.7
Per cent on 20 mesh	17.6	19.3	-----	-----	53.3
Per cent thru 20 mesh	82.4	80.7	-----	-----	46.7
% of 20 mesh material thru 200 mesh	53.0	59.4	18.6	21.7	14.8
Moisture (as Received)	6.61	9.03	5.78	3.22	5.03
Volatile matter (as received)	28.51	29.77	19.83	27.31	25.66
Fixed carbon (as received)	40.90	38.26	29.23	42.24	41.18
Ash (as received)	23.98	22.94	45.16	27.23	28.13
Moisture plus Ash	30.59	31.97	50.94	30.45	33.16

Note: For analysis of sample of coal taken at face of 3rd East entry on May 13, 1919, by J. J. Forbes, see page 14 of the Sopris #2 mine explosion report, of which the above tabulation is an appendix.

Note: It is noted that all of the above samples of dusts from Sopris #2 mine, taken when operating normally, gave ash plus moisture (inert material) much less than the amount of inert material necessary to prevent propagation of an explosion. (For amount of incombustible to prevent propagation of an explosion see Explosion Hazard Report, pages 91 to 99, of 1918 Report of Colorado State Mine Inspector. Also see Appendix #4 for abstracts from that report). For mine air humidity at time of taking the above dust samples see Appendix #1.

APPENDIX #3.

Table of Coal Mine Fires and Explosions in Colorado,

1909 to Date,

Compiled from Reports of State Coal Mine Inspector.

Mine	Company	Date	Number Fatalities	Remarks, Cause, Etc.
Greenville	Cedar Hill Coal & Coke Co.	Dec.14 1909	2	Shotfirers (Gas & Dust)
Morley	C.F.& I. Co.	11/10/09	1	Shotfirers (Gas)
Toller	Cedar Hill Coal & Coke Co.	7/6/09	9	Naked Light and Gas
Primero	C.F.& I.Co.	Feb.1910	75	Probably safety lamp & gas & dust. 1 man recovered alive.
Starkville	C.F.& I.Co.	10/8/10	56	Electric arc and dust.
Delagua	Victor-American Fuel Co.	11/8/10	79	Mine fire & subsequent explosion. 4 lives saved.
Leyden	Leyden Coal Co.	12/14/10	10	Mine fire caused probably by electricity.
Fremont	C.F. & I. Co.	11/22/10	2	Fire in mule stable.
Cokedale	Carbon Coal & Coke Co.	2/9/11	17	Blown out shot and gas.
Hastings	Victor-American Fuel Co.	6/18/12	12	Safety lamp and gas.
Piedmont	Rocky Mountain Fuel Co.	8/29/12	2	Supt. and foreman with naked light and gas.
South Canon	South Canon Coal Co.	10/1/12	2	Shotfirers. Gas and dust.
Simpson	Rocky Mountain Fuel Company, Coryell Mine	11/8/12	1	Gas from mine fire ignited by open lamp.
Vulcan	Leasing Co.	12/16/13	37	Probably shot & dust. May have been open light & gas with dust
Mutual	Mutual Coal Co.	5/2/15	2	Gas & carbide lamp.
Hastings	Victor-American Fuel	4/27/17	121	Safety lamp & gas with dust.
Berwind	C.F. & I.Co.	12/31/17	1	Shotfirer,match,gas & dust.
Vulcan	Coryell Mine Leasing Co.	11/4/18	3	Mine fire and gas
Empire	Empire Coal Mng.Co.	3/31/19	13	Electricity, spark & gas
Oakdale	Oakdale Coal Co.	8/18/19	18	Safety lamp or matches & gas.
Moffatt #1 &#2	Moffatt Coal Co.	2/12/21	5	Blown-out shot & dust.
Satanic	Western Collieries Co.	12/13/21	5	Mine fire gases.
Sopris #2	C. F. & I. Co.	3/25/22	17	Gas & electric spark. Also dust
			490	

The above tabulation gives 490 deaths from mine fires and explosions in Colorado for 13 years, or an average of 37-plus per year, which is about 3 per 1,000 annually for the average of about 12,000 employed in coal mining in Colorado. Of the 490 fatalities from disasters since 1908, 409 are from mines of the Trinidad region, or an average of 31 per year which amounts to about 6 per 1,000 annually for the approximately 5,000 employed in coal mining in the region.

