UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

MINE EXPLOSION

File No. 938

Mine: No 1 Mine Location: Dawson, New Mexico

Company: Phelps Dodge Corporation Mailing address: ____

Date: February 8, 1923 Time of day ____ a.m. 2.20 PM p.m. Mine working or idle ____

Total employment ____ Underground ____ Shifts worked ____ Daily production (tons) ____

Number men killed: 120 Injured ____ In mine: 122

Number men escaped unassisted: 2 Rescued ____ Barricaded ____

Type (gas or dust): dust Ignition source: electric arc Rock-dusted: no

Was breathing apparatus used: no Gas masks ____ Self-rescuers ____

Time required to reach explosion area: all bodies not recovered by Feb. 14, 1923 (108 found the

Classification (gassy or nongassy) ____ Methane exhausted (24 hours) ____

Number of main fans: 1 Quantity air per minute: 108,400

Ventilation (continuous or split): split Face (line brattice or fans) ____

Mine openings: 3 drifts Principal: drift

Coalbed: Raton Thickness: 5' Volatile ratio: .44 Roof: shale Floor: shale

Mining system: room and pillar Pillars extracted: yes

Room support: Main entries: timber Intermediate: same Section: Same

Transportation: Main: trolley locomotive Intermediate: Same Section: mules

Electricity (voltage ac or dc) ____ Face: 250 DC Portable lights: permissible cap lamps

Principal mining machinery (continuous miners, conventional, etc.): Conventional

Was machinery permissible type: no Was it permissible ____

Blasting and explosives: Coal: permissible Grading or special use ____

Cause of explosion: coal dust cloud ignited by an electric arc from the trolley wire or trolley feedcable

Did explosion result in fire or were fires found ____

Point of origin: at an old parting on the main line 1600 from the pit mouth

Area affected: total mine

Was Bureau report made: yes Author(s): D. Harrington

If no Bureau report, what and by whom ____

Remarks ____

7915

R E P O R T

On

NO. 1 MINE EXPLOSION, DAWSON, NEW MEXICO.

February 8, 1923.

By

D. HARRINGTON.

April, 1923.

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TABLE OF CONTENTS.

TABULATIONS

APPENDICES

R E P O R T

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February 8, 1923.

By

D. HARRINGTON.

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INTRODUCTION

About 2:20 P.M. February 8, 1923, an explosion occurred in the No. 1 Mine of the Phelps Dodge Corporation at Dawson, New Mexico, resulting in death of 120 of the 122 men underground at that time. The explosion coming out of the mine practically destroyed the concrete portal at the Main #1 Entry and blew out the explosion doors at the fan, and otherwise damaged the fan approach at the surface but did not injure the fan itself, temporary repairs renewing air circulation near the mine portal in much less than an hour after the explosion. The quick resumption of ventilation allowed of prompt entrance into the mine carrying fresh air, and this, together with the fact that there were so many extended falls of roof in the interior of the mine, made it unwise and unnecessary to try to use oxygen apparatus, hence no apparatus work was done.

This mine was slightly affected by the shotfiring explosion starting in the adjacent connected No. 6 Mine on April 14, 1920, resulting in death of five men, two being killed in No. 1 Mine; there was also an explosion in No. 6 Mine, October 14, 1919, resulting in no loss of life.

On October 23, 1913, there was a disastrous explosion in No. 2 Mine(with portal about 1200 feet from No. 1 and No. 6), resulting in death of 263 persons and in much damage to property.

GENERAL INFORMATION

Location, Ownership, Etc.:

The No. 1 Mine is one of a group of mines being operated by the Phelps Dodge Corporation at Dawson, Colfax County, New Mexico, at the terminus of the El Paso & Southwestern Railraod, and in the general coal field in which are located the coal mines of the St. Louis Rocky Mountain & Pacific Coal Company in Northern New Mexico, and the mines around Trinidad and Walsenburg in Southern Colorado.

Mr. F. G. Beckett, General Manager of the Phelps Dodge interests with headquarters at Douglas, Arizona, has general charge of these properties, the general manager of active operations at Dawson being Mr. W. D. Brennan. Mr. Scott Dupont is underground superintendent of all mines at Dawson.

The mines produce somewhat less than 5,000 tons per day, No. 1 Mine output being 500 to 600 tons daily at the time of the explosion. Somewhat less than half of the production is coked in the underflue coke ovens located about a mile below No. 1 Mine, the remaining output being used chiefly by the various Phelps Dodge interests in New Mexico and Arizona.

Coal Occurrence:

The coal is Cretaceous, the bed worked being termed the Raton, the Van Houten and Koehler Mines of the St. Louis Rocky Mountain & Pacific Company being in the same bed. The coal is friable, is bright in color, somewhat dirty requiring washing before coking, is bituminous and cokes fairly well. Thickness in No. 1 Mine averages around five feet though much greater thickness is found in places; roof is a friable shale for several feet in thickness with immediate floor a bone-shale lying on sandstone. There is a well defined cleat practically parallelling the direction of No. 1 Main Entry. The dip is slight, being usually less than two per cent; there are comparatively few rolls or faults, and there is very little water encountered.

The coal analyzes about as follows:

Moisture	2.5%
Volatile Matter	37.0%
Fixed Carbon	47.0%
Ash	13.5%

with approximately
12,500 B.T.U.

It contains somewhat less than one per cent sulphur. The ratio of volatile to volatile plus fixed carbon is about 0.44.

MINING METHODS AND CONDITIONS

<u>Method of Opening</u>:

No. 1 Mine mouth at an elevation of about 6500 feet, is about 100 feet from mouth of No. 6 Mine, both main entries being essentially level, No. 1 main entries going about S 70° E and main direction of No. 6 entries being about N 20° E. These two mines were formerly connected but are now separated by caved, squeezed regions and by heavy bulkhead stoppings near the mine portals. At present No. 1 Mine is held absolutely separated from No. 6 Mine on the one side and No. 4 Mine on the other. The mines work under less than 1,000 feet of cover.

The No. 1 Main haulage road is the center of three entries driven about S 70° E, the left hand or north entry being the manway, and the right hand or south entry the return air course. Entries are about 10 to 12 feet wide with 35 to 40-foot pillars between. The main entries are in the later portions driven protected by pillars of over 100 feet. The present system of working is to drive a pair of haulage entries at right angles to the main entries, and from these haulage entries drive panel entries parallelling the mains, hence on the "butts" of the coal. Rooms are turned at right angles to these panel entries on both sides, the rooms being 250 to 300 feet long, the rooms being thus worked on the "faces" of the coal.

The practice is to drive the rooms on one side of these panel entries and pull the pillars before driving the rooms on the other side of the panel. In the past rooms from one panel have been driven to intersect rooms coming towards them from the adjacent panel; it is now said to be the intention not to connect panels but to leave a pillar of 50 to 100 feet between ends of rooms. Rooms are about 20 feet wide with 20-foot pillar between rooms.

Practice in the Cutting of the Coal:

The coal at advancing faces and in some pillar workings is undercut by electric machines, 250 volt D.C. and of the non-permissible type, there being five machines in use in the mine. All cutting is done during the day or regular working shift and on account of the dryness and friability of the coal and the fact that cutting is done wholly in coal and without use of water, there is much finely divided coal dust thrown into the air while cutting is being done, as well as subsequently when the cuttings are being shovelled into car. It is stated that machine cuttings are shovelled into car and removed from vicinity of face before blasting is done. Some pillars are pick mined.

Blasting:

This mine, as well as all others at Dawson, is equipped with system of electric shotfiring by which all shots are fired by electricity from the surface, after all men are out of the mine. Permissible explosive is used and it is said that absolutely no explosive except permissible is taken underground; it is stated, however, that charges in holes are not always held within the permissible limit of 1-1/2 pounds of explosive. It is said also that absolutely no blasting is done underground when men are in the mine, and that all holes are stemmed with clay.

Haulage:

The coal is loaded into tight steel cars holding about two tons and is hauled by mules to nearby partings, 14 mules being used. Cars are not topped to any considerable height above car, and cars have no doors, hence spilling of coal on tracks should be comparatively little.

250 Volt D.C. trolley haulage locomotives convey the coal from the panel partings to the assembling parting just outside of the mouth of the mine, where all coal from Mines 1, 2, 3 and 6 is made into trips to be handled by the steam locomotives on the surface to the tipple, approximately a mile down the canon from the mine portal. Main Entry trolley wire was ordinary 2/0 figure eight or grooved, and not protected by guards, and the 400,000 circular mill bare-stranded trolley feed cable parallelled the trolley wire and was supported by clamps on roof timbers, etc., and was in places but a few feet from the trolley wire.

Timbering:

The roof shale is not very strong in this mine and it is necessary to prop extensively, particularly in rooms. Timbering is of usual coal mine nature with posts of round timber 6 to 10 inches in diameter, and where caps are needed they are of slightly larger diameter. Some of the rooms require caps across the room neck and even across the width of the room, but ordinarily lagging was not necessary between caps. In some instances posts were dispensed with by placing caps in notches in the coal near the roof, and in other places "pony" posts a foot or two in length and notched into the coal rib supported the caps, both of the latter practices being good, as many of the caps thus supported, remained in place while nearby caps supported by posts were dislodged and the overlying shale allowed to fall.

TABLE 1

MINE AIR ANALYSES ON SAMPLES TAKEN IN NO. 6 MINE,
By J. J. FORBES, June 8, 1920.

Bottle No.	Lab. No.	Quantity Cubic Ft. Per Min.	CO_2	O_2	CO	CH_4	N_2	Location.
371	12912	2000	.06	20.79	.00	.01	79.14	Between 2 open crosscuts in 2nd South (not representative of return)
370	12913	12780	.07	20.81	.00	.02	79.10	2nd South return, outby from first open crosscut.
620	12914	--	.12	20.73	.00	.10	79.05	Crosscut between 1st & 2nd East, several hundred feet outby from face of entry.
525	12915	23100	.10	20.76	.00	.10	79.04	Connecting room from 1st E. that holes into "A" East, return from 1st & 2nd South.
636	12916	--	.14	20.65	.00	.27	78.94	10 feet back from face of 2nd East, off 2nd S.
518	12917	--	.12	20.74	.00	.18	78.96	20 feet outby from face of 1st E. Last crosscut open 25 feet outby from face.
630	12918	--	.08	20.71	.00	.15	79.06	Face of room 3 off 2nd East, off 5th N. Open crosscut 75 ft. from face of room 3.
727	12919	9400	.08	20.75	.00	.14	79.03	Outby from Room 1 in 2nd E. off 5th N. Return from 1st & 2nd S. & 1st & 2nd E.
728	12920	--	.11	20.73	.00	.12	79.04	Face of 4th North, 75 feet to last open crosscut.
614	12922	21300	.07	20.74	.00	.13	79.06	4th N. 20' inby from 2nd W. off 4th N. Return from 1st & 2nd S. & 4th & 5th N. entries.
519	12923	9450	.07	20.69	.00	.06	79.18	19th E., 50' inside regulator. Return from 19 and 20 East.
524	12924	9000	.06	20.72	.00	.06	79.16	22nd E., off 3rd N., return from 21 and 22, 50 ft. inby from regulator.
615	12925	55300	.12	20.63	.00	.09	79.16	Maih return from No. 6 mine, 40 ft. from upcast shaft.
635	12926	55300	.10	20.69	.00	.09	79.12	Main return from No. 6 mine, 40 ft. from upcast shaft.

Ventilation:

The mine is equipped with a Jeffrey double inlet fan placed in fireproof house provided with explosion doors and with fan offset from direct line of the air course. The fan is so arranged that direction of air currents can quickly be reversed; the fan is ordinarily a suction unit, using the main entry and manway as intakes and the right or south entry parallel to the main as the return. According to measurements taken by the operating company on 2/7/23, the fan was exhausting 108,400 cubic feet of air per minute from the mine with a water gauge of 3.2 inches, using a 100 H.P. motor. There were three major splits with a number of mihor splits for panels. Stoppings, in general, were of concrete blocks and fairly tight; overcasts were of solid permanent construction.

While there are not available analyses of air at ordinary working periods in this mine, there are in the attached table (Table No. 1) a number of analyses of samples taken by J. J. Forbes in the adjacent No. 6 Mine on June 8, 1920, after ventilation had been restored following the explosion in No. 6 Mine on April 14, 1920. These analyses of air from mine workings in the same seam within a few hundred feet of some of the workings of No. 1 Mine, indicate that while there is not an excessive amount of methane, yet there is undoubtedly enough to make it certain that in case of lack of circulation there would soon be gas accumulation of explosive proportion.

No open lights are allowed in the mine, Edison Electric Cap Lamps being supplied and, as an additional precaution, search for matches is said to be made occasionally. Flame safety lamps are used only by fire bosses and foremen.

Dust:

The coal is brittle, apparently undergoes fairly hard shooting and both the underground strata and general outside atmospheric conditions are distinctly dry, all of which tends towards dustiness in underground workings. Most of the coal is undercut by electrically driven cutting machines working in the coal during usual mine working hours, and in this process together with shovelling of the cuttings much finely divided dry coal dust goes into the air to settle later, on timbers, ribs and floor.

While the cars are without doors and excessive topping is not customary, and while roads are comparatively level and with well laid tracks (all conditions which should produce minimum spilling of coal along haulage ways), and comparatively little large sized coal was seen along such places as were not covered by roof falls from the explosion, yet there was considerably fine dry coal seen on the floors and also considerable of the very fine settled dust on timbers and rib ledges.

For about 1,000 feet from the portal, the main haulage way is also the sole opening for intake air and at operating periods over 100,000 cubic feet of air per minute went through this opening, velocity being in excess of 1,000 lineal feet per minute in places. Loaded trips of dry coal coming out at speed of about 500 feet per minute thus had velocity of upwards of 1500 feet per minute as compared to the ingoing air. This carried large quantities of the fine dry coal dust from top of loaded cars back into the mine to be deposited on timbers, rib and roof ledges, floor, etc., in the mine but especially in those parts of the main haulage-way where air velocity was lessened.

Sprinkling, Humidity and Rock Dust Barriers:

From the portal to a point several hundred feet inside, the mine has a three-inch water line in the return air course for sprinkling purposes; the line crosses into the main entry at a point about 2200 feet from the portal. Branch lines of 1-1/2 inch diameter run into the 4th and 7th North, 10th and 11th South and also into some panel entries, taps or connections (to which hose can be attached) being provided at frequent intervals. In some instances sprinkling lines are carried into rooms. The men assigned to sprinkling work are said to be held available for substitutions for absent workers, such as drivers, tracklayers, timber-men, etc., hence are not employed continuously on sprinkling.

At least half a dozen permanent continuous water sprays, manufactured by the American Moistening Company of Boston, were installed at intervals along the main entry from a point about 2200 feet from the portal to the 7th North. These sprays were to a large extent relied upon to keep a portion of the main entry moist.

There was no method of air humidification other than the above mentioned sprays in the interior on the main entry, and the sprinkling in the more actively working portions of the mine. Sprinkling when done was confined chiefly to wetting the floor, as it is said that from past experience it is found that water is injurious to the ribs and roof in mines at Dawson. In winter, both sprinkling and permanent sprays are impracticable near the mouth of the main entry, as outside air temperatures almost daily are below freezing and at times are below zero. Below are given maximum and minimum outside air temperatures at Dawson from Feb. 1 to 13,1923, Feb. 8, being the day of the explosion.

Table 2.
TEMPERATURE READINGS FOR FEBRUARY 1-13,1923,
AT DAWSON, NEW MEXICO.

DATE (Feb.)	TEMPERATURE Maximum	Minimum	Snowfall in inches.
1	34	18	--
2	38	16	--
3	24	10	Trace
4	38	6	"
5	48	6	--
6	40	14	Trace
7	54	6	--
8	46	16	--
9	44	16	--
10	50	9	--
11	44	16	--
12	42	20	--
13	52	28	--

From the above it will be seen that use of water near the mouth of the intake air course (main entry), with about 100,000 cubic feet of air passing per minute, would be impracticable.

The table below (Table 3) on monthly temperature data at Dawson, Feb. 1922 to Jan. 1923 inclusive, shows that below freezing temperatures may be expected at Dawson during the months of October, November, December, January, February and March; hence the above mentioned difficulty in use of water in the main entry would prevail during those months. The underground air temperatures at working faces at ordinary periods run from 57 to 60 degrees and air humidity is, according to readings taken by Bureau engineers at working periods, from 80 to 85 per cent. On Feb. 11, 1923 at 2:15 P.M., outside air temperature was 49° F., and relative humidity 34 per cent; at this temperature and humidity the air would hold about 2.5 gallons of water per 100,000 feet. With the return air 60° F. and 80 per cent relative humidity (about the ordinary condition), the air would have about eight gallons per 100,000 cubic feet, hence would have abstracted from mine workings the

T A B L E No. 3

Temperature Data, Dawson, New Mexico.

1922 Month	Average Daily Temperature Maximum	Average Daily Temperature Minimum	Highest Maximum Temperature	Lowest Minimum Temperature	Greatest Daily Range
February	49	21	62	4	52
March	55	24	70	2	48
April	60	36	76	24	40
May	76	40	84	28	42
June	85	45	94	36	52
July	90	50	94	38	50
August	86	51	92	40	48
September	79	43	86	38	44
October	70	27	82	18	52
November	53	21	68	6	48
December	53	19	66	5	48
January-1923	54	19	68	7	48

difference between 2.5 gallons for intake air and eight gallons for return air or 5.5 gallons per 100,000 cubic feet. Since the mine had at ordinary times slightly over 100,000 cubic feet of air per minute, the moisture abstracted from the mine daily would be about 8,000 gallons, much of which would come from the main haulage road.

At a point on the No. 1 Main entry about 2,000 feet from the portal and a little over 200 feet inside or east of the end of the abandoned parting at which the ignition took place, there were three rock dust barriers of trough variety, the barriers being placed across the entry and spaced about 12 feet apart, the lower part of the barrier being about 7 feet above the rail, the entry being about 11 feet wide and 12 feet high at the barrier location. This allowed an area of about 80 square feet of open space below the barriers and of about 40 square feet above them. In a letter dated March 7, 1923, General Manager Brennan says:

> "In connection with the dust rock barriers on the main haulage road, Mr. Murray advises that he and Mr. English, Assistant Foreman, examined these on the 26th of Jaquary and found them in good shape with but a very slight accumulation of dust. These barriers were covered with adobe dust taken from the road, heaped the full width of the barrier to a point of about 14 inches high in the center. My personal opinion in connection with the reason that the dust barriers did not stop the explosion is that the first car of the trip had been off the track for some distance and had filled the ingoing air with dust to a point considerably beyond these barriers so that the flame was by the barriers by the time they were dumped."

A set of five barriers was placed in the manway about opposite the location of the above described barriers on the main haulage road.

Safety Installations and Systems:

Dawson is known as one of the most advanced coal mining operations in the West, this being true not only as to the very excellent housing and other surface conditions, but also as to underground practices. A few of the latter are given briefly below:

(1) The mines are ventilated separately, each with up-to-date efficient ventilating fans, in fireproof housing, equipped to reverse air currents if desirable and to protect the fan in case of explosion. There are well planned ventilating splits, and stoppings, overcasts, regulators and other ventilating features apparently are efficiently planned, placed and maintained, provision being made not only for handling and bringing air currents at ordinary times to the working faces, but also to be in a position for prompt handling of emergency conditions. The elimination of open lights and universal use of electric safety lamps with occasional search for matches, and with restriction of even flame safety lamps in the mine during mine working hours are all precautionary measures of decided merit.

(2) The system of firing all shots by electricity after all persons, including shotfirers, are out of the mine, and the using of permissible explosive and tamping all shots with clay is certainly a system which merits highest possible commendation, and the company deserves much credit for installing and maintaining it.

(3) The method of rigid checking into and out of the mine of all employees is a thoroughly good practice, and this was proven at the recent explosion in the fact that all bodies of the 120 employees who were killed were identified.

(4) The substitution at heavy financial outlay of all steel closed pit cars, chiefly to reduce dustiness of haulage-ways as against the bad dust conditions on roads with old-time open end car of timber construction, is (condemned.)? commended! V.C.H.

(5) The placing of water lines for purposes of sprinkling of mines (over 20 miles of such lines being said to have been placed in Dawson mines during the past two years), is also very commendable as is the use of permanent continuous water sprays in main entry.

(6) The installation of rock dust barriers in the #1 Main and the #1 Manway is evidence of some of the preventive measures in use, but all traces of shale or rock dust were destroyed by the explosion and judging from the position at which they were placed and the relatively small number of troughs reported to have been used, it appears that certain fundamental features on which the efficiency of dust barriers rely were overlooked and their failure in this instance should not condemn future use of dust barriers that may be installed properly.

(7) The brushing of the manway for several hundred feet to a height of 4 to 6 feet above the coal not only reduced danger of accidents from roof falls and prevented partial plugging of the air course from such falls, and eliminated cost of cleaning those falls, but also provided several hundred feet of airway which acted naturally as a rock dust barrier to limit explosions.

(8) The decision to leave a pillar at end of rooms rather than breaking through, is commended as a safety measure even though it will result in loss of some coal.

(9) The measures taken towards the separation of the various mines from each other, and ventilation and operation of each as a separate unit, are highly commended. Especially is the placing of the heavy two-wall bulkhead-stoppings near the mouths of the No. 1 and No. 6 Mines

a wise action, since they undoubtedly prevented the recent explosion from going into No. 6 Mine.

(10) There is a resident safety engineer who makes underground inspections and reports as well as doing educational work in safety and welfare. There is also a station near the mines with safety equipment, including up-to-date oxygen apparatus kept in good condition, also safety lamps, both flame and electric, and other needed supplies for emergency work. These facts, together with fact that a number of men were at all times available with previous training in and knowledge of the use of the apparatus, indicate commendable foresight and a desire and intention not only to safeguard employees and property, but also to be able to shoulder any or all burdens which would be likely to be encountered in operating the mines.

STORY OF THE EXPLOSION

The explosion occurred between 2:20 and 2:30 P.M., Feb. 8, 1923, there being 122 men in the mine at the time. Underground Superintendent Dupont was at the mine portal but just out of the direct line of the main entry, and while thrown a short distance was not much hurt. The reinforced concrete portal of the No. 1 Main entry was shattered and it partly collapsed, necessitating some immediate work to get past it safely; the fan explosion doors were blown out and fan approach somewhat shattered, the fan itself being unharmed and continuing to run. Upon completion of temporary repairs to the fan approach and making No. 1 Main entry portal safe, General Manager Brennan and a number of helpers went into the mine restoring ventilation as they went, by placing temporary brattices in the crosscuts between the main entry or intake air course and the return air course on the right, the stoppings on the left between No. 1 and No. 6 Mines remaining in place.

Except for the violence seen at the fan and No. 1 Main entry portal together with the blowing toward the return air course and towards the manway of stoppings and occasionally timbers blown towards mouth of mine, comparatively little sign of force was encountered until a point about 1900 feet from the portal was reached. On an abandoned parting starting about 1500 feet from mouth of mine and ending about 1800 feet in, there was a loaded trip of over 20 cars with electric locomotive on outby and with controller on locomotive said to be in the "off" position. There was evidence that the two cars adjacent to the locomotive had been off the track for over 100 feet but had been partly placed on the track by a re-railer located near the outby end of the parting. The motorman, badly burned but body not broken by violence, was found dead at mouth of a crosscut a short distance back of the locomotive, the nipper also burned but not mangled, was found a few feet inby the inside car of the trip. At least two cars (probably three) were off the track about midway in the trip, and these cars had torn out three sets of timber. This abandoned parting was fairly closely timbered with legs and crossbars, also in places with cribs, and practically all timber was standing, everything indicating presence of very little force at any time on this parting.

The exploring party encountered comparatively little trouble with falls until it had gone into the 4th North and inby the 4th North in the Main entry. However, both in the 4th North and in the Main entry and other entries inby the 4th North, falls were numerous, in places almost continuous, and practically all stoppings blown out by a force very evidently going inby.

The 4th North overcasts were temporarily restored and part of the air taken into the 4th North and that region explored and simultaneously part of the air taken in on the Main entry.