The tabulation may be subdivided as to causes about as follows:

Dust	115
Gas	63
Gas & Dust	216
Fires	96
	490

APPENDIX #4.

Conclusions of Bureau of Mines Engineers as to Explosion Hazard Tests of a Coal from a Mine of the Trinidad District.

(Abstracted from pages 95, 96 and 97 of the 1918 Report of the State Coal Mine Inspector of Colorado).

* * * * * * *

RESULTS OF THE TESTS.

Ignition Tests on Coarse Coal:

In Test No. 470, ignition was obtained with a mixture of 20-mesh coal dust containing 39.2 per cent total incombustible, but was not obtained in Test No. 469, with a mixture containing 47.8 per cent total incombustible, both tests being without gas.

In Test No. 471, ignition was obtained with a mixture of 20-mesh coal dust containing 56.5 per cent total incombustible, there being 1.7 per cent gas in the ventilating current. The pressures and flame velocities obtained in this test indicate that the dust would require a total incombustible content of about 65 per cent to prevent ignition in the present of 2 per cent of gas.

Propagation Tests on Coarse Coal:

In Test No. 472, propagation was obtained with a mixture of 20-mesh coal dust containing 56.3 per cent total incombustible, no gas being used.

In Test No. 473, propagation was not obtained with a mixture of 20-mesh coal dust having a total incombustible content of 78.1 per cent, there being 1.6 per cent of gas in the ventilating current. The flame extended only 100 feet into the mixed dust in this test, and in view of this fact it is considered very probable that this mixture would not propagate with 2 per cent of gas in the ventilating current. A still better conclusion would be to consider 80 per cent total incombustible as a safe mixture with 2 per cent of gas present.

Propagation Test on Pulverized Coal:

In Test No. 474, propagation was obtained with a mixture of pulverized coal dust containing 78.2 per cent total incombustible, there being no gas in the ventilating current.

APPLICATION OF EXPERIMENTAL MINE DATA.

The tests show that the coal dust from the Trinidad Mine as represented by this sample will propagate an explosion with considerable violence, even when mixed with a large percentage of inert material, and also that an explosion could easily be started by a blown out shot of black powder or by the ignition of a sufficient body of explosive gas. The danger of propagation of the explosion is greatly increased by the presence of gas, even in small quantities.

The total amount of incombustible necessary in a mixture to prevent ignition or propagation of an explosion under the test conditions is shown in the following table. The total incombustible includes the moisture and ash of the coal, as well as the admixed inert material.

20-MESH COAL OF WHICH 20% WILL PASS THRU 200-MESH.

	% Gas	Total Incombustible
Non-ignition	0	48
	2	65
Non-propagation	0	65
	2	80

The values given above are based on the results of tests in the Experimental Mine, which were made upon 6 x 9-foot entries. The danger of an explosion originating in room entries and in wide places is somewhat less than in entries without rooms.

Dust Accumulations:

Tests in the Experimental Mine have shown that a strong propagation could be obtained with as little as five ounces of coal dust per foot of entry when the dust was fine and dry. The coal dust, which is always present to some extent, should be rendered inert by wetting or by some other method such as stone dust.

Watering:

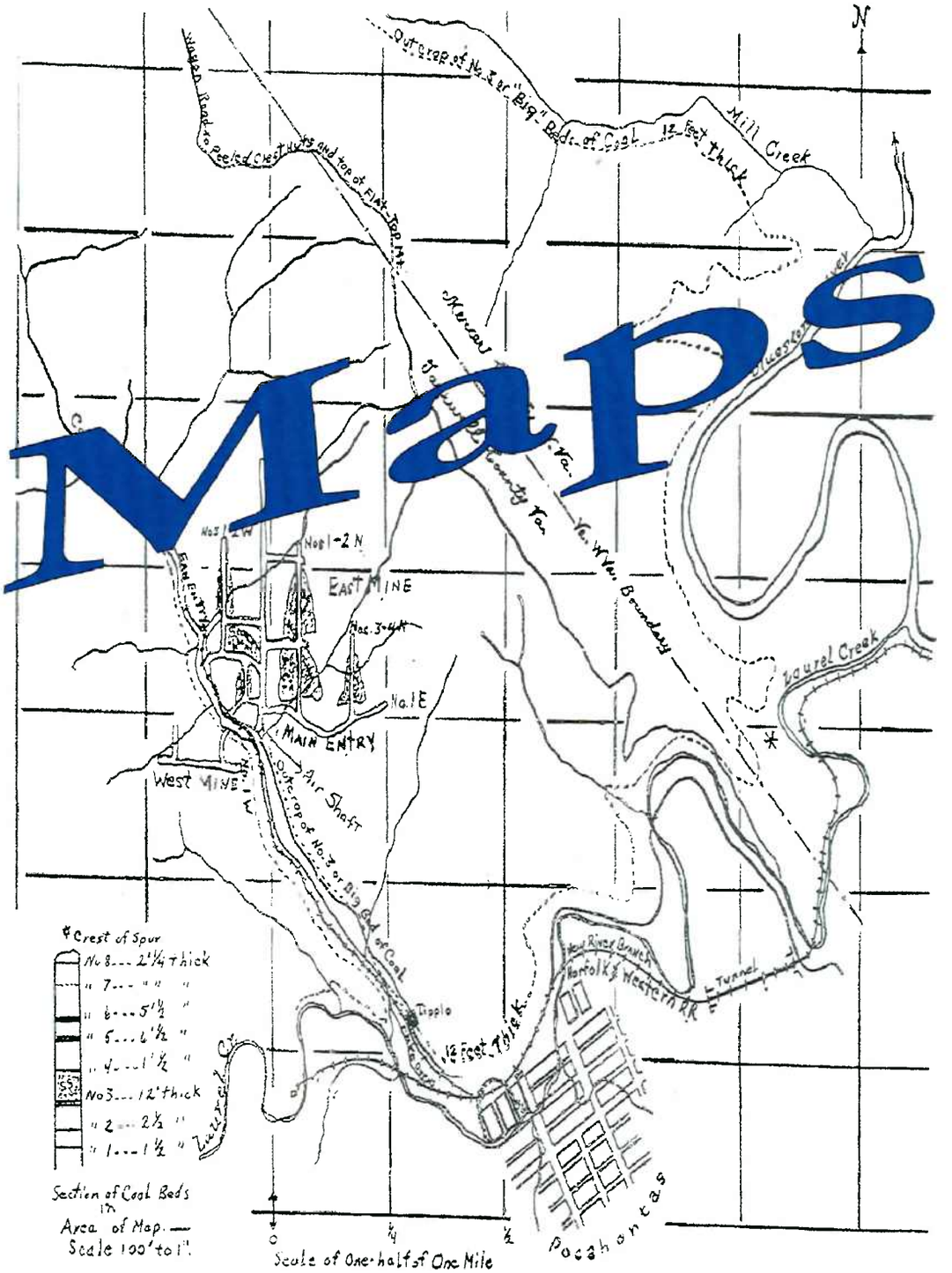
In rendering the coal dust inert by the use of water, the watering must be done regularly and at sufficiently close intervals to keep the dust wet at all times. The length of time between applications of water would depend upon whether the section treated was naturally dry or wet. The water should be applied to all surfaces and with enough force to wash down the dust from the timbers and ledges. Tests in the Experimental Mine have shown that an explosion started in dry dust will be propagated by mixtures of coal dust and water, unless there is enough water present to make a pasty mass of the dust.

ROCK DUST.

Kind of Dust:

Another method of rendering coal dust inert is the application of dry rock dust. For this purpose a dust should be chosen which contains no sharp particles such as are found in silica dusts and which should contain as little combustible material as possible. All dust should be fine enough that practically all of it will pass thru 20-mesh, and 30 per cent or more thru 200-mesh.

Some mines in the Pittsburgh, Pa., district have used limestone for this purpose, getting that material which is prepared for fertilizing farms. A mine in Colorado has obtained sweepings ("adobe dust") from the dirt roads, which makes an excellent material for this purpose.



Maps

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