On account of numerous falls encountered inby the 4th North and because it was found feasible to carry circulating air along by temporary bratticing, oxygen breathing apparatus were not used though both apparatus and apparatus wearers were quickly available. Apparatus explorations inby the 4th North would have been impracticable except for very short distances, as the falls were of such nature that apparatus wearers would have been seriously handicapped.

On the morning of Feb. 9, about 8:00 A.M. at a time when there were no persons in the mine on rescue or recovery work, two men who had been working in an unventilated portion of the mine extracting some pillars West of the 4th North and opposite region between 4th and 5th East off 4th North, walked out of the mine unharmed and unaided after having been in the mine at the time of the explosion and remaining there for about 18 hours afterwards.

Notwithstanding the numerous falls encountered, there was not much extreme violence and the recovery work as to bodies was comparatively rapid, being facilitated by the fact that only about 11 or 12 bodies were under falls; by the night of Feb. 10, or 48 hours after the explosion, 53 bodies were out of the mine, and by Feb. 13, 108 bodies were recovered, the inquest being held on Feb. 14. It is understood that the entire 120 bodies were later on recovered and that all were identified.

Bureau of Mines Activities:

The Associated Press in Denver called the Denver Office of the Bureau of Mines about 1-1/2 hours after the explosion, whereupon a wire was sent to General Manager Brennan offering Bureau Car or other aid, a reply being filed by Mr. Brennan at 5:00 P.M. that while the offer was appreciated, no outside aid was needed at least immediately. However, about 8:15 P.M. another wire was received from Mr. Brennan asking for a car and Car 2 at Hanna, Wyoming, was ordered to proceed. Later that night, Mr. Brennan having secured the services of the Colorado Fuel & Iron Company's car from Trinidad, Colorado, only a few miles from Dawson, wired Mr. Harrington at Denver and Car 2 at Hanna, Wyoming, that the services of Car 2 were not needed. Mr. Harrington, however, again wired Car 2 to proceed and meanwhile Car 1 was instructed by Pittsburgh to go from Ajo, Arizona, to Dawson and both cars arrived at Dawson at about 3:30 P.M. on Feb. 10, 1923, Car 1 having Messrs. Gregory, Martinson and J. M. Harrington, and Car 2 having Messrs. Sullivan, Birchard and D. Harrington. Mr. Beckett, General Manager of the Phelps Dodge Corporation's coal and metal interests in the West, was on Car 1 during much of the trip from El Paso to Dawson.

Immediately upon arrival at Dawson, an offer of Bureau aid was made to General Manager Brennan who said there was little or nothing we could do as his organization was handling everything. However, he was perfectly willing that we delegate members of the Bureau crews to go in with the various working shifts, and told us that we could make such investigations and take such samples as we might desire.

As heretofore stated, oxygen breathing apparatus was not used and there was practically nothing Bureau of Mines men could do except observe conditions and later on take some samples. As ventilation was withdrawn from each section as soon as available bodies were removed, there was not much territory available at any time for entrance or examination. Messrs. Martinson, J. M. Harrington, Birchard and Sullivan, in squads of two, went in with several shifts but were able to render little or no aid to the mining company. Similarly Messrs. Gregory and D. Harrington made numerous trips underground, chiefly for purpose of observation, and on Feb. 13 some air and road dust samples were taken by Bureau members from both cars. Car 1 left for Arizona on the morning of Feb. 14, and Car 2 for Denver on the morning of Feb. 15.

<u>Mine Examinations</u>:

As heretofore stated, an outcoming force dislodged the concrete portal of No. 1 Main entry and damaged the fan approach. From the mine portal to the previously mentioned abandoned parting on the Main entry, there were evidences of an outgoing force travelling chiefly along the main entry and fording the concrete block stoppings South towards the return air course, and putting much pressure against the block stoppings (dividing No. 1 from No. 6 Mines) on the North side of the Main entry near the portal. After the explosion in No. 6 Mine in 1920, which found its way into No. 1 Mine through forcing the stoppings in old connections near the portal, an effort was made to isolate the two mines by placing in each opening between the two mines powerful bulkhead-stoppings consisting of a concrete wall somewhat less than two feet in thickness on the No. 1 side of each opening and a similar wall on the No. 6 side, with the intervening space tightly packed with rock, this space being from 25 to 75 feet in length. While none of these bulkhead stoppings was actually forced at least one was decidedly damaged on the No. 1 side, and several others showed signs of having undergone stress; there were 14 such bulkhead stoppings in place between the two mines near the portal.

As heretofore stated, there was little or no evidence of force going in any direction at the abandoned parting where the loaded trip was found. Detailed description of conditions on this parting are given later.

Almost immediately upon leaving the abandoned parting going inby or East on the Main entry, evidences are found of forces going inby, though all observed evidences on the outby side of the abandoned parting were of forces going out towards mouth of the mine. The rock dust barriers located on the Main entry about 200 feet East of the end of the abandoned parting were almost totally destroyed, portions of the one-inch boards of which they were constructed being found at intervals inby almost to the 4th North, and a splinter of one of these one-inch boards was found driven about 1/2 inch into the outby side of a timber post located about 100 feet inside of or East of the location of the barriers; this splinter which was about 1/2 inch by 1/2 inch by about 8 inches in length, had been going towards the inside of the mine when it hit the post.

At the 4th North the force went South into the first-aid cabin, North into the 3rd, 4th and 5th North entries and continued East on the main entries. The writer had no opportunity of going into the 4th North region but was informed that there was much roof material down in the entries with forces unmistakably going <u>in</u>, and with some evidences of coking and of heat and violence especially at entry faces. Somewhat over 50 bodies were taken out of the 4th North region and the two men who came out alive about 18 hours after the explosion, had been working in the 4th North region in some old pillars several hundred feet West of the 4th North and adjacent to No. 6 Mine between the 6th and 7th cross entries. After the explosion these men remained at their working place which, at ordinary times, had comparatively little air circulation, and it is thought by the mine officials that they probably received some slight amount of fresh air from No. 6 Mine through the squeezed-caved region between the place in No. 1 Mine where they were working, and No. 6 Mine.

On the main entries between the 5th and 6th North, there was much evidence of violence with direction of force uniformly inwards or towards the face. There was much caving of roof inby the 4th North, timbers being blown towards direction of face. On the Main entry there were practically continuous falls of 3 to 6 or more feet inby the 4th North, and essentially the same condition in the 7th North and in some of the side entries off the 7th North, though the rooms of this region were scarcely touched by flame or violence and had comparatively few falls. At least some of the men working in the rooms of the 7th North region came out of their rooms after the explosion and were killed in the entries by hot, poisonous gases; in some instances these men's footprints were found in the dust settled after the explosion, showing they walked out of their rooms to the entry some time after the explosion occurred, yet these men had hair badly singed indicating that the gases encountered were hot. Bodies found near the face of the

6th North were burnt and showed definite signs of violence. Approximately 25 bodies were recovered from the 6th and 7th North entries and adjacent workings.

Some empty cars at the mouth of the 11th South were thrown slightly off the track and further on in the 11th South, there were some timbers blown inby with attendant falls of roof, but the comparatively loosely placed timbers in 12th South were hardly disturbed. The force passed into the 1st and 2nd East off 11th South driving timbers inby and letting down 2 to 4 or more feet of roof. Over 20 bodies were taken out of the region of 11 and 12 South. The direction of force was into the 7th, 8th, 9th and 10th South and there was considerable caving there, and about 15 bodies recovered from the 9th and 10th South and about 7 from the 7th and 8th South.

While there were falls of roof to a depth of 2 or more feet extending over several thousand lineal feet of entry and probably also in some rooms, there were very few bodies found under falls, about 10 or 11.

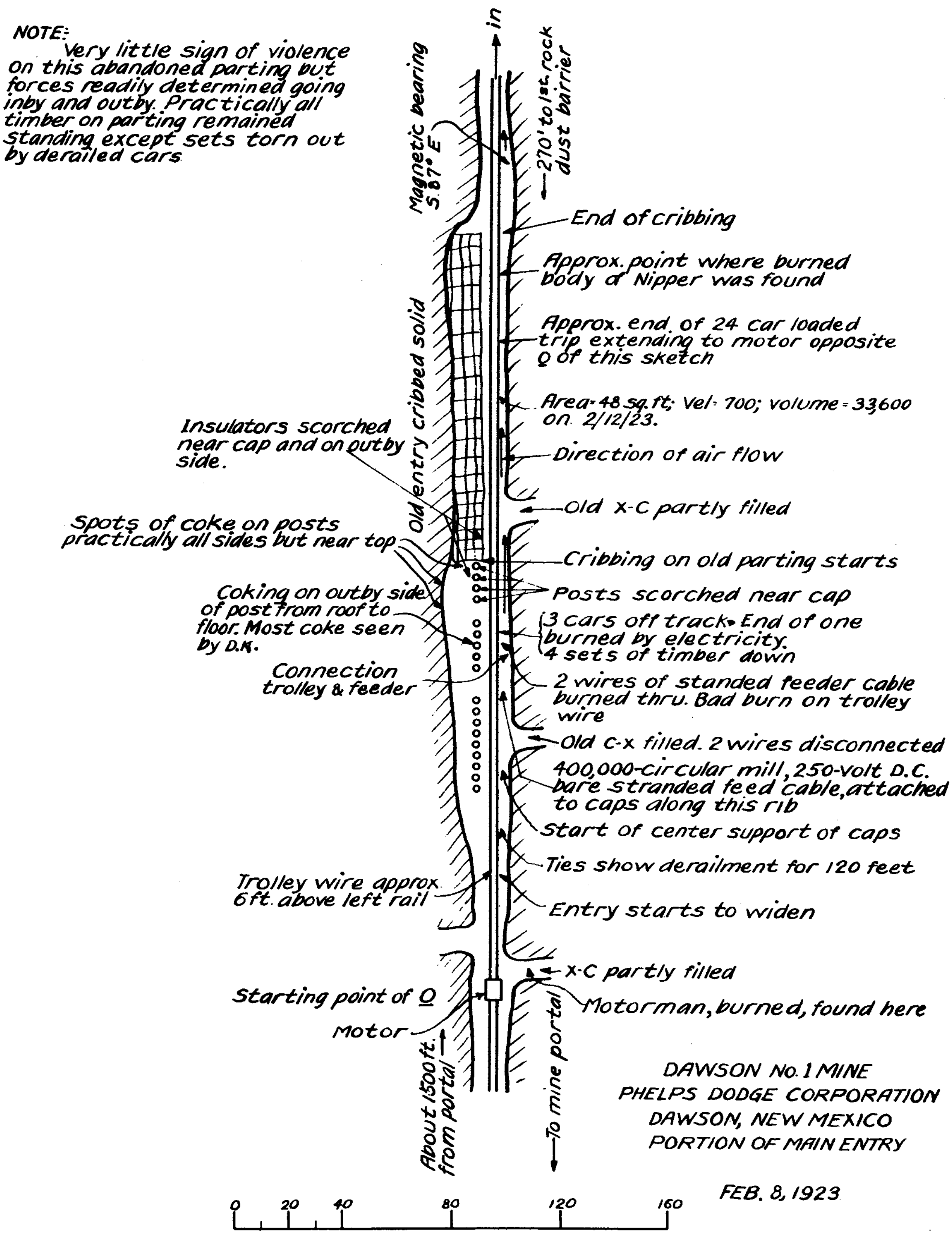
<u>Cause of the Explosion</u>:

During the first few days after the explosion there were the usual numerous rumors as to the cause, among them the lighting of a match for smoking purposes with ignition of methane, this being disproved in a number of ways, among them the fact that no matches were found on any bodies and no positive evidence was produced showing that methane entered at all actively into the explosion. Another rumor was that methane had been ignited by one of the five old type 250 Volt D.C. non-permissible electric cutting machines in use; this was disproved also, as it was found that all of the five machines had power disconnected (controller in "off" position), and there was no evidence that force or violence came from region in which any of the machines was located. One cutting machine out of order was in a parting off the 3rd North opposite the 4th East; one machine was at face of 6th North with power shut off though the machine was in position ready to sump, the machine men being burned and somewhat battered by violence; a third machine was found on a parting in the 3rd East off the 7th North; one machine was found at the face of Room 10 off the 2nd East off the 12th South, but the men were placing bits hence power was off, these men too were burned and battered by force coming from outside; the fifth machine was in the neck of Room 4 off 2nd East off 10th South, the machine man having gone out because of lack of places to cut.

It was also thought at first that trolley locomotives operating in the interior of the mine near possibly gaseous faces might have ignited methane. However, the locomotives were found with power off and, as with the electric cutting machines, there was absolutely no evidence that the explosion originated at or near these interior locomotives.

The actual point of ignition was undoubtedly the place where timbers were torn out by derailed cars on the abandoned parting on the main entry about 1600 feet from mouth of mine; and the cause of the explosion was undoubtedly ignition of coal dust by electric arcs from short-circuit of trolley wire and trolley feed cable when the latter were thrown upon the steel cars by dislodged timbers from the derailed cars. The coal dust for the ignition was probably supplied partly by the settled dust which had been on the dislodged timbers, together with dust thrown into the air from a car of machine cuttings off the track at the head end of trip and "bumping" over ties for over 100 feet before it came to a re-railing device near the outer end of the old parting. Fuel for propagation of the explosion was supplied by dry, very fine settled dust on timbers and rib and roof ledges, together with dry dust from floor, there being much comparatively fine material on the floor though the roadways had apparently been comparatively free of the usually found accumulations of large sized coal, rock, etc.

The attached sketch of a "Portion of the Main Entry" shows, in general, the conditions found at the abandoned parting at which the loaded trip with bodies of motorman and nipper were found. The trolley locomotive at head or outer end of trip had proceeded a few feet out of the old parting and was on the track, and while somewhat dust-covered, was in good condition mechanically and electrically. There was evidence that at least one, probably two, loaded cars (one with machine cuttings) adjacent to the locomotive had been off the track for at least 100 feet within the old parting and were placed, at least partly, on the track by a re-railer in the track a short distance back of the place where the locomotive was found. The motorman, burned to some extent, was found dead at the mouth of a South crosscut near the locomotive. The old parting had cross bars from rib to rib practically throughout, there being center posts a few feet away from the north rail; however, the east end of the parting for a distance of about 100 feet was filled on the north side with timber cribs, leaving but 7 or 8 feet to the south rib. Practically none of this timber on the abandoned parting was disturbed by the explosion, though a few sets had been pulled out by some derailed cars about 125 feet back of the locomotive, these timbers letting the trolley wire and 400,000 circular mill bare stranded trolley feed cable down on the end of the steel cars.


NOTE:
Very little sign of violence on this abandoned parting but forces readily determined going inby and outby. Practically all timber on parting remained standing except sets torn out by derailed cars
in
Magnetic bearing S.87° E
270' to 1st. rock dust barrier
End of cribbing
Approx. point where burned body of Nipper was found
Approx. end of 24 car loaded trip extending to motor opposite Q of this sketch
Area=48 sq.ft; Vel=700; volume=33,600 on 2/12/23.
Old entry cribbed solid
Insulators scorched near cap and on outby side.
Direction of air flow
Old X-C partly filled
Spots of coke on posts practically all sides but near top
Cribbing on old parting starts
Coking on outby side of post from roof to floor. Most coke seen by D.K.
Posts scorched near cap
3 cars off track. End of one burned by electricity. 4 sets of timber down
Connection trolley & feeder
2 wires of standed feeder cable burned thru. Bad burn on trolley wire
Old C-X filled. 2 wires disconnected
400,000-circular mill, 250-volt D.C. bare stranded feed cable, attached to caps along this rib
Start of center support of caps
Ties show derailment for 120 feet
Trolley wire approx. 6 ft. above left rail
Entry starts to widen
X-C partly filled
Starting point of Q
Motorman, burned, found here
Motor
About 1500 ft. from portal
To mine portal
DAWSON NO. 1 MINE
PHELPS DODGE CORPORATION
DAWSON, NEW MEXICO
PORTION OF MAIN ENTRY
FEB. 8, 1923
0
20
40
80
120
160

Undoubtedly there were two decided arcs as the trolley wire showed a decided burn, and opposite it the stranded feed cable had two or three wires severed by burns. There was much very fine dry settled dust on the timber caps in this region, as well as in the adjacent cribs and on the floor, and the dislodged timbers undoubtedly released considerable of this dry fine dust, and this dust together with that brought back from bumping over ties of the derailed car of machine cuttings gave the fuel for ignition in contact with the intense heat from the two arcs.

Posts, as well as longitudinal lagging in the vicinity of the burned places on the trolley wire and trolley feed cable, showed decided evidence of being scorched, especially near the roof, this being true for a distance of about 25 to 40 feet inside the point of arcing. There was decided coking on a center post about 15 feet outby the point of arcing, the heaviest coking being on outby side and extending almost from roof to floor. There was also spotted coking on nearby timbers and particularly on some posts on the north rib of the point of arcing; porcelain insulators about a foot from the roof showed decided scorching on outby side with little or no signs of scorching or soot on inby side.

Several cars of the loaded trip were located opposite the cribbed region of the old parting and practically plugged the available opening, yet the rear cars of the trip showed little or no sign of violence; and the timbers in the cribs or other places on the parting showed that no material amount of force had come past the loaded trip, though there was abundant evidence of force <u>going in</u> as soon as one went inside the old parting, and of force going out towards the surface as soon as one went outside the parting.

GENERAL DISCUSSION

The Coroner's Inquest, held on Feb. 14, 1923 at Dawson, heard as witnesses - General Manager Brennan, General Superintendent Dupont, Mine Engineer Soderstrom, Mine Foreman Thomas, Safety Engineer Murray, Fire Boss McBrayer, and a few others, fire bosses, machine men and coal diggers, among the latter being one of the two men who were in the mine at time of the explosion and came out unhurt about 18 hours afterwards. The Coroner's Inquest reported as follows:

> "We, the undersigned justice of the peace and the jury who sat upon the inquest held this 14th day of February, on the bodies of Albert English, Jr., (mine foreman), and others, found in precinct No. 13 of the county of Colfax, State of New Mexico, find that the deceased came to their deaths by reason of a dust explosion in Mine No. 1 of the Phelps Dodge Corporation, at Dawson, New Mexico, on or about the 8th day of February, 1923; that said explosion was caused by the derailment of an outcoming trip, which knocked down the timbers to which the trolley feed line was attached, raising a quantity of dust, which was ignited by an electric arc, resulting from the feed wire coming in contact with one of the iron pit cars."

Practically all acquainted with underground conditions after the explosion are in essential agreement with the decision by the Coroner's jury, but it fails to discuss underlying causes or to recommend remedial measures.

Notwithstanding the numerous precautionary safety measures taken by this company, some of them costing large sums of money for installation or maintenance, or both, a few of these excellent measures being heretofore referred to in this report, it is evident that something is lacking otherwise there would not occur at least three (probably more) serious widespread explosions in Dawson mines within a 10-year period; this situation appears to justify a fairly full and free discussion of conditions, with no intent at making offensive criticism but wholly with desire to try to aid in the solution of the very evidently serious problem existing in connection with procuring safe operating conditions in the Dawson mines.

While comparisons are odious and frequently unfair, it does not seem out of place here to refer to the fact that no explosions are known to have been experienced in the neighboring Van Houten and Koehler Mines, said to be operating in the same seam and under essentially similar conditions; the writer is not sufficiently familiar with conditions to draw definite conclusions but would suggest the desirability of the making of a study with intent to try to determine the underlying facts.

Ventilation Conditions:

While the mines at Dawson (and especially No. 1 Mine) are not particularly gaseous, yet a study of the tabulation of analyses of air samples taken by J. J. Forbes in No. 6 Mine in 1920, as well as an inspection of other analyses of mine air samples, taken in these mines, indicate that if air circulation should be interrupted explosive accumulations could quickly form. This is recognized by the operating company in the fact that up-to-date, well arranged and apparently well maintained ventilating systems are in operation at each mine, and by the fact that open lights are excluded.

Nevertheless some possible, even probable, dangers appear to exist: Each mine has but one fan and in the nature of things this fan must occasionally be stopped for some purpose, such as inspection, repairs, oiling, etc., and during this period methane will undoubtedly accumulate not only at working faces in rooms, entries and pillars, but also in the caved regions which are being ventilated. These accumulations at faces would be decidedly dangerous should shots be fired immediately after resuming fan operation and before making fire boss inspection, this being true even if it be taken into consideration that nothing but permissible explosive is used in blasting. Another possibly dangerous ventilation condition might arise from the fact that methane accumulating in caved or gob regions during fan shut-down, may not be removed immediately upon fan resumption and a considerable body of gas might readily be moved several hours, even several days later when the mine would be in operation, and this might be ignited by electric arc from cutting machines, electric locomotives or wires or even from firing of shots.

While some of the above may seem "far fetched", they are distinctly possible; remedies are somewhat drastic. One is rigid fire bosses' inspections of all places before blasting but particularly before blasting after the fan has been shut down or circulation otherwise interrupted for any considerable period; another is sealing instead of trying to ventilate abandoned workings; another is the placing of two fans, each with different kind of power for use in providing continuous ventilation in case one source of power or one fan fails (this system with one electrically driven fan and one fan driven either by electricity or by gasoline engine undoubtedly saved many lives in a recent coal mine explosion in Alabama). Another precaution would be the use of none but permissible coal-cutting machines with simultaneous taking of measures to prevent sparking in the use of "nips" and otherwise at or in connection with underground power wires. Another would be the use of permissible storage battery locomotives and elimination of trolley locomotives and bare power wires. Still another precaution would be the institution of a more rigid and more systematic seardh of workers for matches, and another would be the absolute elimination of flame safety lamps except those magnetically locked.

Shotfiring Conditions:

The writer considers the system of firing of all shots electrically from the surface with all persons out of the mine to be the best possible coal mine shotfiring system from viewpoint of safety; this is in use at Dawson and while it certainly is good, it has points of weakness especially where the human element comes into effect. If the regulations in connection with the shotfiring system are obeyed there will be very small probability of any loss of life, though the explosion in No. 6 Mine in 1920 indicates the uncertainty of placing entire dependence on men, even when it comes to protecting their own lives.

There seems to be a tendency to load holes above the 1-1/2 pound permissible limit of explosive when probably better (and certainly safer) results could be obtained by drilling more holes and loading them more lightly. Unless the man who inspects loading of holes in the afternoon is particularly conscientious, he is likely to leave the inspection, loading and tamping of holes largely to the miner who, unfortunately, does not always work towards his own safety or the safety of his comrades or of the mine. When the miner knows his own life will not be endangered, he may drill holes beyond the undercutting, inserting a stick or two of permissible explosive or even of dynamite into end of the hole before inspector's arrival, or, if allowed by inspector to load or to tamp holes after departure of inspector may use more explosive than allowable, or may fail to put in sufficient clay stemming, or may use coal dust for stemming, or may even omit stemming altogether.

There are also possible dangers from premature blasting by short-circuiting of wires by falls, carelessness with switches, etc., especially in mines having electric coal-cutting machines with live power wires to working regions as well as on main entries. A coal mining company in Colorado using this shooting system with permissible explosive has had some difficulty with local explosions at shooting time, and has practically concluded that the explosions are due to ignition of gas or dust, or both, by wires short-circuited at the working faces by the shots. The short-circuiting, of course, is due to the blasting with consequent mingling of wires, the attendant arc being of sufficient intensity to ignite dust or gas, though the mine faces are at least fairly well ventilated and sprinkled. It is thought that this difficulty can be overcome by material reduction of voltage from the 250 D.C. now used.

If there are too few inspectors and shotfirers, necessitating a delay sufficient to allow of methane accumulations at faces after miners leave the mine and before shots can be fired, this gives an opportunity for ignition of gas by blown-out shot, short-circuited wires, etc. It is even said that in mines with this system of shotfiring instances are known of use of electric detonator wires with detonator attached (and detonator left outside of holes) in connecting up the wiring at faces when the proper kind of wire was not readily at hand. Again, there is the temptation occasionally to shoot part of a mine while miners are in the other parts, or to fire a shot or two in rock using dynamite, and some explosions have undoubtedly been caused by throwing the surface shooting switch twice or by holding the switch in contact several seconds. Moreover, mines supplying coal for coking usually try to produce a product with maximum fines, thus reducing amount of crushing necessary, and this causes heavy shooting in the mines giving an extra safety hazard.

Some of the above mentioned poor practices in connection with coal mine surface electric shooting system have been observed at or in connection with mines in other regions using this system; some of the practices are rumored to have been in effect in Dawson and all are mentioned only to call attention to possible dangers.

Remedies are that so long as the system is in use, it should be carried out in its entirety at all times, allowing no deviations for special reasons; there should be a sufficient number of inspectors and shotfirers (and they should be carefully chosen) to insure careful inspection and prompt and efficient loading and firing of the shots; those in charge of or connected with the shotfiring should be checked up from time to time to make certain that they do not become careless or inefficient; under no circumstances should <u>any</u> shots be fired while <u>any</u> men are in the mine; dynamite or black powder should not be used underground for any purpose whatever; electric wiring of all character should be <u>very</u> carefully located and maintained; shotfiring is one of the most important features in the safety of all coal mines, and particularly those at Dawson, and it should be very carefully safeguarded from all possible viewpoints.

Dust:

The outstanding feature in connection with the explosions in mines at Dawson is that the dust is very dangerous; in each of the three general explosions the widespread character of the disaster was directly traceable to dust, and in the recent No. 1 Mine explosion certainly dust was the predominating factor both as to ignition and as to propagation.

Tests on various kinds of coal dust at the Experimental Mine at Pittsburgh, Pa., by the Bureau of Mines, indicate "a surprisingly regular relation was found to exist between the explosibility of the dust and the ratio of the volatile combustible to total combustible of the coal, the explosibility increasing as this ratio increased". (See discussion of this on page 23 of Bulletin 167, U. S. Bureau of Mines). The ratio of volatile combustible to total combustible of coal from Dawson is about 0.44 which, according to Tabulation on page 23 of Bulletin 167, as well as according to Fig. 45, page 342 of same publication, places this coal among the most explosive in the United States.

The attached tabulation (Table 4) of samples of floor dust taken on Feb. 13, 1923, at various points along the No. 1 Main haulage-way and intake from the portal to points covered with falls from the explosion, show that for road dust the above mentioned ratio runs from as low as 0.432 to as high as 0.702 which, according to Fig. 45, page 342 of Bulletin 167, indicates that fine dust of this character would be explosive unless mixed with 75 to 85 per cent of incombustible matter; and since all of these road dusts had less than 65 per cent incombustible (ash plus moisture), and most of them had less than 40 per cent and all had large proportion of through 200-mesh sizes, all of those samples of road dust from No. 1 Mine were definitely explosive.

TABLE 4

TABULATION OF ANALYSES OF ROAD DUST SAMPLES
DAWSON #1 MINE MAIN ENTRY.
Sampled 2/13/23.

No.	Can Number	Lab. Number	Approx. distance from portal (Feet)	Gross Weight of Sample (Lbs)	Amount of Sample Thru 20 Mesh (Analyzed)		Sizing of Thru 20 Mesh Material Cumulative Per Cent				Proximate Analyses As Received (Per Cent)					Ratio Volatile to Volatile plu Fixed Carbon
					%	Wgt. Grams.	Thru 20 mesh	Thru 48 mesh	Thru 100 mesh	Thru 200 mesh	Moisture	Volatile Matter	Fixed Carbon	Ash	Total	
1	18102	89659	400	12	68.2	1015	100	61.2	35.0	14.0	2.1	27.2	30.4	40.3	100	0.473
2	70930	89658	900	13	64.3	857	100	56.3	34.2	20.7	2.9	30.6	34.9	31.6	100	0.467
3	250	89657	925	10	63.8	762	100	58.8	38.2	20.6	6.3	27.1	30.7	35.9	100	0.468
4	Z-79	89656	950	11	64.5	908	100	57.4	36.6	22.6	3.0	28.5	33.6	34.9	100	0.459
5	20144	89655	1500	13	69.5	1193	100	70.4	45.2	24.4	2.4	18.1	18.2	61.3	100	0.500
6	18	89654	1600	15	62.0	956	100	64.6	39.8	23.5	2.5	32.7	13.9	50.9	100	0.702
7	Z-106	89653	1900	4	63.4	975	100	67.7	41.5	20.3	2.7	25.1	33.1	39.1	100	0.432
8	Z-42	89652	2300	4	62.6	954	100	63.1	42.2	26.0	2.5	19.8	22.2	55.5	100	0.472

(NOTE): Above samples were taken of a six-inch width trench to a depth of not over one inch in road dust going from rib to rib, rejecting all material which would not go through the scoop sieve. The gross sample after being weighed was coned and quartered to four pounds and immediately placed in a sampling can and sealed.

Of the road dust samples taken at roughly 300 to 400-foot intervals, there was found a gross quantity of from 10 to 15 pounds in 6 out of 8 samples, taken to a depth of about one inch and a width of six inches extending from rib to rib across the entry floor. Of this material upwards of 60 per cent went through 20-mesh, hence could possibly enter into propagation of an explosion; and of this through 20-mesh material in all but one case over 20 per cent went through 200-mesh, and in all cases over 30 per cent went through 100 mesh. This indicates that in the upper one-inch layer of material along the No. 1 Main haulage-way there was at least three pounds of through 200-mesh dry dust (moisture content being from as low as 2.1 per cent to as high as 6.3 per cent) per lineal foot of entry, and at least 4.5 pounds of through 100 mesh material per lineal foot of entry, while probably as little as 1/2 to 1 pound per foot of entry would be sufficient to propagate an explosion with violence.

This tabulation of No. 1 Main haulage road dusts also shows how very little moisture was present, average moisture of the "As Received" analyses of the 8 samples being but 3 per cent, while the average "As Received" analysis of face samples is about 2.5 per cent; hence the road dust has essentially the same moisture content as the coal in place, or as it is shot down at the face.

It will be noted that samples #5 and #6 were taken on the abandoned parting determined as the point of ignition and both indicate much road dust, much fine dust, and the ratio of volatile combustible to total combustible is much higher than the average, apparently indicating unusual explosibility; the ash content, however, was high, with moisture fairly low, but moisture plus ash were not near high enough (according to Fig. 45, page 342 of Bulletin 167) to prevent ignition or propagation of an explosion.

When taking the road dust samples (above discussed) on 2/13/23, a sample of fine settled dust was also taken by sweeping the settled dust off timbers on the abandoned parting and more or less in the vicinity of the point of ignition of the dust which started the explosion. A 4-pound sample was obtained from brushing the fine dust from about 200 lineal feet of timbers (caps, etc.), this giving about an ounce of dust for each three feet of timber cap. 61.7 per cent of the material in the sample went through 20-mesh, and of the through 20-mesh material 78.5 per cent went through 48-mesh, 60 per cent went through 100-mesh, and 45.7 per cent went through 200 mesh; hence there was about an ounce of through 200 mesh dust on every 10 feet of timber cap. It was found that over 93 per cent of the through 200-mesh material would also go through 325 mesh. This settled dust analyzed "As Received" as follows: Moisture, 2.7%; volatile matter 14.7%; fixed carbon 19.0%; ash 63.6%. The ratio of volatile combustible to total combustible was 0.436 and this, together with the large percentage of very fine sizes stamp it as very dangerous notwithstanding that it had 66.3% incombustible matter (ash plus moisture). It would probably require at least 85 per cent of incombustible to make this dust non-explosive, and it is extremely likely that it was some of this dust falling from the dislodged timbers which was ignited by the arcs from the trolley wire and trolley feed cable, and this started the explosion.

While it is recognized that all of the samples of road dust and settled dust were taken five days after the explosion when conditions would be such that there would probably be much drying out of dust, yet there appears to be no doubt that portions of the mine were dry and dusty even at ordinary times. The coal is naturally friable and apparently is shot hard, reducing it to a large percentage of fine material; electric cutting machines are used cutting a kerf of at least four inches high in a 6-foot seam, this one operation reducing at least 10 per cent of the product to fines, and this material is all dry and much of it is handled two or three times before it leaves the mine, each handling throwing much dust into the air to settle out later on. The shooting throws into the air much fine dust to be settled later on ribs, timbers and floor, and this is true also as to shovelling of the coal into cars. And while the cars have little or no leakage and are not topped very high, yet the loads are pulled at fairly high speed against high velocity air especially intake air on the Main entry, and the loose dry, fine dust is swept along in the air current - also to settle on timbers, ribs, floor, etc. And since sprinkling is said to be harmful to roof and even to ribs, this dust once settled is not removed until disturbed by some untoward occurrence as on the day of the explosion. Moreover, abandoned but open places are not sprinkled or otherwise treated to remove dust, yet they certainly act as a reservoir for dangerous fine dry settled dust, as well as of coal left on floor and gradually but surely breaking into fines.

Sprinkling and Humidification:

While the mine is provided with sprinkling lines practically to face of active entries and into some rooms, and while two men are said to be assigned to sprinkling, in the present instance the sprinkling lines were said to have been frozen on Feb. 3 and no sprinkling whatever was possible from Feb. 3 until the date of the explosion, Feb. 8. It does not appear that the two men assigned to sprinkling might not be taken away at almost any time to replace an absent tracklayer, timberman, driver or other worker.

Moreover, it is said that it was destructive of roof to allow water to come in contact with it, hence there was little or no washing down of settled dust on ribs or timber posts or caps, and what sprinkling was done had to be confined chiefly to wetting down the floor. As heretofore shown, the climatic conditions were such that water could not be used in the intake air course to a distance of about 3,000 feet from portal for nearly six months in the year, and the portion of the main haulage road thus left unprotected not only had the drying conditions due to continuous passage of large quantities of cold dry, high velocity air, but also much fine dry dust was pulled from cars passing through the main entry, and especially from top of loaded cars coming out at high speed against (swiftly) air going in.

Some continuous sprays were placed on the main haulage inside of the location of the rock dust barriers, but while they aided towards humidifying to some extent the ingoing air and aided (locally) in moistening the dust on a section of the entry floor, they were by no means able to prevent the inside region from remaining dry and dusty, and only partly relieved dust conditions along the entry.

An inspection of some room necks of abandoned places as well as a few trips into entries on which no hauling was being done, indicate that seldom, if ever, is sprinkling done in such places and much fine dust was seen on the floor as well as on timbers and ribs. It would appear that sprinkling when done is confined chiefly to interior haulage entries and to working rooms, entries and pillars.

While it must be admitted that comparatively little of the mine was seen and even that was seen after the explosion when conditions were abnormal, yet a very definite impression was gained that sprinkling had been done spasmodically rather than continuously and systematically. If ribs and timber posts and caps can not be washed down, and if all open, even if abandoned, places are not sprinkled, dangerous conditions will continue to exist; and sprinklers must be kept at work and sprinkling must be done practically continuously or it certainly will fail of its purpose. Moreover, the dust should be "killed" at its inception wherever possible, and to this end coal-cutting machines should have sprinklers attached; miners should have water pipe in working places with supply of hose and be required to keep the region of the working face damp and to <u>wet</u> thoroughly at least the top of every loaded car before it leaves the face. Where sprinkling is clearly inapplicable, other provision should be made to prevent accumulations of dry dust; abandoned places, such as old gobs which are open to dust but practically inaccessible to sprinklers should be sealed; entries which must be held open for air purposes should be rock dusted if they can not be sprinkled, and such places as the first 3,000 feet of the Main entry where water can not be used a large part of the year, certainly should be rock dusted.

Rock Dusting:

In recent years coal mining people, especially in Europe, have felt that rock dusting is far more effective than sprinkling in preventing and limiting explosions, many going so far as to condemn sprinkling altogether with simultaneous advocacy of installation of rock dusting. The writer is inclined to take the middle ground that some conditions give sprinkling the preference, other conditions almost require rock dusting for safety, while in some instances (Dawson being one) both sprinkling and rock dusting can be done to advantage.

It may be thought by many that rock dusting failed in the present instance since there were rock dust barriers a few hundred feet inside of the point of ignition, and the explosion evidently went through these barriers destroying the barriers and killing 118 men inside of them; whereas had the barriers stopped the explosion there would have been but two persons killed and the damage to the mine would have been trivial. However, rock dust barriers alone are not held to be sufficient to limit an explosion and aid very little, if at all, in preventing one; to be efficient for stopping or limiting an explosion the barriers must be properly constructed, and there is reason to believe these barriers were not very efficiently constructed. Besides, while there were rock dust barriers in the No. 1 Main haulage entry and in the manway opposite, there were no barriers in the return air course, hence even had the barriers in the main haulage and manway acted perfectly, the explosion could still have been extended both into and out of the mine through the return air course. In the present instance the flame undoubtedly went past the barriers on the main haulage probably because the dumping mechanism on the barriers was not in good working order, or possibly there was much fine settled coal dust on the rock dust in the barriers; moreover, there was much space both above and below the rock dust holders allowing of flame to get through both above and below before the barriers acted. In the opinion of the writer there should have been provided vanes located at least 100 feet each side of the barriers and connected to them by wires or rope or chain in such manner that the "pioneering wave", or compression wave preceding the actual explosion wave would act on the vane which in turn would trip the rock dust barriers and have the rock dust in the air before or at least at the same time the flame reached the barriers. And instead of having been placed where the entry was of enlarged cross section, it would have been better to have the barriers so located as to give only necessary head room; and complete protection was lacking in any event unless the return air course also was equipped with barriers at location approximately opposite the barrier location in the main entry and manway. Hence it can not be said that rock dusting failed on the present occasion any more than it can be held that sprinkling failed.

As previously stated, it is manifestly impracticable during winter to use water in almost any form on the outside 2,000 to 3,000 feet of the main (intake) entry, this being especially the case since there seems to be a definite feeling by operating officials that pre-heating and humidifying methods would result disastrously to roof. This being the case, it would appear that rock dusting of ribs, roof, timbers and floor should be carried on in the No. 1 Main entry at least as far as the 4th North and preferably to the 6th North; where the manway is brushed as it is outby the barrier location, sprinkling, rock dusting or barriers are not needed and either sprinkling, or permanent sprays could be used in the manway inby the 4th North, and in the return air course throughout, as there would be no probability of freezing in the return air course and little or none in the manway inside of the 4th North.

If rock dusting of the floor, ribs, timbers and roof is adopted for the main entry and other parts of the mine, the application of the rock dust to be effective must be made systematically and at such intervals as to insure the required percentage of inert material at all times. An inspection of the table of floor dust samples in No. 1 Main entry shows that ash content was well over 30 per cent and in cases ran above 50 per cent, and the very fine settled dust collected from timbers had nearly 64 per cent ash, yet the latter dust probably furnished the fuel which was ignited by the electric arc; and the resultant explosion certainly was propagated by dust (either that along the floor or that settled on ribs and timber, or both) in the Main and other entries. Hence there should be some means of preventing the very fine dust from settling or to remove those dusts, otherwise the inert content of dusts (floor and settled) must be held above 75 per cent, probably above 80 per cent, a somewhat difficult thing to do.

It is the writer's opinion that the above situation demands the use of sprinkling in various forms in the interior of the mine, such as on machines when cutting; at and around faces at various times but especially when shovelling, when cutting and before and after blasting; and at least the top of loaded cars should be wet before leaving the face and probably subsequently on partings to prevent the fine dust from being bumped or blown off as at present. Rock dusting could be applied to ribs, timbers, roof, etc., since sprinkling is said to be harmful at those places, and the floor of rooms, haulage entries, operating pillar regions, partings, etc., could be sprinkled and air courses not used as haulage-ways could be moistened by permanent sprays, or otherwise protected. If the above were done, and abandoned places sealed and rock dust barriers of approved construction placed to isolate or limit to any section an explosion started in that section, it would appear that the dust situation would be fairly well covered.

Electricity:

One of the greatest hazards in present-day mining is the electric current, the hazard, of course, being greatest in coal mines with gas and explosive dust. The present disaster (as well as others during recent years) shows that coal dust and electric arcs constitute a dangerous combination; and the danger is intensified where methane may be present.

It appears that it would be advisable in a mine with dust as dangerous as that at Dawson and with possibilities of methane accumulations, that nothing but permissible electric coal-cutting machines be used; that power wires for the interior of the mine be thoroughly protected; that provision be taken to prevent arcs at all points such as at commutators, at point of attaching trailing cable to machine and to power wire (nips); that only the best quality of protected trailing cable be used and that kept in absolute repair; that bare spots on power wires for attachment of "nips" be protected from short-circuiting or arcing, etc. Particularly should every possible precaution be taken to prevent possible short-circuiting between live power wires and shooting wires.

The use of trolley locomotives also seems somewhat dangerous since there are available permissible storage battery locomotives. If the trolley locomotive is used the trolley wire should be boxed where less than 6 feet from rail, and trolley feed cable should be insulated rather than bare and preferably should be buried along haulage road rather than attached to timbers or roof, the latter constituting an added menace as to arcing, fires and electrocutions. It seems particularly dangerous to use trolley locomotives in or along panel regions where rooms or pillars are working, or where pillars have been pulled, as methane accumulations may take place by local ventilation derangement and be sent out on adjacent entries to be ignited by spark from trolley wheel or other part of trolley locomotive system.

CONCLUSIONS

There is practically no doubt that the explosion in No. 1 Mine at Dawson on Feb. 28, 1923, was caused by ignition of coal dust by electric arc at a point about 1600 feet from the mouth of the mine and on the main intake air course. The electric arc or arcs were caused by falling of 250 Volt D.C bare trolley wire or bare trolley feed cable, or both, upon steel mine cars with consequent short-circuiting and partial burning of both trolley wire and feed cable. The falling of the electric conductors was due to dislodging of the timbers supporting the cables by two or three derailed cars of an outgoing loaded trip. The dust which was ignited by the hot flame from the electric arcs was either settled dust upon the timber caps which were dislodged, or dust in the ingoing air shaken from cars ahead, particularly a car of machine cuttings which had been off the track for over 100 feet; possibly dust from both sources came in contact with the flame.

Fuel for propagation of the explosion towards the mouth of the mine as well as towards the working faces, was supplied by fine dry dust from the floor and from ribs and timbers, explosive gas entering into the explosion very little if at all; and in any event participation of explosive gas was confined almost wholly to vicinity of working faces and not to any great extent then.

While the explosion was widespread, entering practically all sections of the mine and going to the face of nearly every open entry, while there were several thousand lineal feet of entry with falls of roof of 2 to 3 or more feet, and while a large number of concrete block stoppings were blown out and several well constructed steel-concrete overcasts destroyed, the explosion was not one of extreme violence as mine cars in its path were little, if any, damaged, in most cases not even derailed, and bodies found were not badly mangled (except in a few instances).

There certainly was, at least on the main entry, an abundance of fine dry dust to aid in propagating an explosion and it seems probable that there was also much dry dust in the interior of the mine also, and undoubtedly dust was the principal factor in the extension of the explosion, yet there was comparatively little coke left on ribs or timbers, except in vicinity of entry faces (blind ends) where the explosion had to stop.

The road and timber dust samples taken on the Main entry after the explosion show very little moisture, large quantity of fine road dust per lineal foot of entry, large percentage of very fine sizes and relatively high ash content (30 to 60%). The high ash content is due probably to the fact that the dirt seams in the coal are thin, hence shot into fine sizes, readily taken off top of loaded cars by air currents and deposited later; moreover, the roof in the outer parts of the mine is shale and this falls, especially on top of timber caps, in small sizes. It is probably due to this high ash content of the dust that there wasn't more violence to the explosion.

This explosion, as well as others which have taken place at Dawson, make it certain that the dust is very explosive and that as yet the correct method of handling it has not been placed into operation. It would appear advisable to make a thorough detailed study of the mines at Dawson and vicinity to try to determine the best methods of handling these mines to prevent explosions. In appendix No. 1 is a report taken from the 1918 Annual Report of the State Coal Mine Inspector of Colorado, giving details of a study by the U. S. Bureau of Mines of dust of a mine in Southern Colorado, with conditions similar to those at Dawson, and it is suggested that a similar study be made at Dawson.

Until a more detailed and more systematic study, such as was made in Southern Colorado, may be made in Dawson, the writer is of the opinion that rock dusting of ribs, roof, timbers and floor should be done at least in the main haulage (intake) entry of No. 1 Mine and possibly in the other haulage entries, and that properly constructed rock dust barriers should be placed to confine or limit explosions; in addition, sprinkling should be systematically and continuously practiced, particularly at the working faces.

While much has been done at Dawson towards making mining conditions safe and up-to-date, there are some essential particulars in which decided improvements could be instituted. It seems to the writer that it would be very good policy for as large an organization as that at Dawson to have at least once annually an inspection made with report by some qualified outside person, preferably an engineer, who will call attention to deficiencies both in safety and in operating efficiency, and thus keep the management "on its toes" as well as furnish new and up-to-date ideas.

Following is a summation of some of the suggestions which occur to the writer with idea of trying to aid in solving the very serious problem confronting the management of the mines at Dawson. Some of the suggestions are probably already in effect but it generally does no harm to call attention to existing practices occasionally to prevent their being forgottan in stress of other affairs; some of the suggestions may be considered too expensive to install, but the expense in such case should be carefully weighed against the many ramifications of expense in case of an explosion.

These suggestions embody ideas pertinent not only to conditions surrounding the recent No. 1 Mine explosion but also features which, in the writer's opinion, may be of aid towards warding off future trouble from sources not involved in the recent explosion.

SUGGESTIONS OR RECOMMENDATIONS.

(1) The Main entry should be rock dusted (ribs, roof, timbers and floor), and if it is not feasible to wash down timber posts and caps and ribs where sprinkling is done in the interior of the mine, rock dusting of ribs, roof and timbers should be applied to such places and sprinkling used along the floor.

(2) Rock dust barriers of construction of proven efficiency (see Bureau of Mines publications of work at Experimental Mine), should be installed at places connecting sections of the mine such as just off the No. 1 Main entry in the 3rd, 4th, 5th, 6th and 7th North, and 5th, 6th, 7th, 8th, 9th, 10th and 11th South. Also at entrances to any panel thought to be particularly dangerous as to gas or dust.

(3) The rock dust to be used should be subjected to chemical and microscopic analytical inspection before applying it in order to determine its suitability. The Bureau of Mines Station at Pittsburgh is equipped to do this work.

(4) As with sprinkling, rock dusting to be effective must be done systematically. It will be essential to do considerable sampling at intervals of not over two or three months to ascertain whether the dust

condition continues to be safe. The analytical work could undoubtedly be done by chemists at Dawson connected with the coke plant.

(5) Sprinkling of the interior of the mine, particularly in region of working faces, should be continued, and even largely expanded even if rock dusting is adopted. Water should be used on the cutter-bar with electric cutting machines, and sprinkling lines should be sufficiently close to all working faces (even in rooms) that the miner by use of hose (with which all working faces should be supplied) should keep the region of working face wet down at all times, but particularly before blasting. He should also thoroughly wet down the top of all loaded cars before they leave the working place.

(6) Water lines should be removed from main intake air course where they are likely to freeze, and if water lines in any part of the mine are put out of commission for any reason, their repair should be hastened as much as would be the repair of main haulage track.

(7) A mine of size of No. 1 should have at least two men doing nothing but sprinkling and they should preferably be under instructions to do nothing but sprinkle unless otherwise ordered by the General Manager of the mining company. And preferably they should make reports (at least as to difficulties) not only to the mine foreman but also to higher officials as the safety engineer or general manager.

(8) In all parts of the mine where it is feasible to do it, sprinklers in addition to thoroughly wetting the floor should wash down ribs, timbers and roof. This certainly can be done without harm where there is coal roof and, in the writer's opinion, should be feasible where roof is held by timbers.

(9) The use of permanent sprays is commended and should be extended.

(10) It would appear advisable to frame suitable rules and regulations concerning sprinkling and have them always posted in a prominent place to keep every underground worker acquainted with his personal obligation towards sprinkling.

(11) While the mine is not dangerously gaseous, there is enough gas present to make it advisable to take definite precautions, particularly since the dust is definitely dangerous. There should be employed experienced competent fire bosses, who make rigid inspections with subsequent full written reports, and fire bosses should be kept in up-to-date information as to State Laws, company regulations, and particularly as to matters pertaining to ventilation, properties and dangers of gases and dusts.

(12) While the mine fan installation is excellent, it is suggested that at least in case of some of the Dawson mines it may be advisable to place a second or emergency fan to be driven either by electricity or by some other power, such as gasoline, steam, etc. This would allow of continuous air circulation, even should one fan become injured or should electric current be "off". An installation of this nature undoubtedly saved many lives recently in Alabama.

(13) It is suggested that occasionally the feature of the fan supposed to cause reversal of direction of air currents be tried out. If this isn't done and an emergency should arise demanding reversal of direction of air, there might be (probably would be) difficulty in bringing about the desired change.

(14) It is suggested that particularly in gaseous rooms or entries line brattices be used from the last crosscut to the face. This is of

particular importance in connection with the use of the present electric shotfiring system.

(15) It is felt that leaving open and trying to ventilate abandoned and partly caved regions is dangerous, and that there would be much less danger from dust and gas accumulations if all such places were securely sealed.

(16) It is recommended that no flame safety lamps be used except those magnetically locked, and that even then those lamps should be used only by foremen, fire bosses or other persons who realize their dangers and limitations.

(17) Regulations as to explosives and general shotfiring practice should be formulated and kept posted in a prominent place, and every one should be compelled to be familiar with those regulations and to abide by them.

(18) Shotfirers should be carefully chosen, competent conscientious men, and there should be a sufficient number of them to make it feasible to have all shots carefully loaded and inspected, and the firing completed within an hour after the time the miners leave the mine.

(19) Provision should be made to check all shotfiring practices at comparatively frequent intervals to prevent slip-shod methods, carelessness, etc., from being indulged in by shotfirers, wiremen, miners and others who are involved in shotfiring.

(20) Shooting wires, switches, etc., should be carefully installed and maintained and especial care taken to prevent short-circuiting of power to shooting lines while men are in the mine at working faces.

(21) There appears to be danger of ignition of gas by short-circuiting of tangled wires at time of shooting, this danger seemingly being greatest when voltage is high; a mining company in Colorado

using this system of shooting is making a study of this.

(22) It is suggested that all possible precautions be made to prevent over-charging of holes (over 1-1/2 pounds of permissible explosive per hole,) that nothing but permissible explosive be used under any circumstances, that proper inspection be made of all holes before loading, that a sufficient number of holes be used to bring down the coal without over-charging, that coal dust should not be used to tamp holes, that sufficient clay should be used for that purpose, that the main shooting switch be "thrown in" but once and then not be held in contact any considerable length of time. In fact it is earnestly recommended that utmost vigilance be used to insure that the very excellent shotfiring system in use shall be so maintained that it will safeguard the mines at Dawson as it is designed to do and should do.

(23) If the trolley locomotive system is continued in this mine, the trolley wire and the trolley feed cable, where less than 6-1/2 feet above the rail, should be on the same side of the haulage road and be boxed to prevent accidental contact by persons walking or riding along the haulage road.

(24) It is recommended that permissible storage battery locomotives be substituted for trolley locomotives; at least permissible storage battery locomotives should replace trolley locomotives in the interior of the mine and in the vicinity of places which are likely to have methane accumulations and certainly are likely to have dangerous dust conditions.

(25) Non-permissible electric coal-cutting machines should be replaced by permissible machines, and precautions should be taken to prevent any considerable amount of sparking or arcing in connection with trailing

cables, with "nips" or connections on trailing cables, with bare places on power lines to which the "nips" are attached, etc.

(26) The method of placing timber caps in hitches or notches in the rib and thus dispensing with posts seems effective where used, and its extension is desirable.

(27) The timber crib on the old parting on the main entry should be gunited or otherwise treated to prevent its acting as a dust catcher.

(28) It would be advisable to have a systematic method of searching of underground workers for matches; this searching should be done fairly frequently and the person doing the searching should be changed from time to time. It might be advisable to search the men underground also at times, as habitual smokers are likely to resort to various tricks and to take "long chances" in order to satisfy their desire.

(29) The mines should be subject to rigid safety examination periodically by the safety engineer with detailed written report, copy to go not only to mine foreman, mine superintendent and general manager, but also to non-resident officials, and there should be follow-up reports denoting progress as to recommendations, etc., with reports as before listed.

(30) In order to secure benefit of up-to-date outside safety and efficiency practice, it would be advisable to have an inspection, at least annually, by competent outside mining man, preferably an engineer. Or the same object might be obtained if safety inspection service be interchanged with up-to-date coal companies such as Colorado Fuel & Iron Company, Union Pacific Coal Company, Utah Fuel Company, United States Fuel Company, etc. Such interchange of inspection service would allow of spread of good methods of all and of probable correction of many poor practices in safety or efficiency.

(31) In view of the several disastrous explosions which have occurred in mines at Dawson, a detailed careful study of conditions appears almost necessary. And since gas and dust, particularly the latter, apparently are the vital elements, it is suggested that an explosion hazard study be made by the engineers of the U. S. Bureau of Mines in which much data with many samples of various kinds are taken in the mines, and subsequently dust from a large (say 2-1/2 ton) sample of coal is tested under various conditions in the Experimental Mine at Pittsburgh, Pa., as to its explosibility, and methods necessary to prevent ignitions and explosions are determined.

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation of the willingness shown by General Manager Brennan and other officials of the Phelps Dodge Corporation that Bureau of Mines representatives should enter the mine at any time to obtain data and evidence as to the effect of the explosion, causes, etc. And subsequently maps and other data requested of Mr. Brennan by letter were also furnished promptly, fully and willingly.

Appreciation is also due the members of the crews of Bureau of Mines Cars One and Two, especially Mr. Gregory of Car One, for their cordial cooperation at Dawson though there was very little any of us could do. The Pittsburgh Station acted with commendable promptness in supplying analyses of samples of air and dust in making up and furnishing maps, photostats of maps, etc.

REPORT OF THE EXPERIMENTAL MINE TESTS WITH COLORADO COAL FROM A TRINIDAD DISTRICT MINE.

* * * * * * *

A 2-1/4 ton sample of "run-of-mine" coal was secured from the face of a new crosscut. This sample was loaded into tight barrels and shipped to the Experimental Mine near Bruceton, Pa. The large sample of "run-of-mine" coal was crushed and pulverized to correspond with the size of the road dust found in the mine and was used for the tests covered by this report. The face samples gave the following average analysis:

Coal as Received:

Moisture	2.54
Volatile Matter	34.53
Fixed Carbon	50.16
Ash	12.77
Moisture plus ash	15.31
Ratio $\frac{\text{Vol.}}{\text{Vol. plus F.C.}}$	40.75

Upon arrival of the large coal sample at the Experimental Mine, a sample representing the entire shipment was taken for analysis and the remainder was stored in the mine in a saturated atmosphere to prevent loss of moisture. The following is the analysis of the sample:

Laboratory No. 30146

Moisture	1.86
Volatile matter	34.89
Fixed carbon	47.99
Ash	15.26
Moisture plus ash	17.12
$\frac{\text{Vol.}}{\text{Ratio Col. F.C.}}$	42.09

This sample approximates the face sample (No. 29465) taken when the large sample was prepared, except for the loss of a small amount of water and the addition of five per cent of ash. Samples of the coal taken during the series of tests showed an average ash content of 11.15 per cent, which more nearly approximates the face sample.

A sample of road dust was taken in 1911 and two more in 1917. All particles coarser than 20-mesh were discarded from consideration, since previous testw in the Experimental Mine have indicated that they do not materially affect the explosibility of the dust.

ANALYSIS OF ROAD DUST SAMPLES

Lab. No.	Moisture.	Volatile Matter	Fixed Carbon	Ash	Moisture Plus Ash	Ratio	Screen Test Cumulative % Thru 100	200
12030	6.02	28.47	44.10	21.41	27.43	39.23	---	---
29276	10.23	26.07	30.13	33.57	43.80	46.39	18.0	5.6
29275	4.80	31.16	37.42	26.62	31.42	45.43	38.5	23.0

EXPERIMENTAL MINE TESTS

Plan of Tests:

Two classes of tests, termed ignition and propagation tests, were made. In ignition tests, a mixture of the coal and shale dusts is distributed from the face of the entry outby for a distance of 350 feet in the main entry (see attached diagram), and also for a distance of 50 feet thru the last cut-thru and 300 feet outby along the parallel entry. A blowout shot of four pounds of FFF black powder is then fired into the mixture from a cannon at the face of the entry. The ignition series determines what percentage of rock dust and moisture will prevent an explosion starting from a blowout shot under the test conditions.

In propagation tests the distributioh is the same as in ignition tests, except for the first 50 feet outby the cannon; that is, from the face of the entry to the cut-thru. Pure Pittsburgh dust is distributed in this 50-foot zone, and the explosion originated by firing the blowout shot into it. The effect of the explosion in the 50-foot zone of Pittsburgh dust is approximately equivalent to the explosion of a body of explosive gas in the 50-foot zone or to an explosion of coal dust of less explosibility in a longer zone. The propagation series determines what percentage of rock dust and moisture, mixed with coal dust, will not permit propagation of an explosion under the test conditions. The sketch attached to this report shows the arrangement of zones in a propagation test.

Gas:

After the percentages of shale necessary to prevent ignition and propagation in the absence of gas are determined, tests are made to determine the additional amount of shale necessary to offset the presence of one per cent and of two per cent of gas in the ventilating current. The gas used in such tests is a natural gas which has a slightly lower explosive limit than methane, due to the presence in it of some ethane and possibly other members of the paraffin group. The gas is turned into the air current at the fan about 1,300 feet from the test zone; it is thoroughly mixed with the air when it reaches the test zone. Tests are made from time to time with flame safety lamps and by analysis apparatus to determine when the desired percentage of gas has been obtained. The igniting shot is fired as soon as possible after this condition is obtained, which is generally less than ten minutes.

Moisture:

In all tests an attempt is made to have the coal, so far as moisture is concerned, as nearly as possible in the condition obtaining in the mine from which it comes. Coals of high moisture content generally lose most of this moisture when put through the crushing machinery. To overcome this, the coal is wetted before it is put through the machinery and after grinding it is stored in the mine in a saturated atmosphere. If the moisture content is still low, enough water is mixed with the coal dust just before it is placed in the mine for the test to bring the moisture up to the proper percentage.

Size of Dusts:

Two sizes of dust were used in the tests, one approximating the size of the road dusts found in the Trinidad Mine and the other a very fine dust giving the maximum explosibility.

The screen analyses indicate that the dust might average about 20 per cent through 200-mesh for a larger number of samples. Furthermore, dusts of this size have been frequently met with in other mines in which the coal somewhat resembled that obtained from the Trinidad Mine.

For the Experimental Mine tests, therefore, the coal dust was prepared so that 20 per cent of it would pass through 200-mesh, this being one of the standard sizes which have been adopted for regular testing. The size rating is always given by the per cent of 200-mesh dust present, because the finest dust is the most easily ignited, the most explosive, and therefore the most dangerous.

A small part of the coal sample was tested after being pulverized until practically all of it would pass through 100-mesh, with about 85 per cent through 200-mesh. This size furnished a basis of comparison for different coals which have been tested in the Experimental Mine, besides showing the maximum explosibility of the coal.

Preparation for Tests:

That part of the mine in which the tests are made has been covered with cement by means of the cement gun, and has a concrete floor. Before the dust to be tested is taken into the mine, the test zone is thoroughly cleaned by means of brooms and by blowing with a compressed air jet, which removes all traces of dust remaining from the previous tests. The dust to be tested is mixed in 100-pound lots and taken into the mine in closed metal cans. It is then distributed uniformly throughout the test zone, at the rate of one pound of coal dust per lineal foot of entry, except in the first 50 feet from the cannon, where two pounds per foot are used. One-third of the dust is placed on overhead cross shelves spaced ten feet apart, one-third on 3-inch shelves running along both ribs, and one-third on the floor.

In the 50-foot ignition zone, the dust is placed on side shelves along the ribs and scattered over the floor. Twenty-five pounds of the coal dust are placed on a plank platform laid on the floor in front of the cannon.

The more important data of the explosion tests is shown in the following table:

EXPERIMENTAL MINE TESTS ON COAL FROM THE TRINIDAD MINE.

Test No.	Mixture as Prepared: % Coal	Mixture as Prepared: % Shale	% Incombustible in Mixture H_2O - Ash	% Gas	% Coal Thru 200-M.	No. sq. In. E 950 (Pressure)	No. sq. In. A950 (Pressure)	Was ignition or Propagation obtained? Length of flame.
			Ignition Tests, 20 Mesh Dust					
470	70	30	39.2	0.0	20	2	2	Yes, thru zone
469	60	40	47.8	0.0	20	1	1	No, 125 feet
471	50	50	56.5	1.7	20	8	7	Yes, thru zone
			Propagation Tests, 20 Mesh Dust					
472	50	50	56.3	0.0	20	5	3	Yes, thru zone
473	25	75	78.1	1.6	20	1	1	No, 100 feet
			Propagation Tests, Pulverized Dust					
474	25	75	78.2	0.0	92.4	3	3	Yes, thru zone

Note: Unless the flame passes thru the entire 350 feet testing zone, it is classed as having failed to ignite or propagate.

Series of Tests:

Three ignition tests were made, all with 20-mesh dust; two of these were without gas, and one with 1.7 per cent gas.

Two propagation tests were made with 20-mesh dust, one without gas and one with 1.6 per cent gas. One propagation test was made with pulverized dust, this being without gas.

The average analysis of the 20-mesh Trinidad coal, just before mixing for the tests, was as follows:

Moisture	1.60
Volatile matter	36.67
Fixed carbon	50.58
Ash	11.15
	100.00

Ratio of volatile matter to total combustible is 42.03

The analysis of the 100-mesh Trinidad coal, just before mixing for the test, was as follows:

Moisture	1.59
Volatile matter	36.19
Fixed carbon	51.06
Ash	11.16

Ratio of volatile matter to total combustible is 41.48

The average analysis of the shale dust used in these tests was:

Moisture	1.23
Total incombustible	99.30

The average sizing tests of the coal and shale is as follows:

Material	Thru 20 Mesh	Thru 48 Mesh	Thru 100 Mesh	Thru 200 Mesh
20 mesh coal	98.6	95.0	56.2	20.0
Pulverized coal			99.2	92.4
20 mesh shale	95.6	76.4	53.6	40.8
Pulverized shale			99.8	97.0

The average sizing test on the pulverized Pittsburgh coal dust used in the ignition zone in propagation showed 99.8 per cent through 100-mesh, and 88.2 per cent through 200-mesh. The average analysis of this coal dust gave a moisture plus ash content of 5.85 per cent and a ratio of volatile combustible to total combustible of 39.42 per cent.

RESULTS OF 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 presence 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 quantitites.

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 6x9-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 through 20-mesh, and 30 per cent or more through 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.

Quantity Necessary:

Since the effectiveness of this method of preventing coal dust explosions depends upon the ratio of the inert dust to the coal dust, as much of the accumulations of the coal dust should be removed as possible before adding the rock dust.

The table on page IV shows that with the 2 per cent of gas in the ventilating current and where the fineness corresponds to that of the samples taken from the Trinidad Mine - that is, not more than 20 per cent through 200-mesh - enough inert dust should be added to make the total incombustible content 80 per cent, in order to prevent the propagation of an explosion. Since this usually figures out to be a comparatively small amount (two or three pounds per foot of entry), additional dust should be put in at the same time in order to neutralize the continued accumulation of coal dust.

In figuring the amount of rock dust necessary to use, only that portion which is 20-mesh and finer should be considered. If the rock dust used contains combustible matter and a proportionate amount of the incombustible amount of the rock dust is not available in rendering the coal dust inert, an extra amount should therefore be used.

Method of Application:

Where this method is used today the first application of rock dust to an entry is generally by hand, and in this manner may be made to stick upon the roof and ribs to the thickness of 1/4 to 1/2 inch, even when these surfaces are comparatively smooth. Where the accumulations of fresh coal dust are rather large, it is often necessary to apply a second coating of rock dust after a few months. This may usually be accomplished by means of some sort of an injector, most of the dust being thrown in the air and carried along by the ventilating current from which it is deposited over the previous coatings of rock dust and coal dust.

The effectiveness of rock dusting may be retained for a much longer period, if every precaution is taken to prevent the forming and accumulation of fresh coal dust.

The development of a suitable machine for applying a thick coating of rock dust to the roof and ribs of entries would greatly stimulate introduction of this method of explosion prevention.

Rock Dust Barriers:

Attention is called also to the use of rock dust barriers for separating one section of the mine from another, so that in case an explosion should occur in one section, it would not be able to pass beyond the barriers and spread to other portions of the mine. Explosion tests in the Experimental Mine are always stopped at the end of the test zone by means of these devices. Such rock dust barriers and the rock dusting method are described in Technical Paper No. 84, which may be obtained on application to the Bureau of Mines, Washington, D.C.

Effect of Gases:

Attention is called to the fact that a small percentage of gas in the ventilating current greatly increases the explosibility of the dust as shown by the table on page IV.

CONCLUSION

The Experimental Mine tests show that the dust from Trinidad coal is very explosive when dry, unless mixed with some inert material.

APPROVED: (Sgd) J. W. PAUL,
Chief of Coal Mine Investigations.

APPROVED: (Sgd) GEORGE S. RICE,
Chief Mining Engineer.

(Note: Printed with the consent of the U. S. Bureau of Mines).

(Above copied from Sixth Annual Report of the State Inspector of Coal Mines, Colorado, 1918, pp. 91 to 99).

A P P E N D I X No. 2.

This appendix is a list of names of those killed, together with nationality, place of residence, and whether married or single. There is also a summation as to nationalities sub-divided into those married and those single.

A P P E N D I X No. 2 (Cont.)

Summation as to Nationalities Sub-divided into those Married and Single.

GREEK		AUSTRIAN		ItALIAN		RUSSIAN		NEGRO (U.S.)		MONTENEGRO		MEXICAN		AMERICAN	
Mar-ried	Sin-gle	Mar-ried	Sin-gle	Mar-ried	Sin-gle	Mar-ried	Sin-gle	Mar-ried	Sin-gle	Maŕ-ried	Sin-gle	Mar-ried	Sin-gle	Mar-ried	Sin-gle
7	9	3	4	9	9	--	1	1	--	1	5	15	13	26	17
TOTALS															
16		7		18		1		1		6		28		43	

GRAND TOTAL --- 120

Note: 1 Single - No Nationality Given
1 Married - No Nationality Given

APPENDIX No. 3.

Explosibility of Dust from the Dawson No. 1 Mine,

Phelps Dodge Corporation, Dawson, New Mexico.

Explosibility of Dust from the

Dawson No. 1 Mine.

A study of the laboratory tests on the samples of road and timber dust collected in the No. 1 Mine after the explosion of the mine on February 8, 1923, and one sample of face coal secured in the mine in the year 1919 affords an opportunity to compare the explosibility of the dust from this mine with dusts from other mines that have been tested in the laboratory and in the Experimental Mine of the Bureau.

The following tabulation gives the analyses, sizing and location of the samples:-

MINE AIR SAMPLES COLLECTED IN DAWSON NO. 1 MINE, FEBRUARY, 1923

Lab. No.	Location of Sample	Volume of air passing cu. ft. per minute	CO_2	O_2	CO	CH_4	N_2	Volume of CH_4 Per Hr. cu. ft.	Volume of CH_4 Per 24 Hrs. cu. ft.
18085	Main return at fan, Feb.20	75,000	0.08	20.82	0.0	0.01	79.08	450	10880
18086	" " " " " 20	75,000	0.08	20.79	0.0	0.01	79.12		
18087	" " " " " 14	75,000	0.09	20.79	0.0	0.01	79.11		
18088	" " " " " 14	75,000	0.09	20.76	0.0	0.01	79.14		

At the rate of 450 cu. ft. of methane (CH_4) per hour, this is sufficient to make 8181 cu. ft. of air explosive.

These analyses indicate that the mine does not liberate a large volume of gas but the amount is such as to become an explosion hazard if the ventilation should be interrupted.

The origin of the explosion having been on the intake air current, the gas was not a factor in the ignition.

Tests on the explosibility of dusts from the Dawson No. 1 Mine were conducted in the laboratory steel dust gallery at Pittsburgh and the length of flame compared with the explosibility of Pittsburgh pulverized coal dust:

> Pulverized Pittsburgh coal dust has been ground until 98 to 99% passes through 100-mesh screen and 85 to 88% through 200-mesh screen.
>
> When tested in the Laboratory steel gallery, the igniting flame is produced by firing 9.66 grams of fffg black powder from the bore of a small steel cannon. The gallery is 10 inches in diameter and 17 ft. long.
>
> The following lengths of flame in the laboratory gallery are recorded when using pulverized Pittsburgh coal dust at the rate of 285 grams per 1000 cu. ft. of space:

Length of powder flame alone	11.1 ft.
" " flame with shale dust	8.5 "
" " flame coal dust alone	17.5 "
" " " " " 50% + shale dust 50% . .	13.3 "
" " " " " 40% + " " 60 . .	12.5 "
" " " " " 30% + " " 70 . .	12.1 "
" " " " " 20% + " " 80 . .	11.7 "

The length of flame of the samples from the Dawson No. 1 Mine were as follows:

Lab. No.

89651 ---	12.5,	14.0	and 14.5 feet
89654 ---	13.0,	13.5	and 14.5 feet
89658 ---	12.0		and 12.5 feet.

Laboratory sample 89651 tested in the gallery had been resized and only that part that passed through a 200-mesh was used in the gallery test. However, the flame lengths from this sample were not in excess of sample 89654 which had not been resized. The excess moisture plus ash in the sample 89651 may account for the flame length not being in excess of 89654.

The road and timber dust samples taken from the main entry show high percentage of ash, the timber dust being the highest. It is most probable that the timber dust sample derives a large part of its inert material from the disintegration of the roof shale.

Application of results:

Compared with the laboratory gallery flame lengths obtained, the samples are more explosive than Pittsburgh pulverized coal dust although the Dawson mine samples contain much less percentage of fine material than Pittsburgh pulverized coal dust.

The ratio between the volatile and total combustible

$\frac{V}{V + F.C.}$ for all the Dawson mine samples ranges between .43 and..70 with an average of .49 whereas Pittsburgh coal dust has a ratio of .40.

Compared with the results of tests in the Experimental Mine, reference explosibility chart figure 45, B. of M. Bulletin 167, it is found that all the Dawson samples fall within the "region of explosibility".

To prevent propagation of an explosion, in the absence of explosive gas, the dry dust in the Dawson mine should have not less than 77% of inert material in the form of shale or rock dust and with 1% of gas in the air the inert material should be 80%.

To prevent propagation of an explosion by the application of water, the fine coal should have not less than 25% moisture, and to maintain this condition, the application of water would constitute a major operation since a relatively large number of men would be required to apply the water and a man would be required to systematically take samples of the rib and road dust for the determination of the moisture and other inert material.

In those parts of the mine where a freezing temperature prevails during a part of the year, the application of water is impracticable and stone dusting is the only alternative.

Barriers of rock or stone dust are effective in stopping an explosion or limiting its scope, but to be effective the barriers must be of ample capacity and properly located with respect to the plan of the mine development; such barriers, altho effective in stopping an explosion, give no protection against the spread of the afterdamp which may be carried to other parts or sections of the mine where men may be working. The Bureau of Mines, therefore recommends dust barriers as supplementary to other preventive measures such as stone dusting or a system of watering that renders the coal dust inert to explosibility.

(Sgd). J. W. Paul, Chief of
Coal Mining Investigations.

Pittsburgh, Pa.
April 20, 1923.

Approved:
J. W. Paul, Acting
Chief Mining Engineer.

NAME	CITIZENSHIP	CIVIL STATUS	FAMILY RESIDENCE
Cantalie, Chas. (Out)	Greek	Married	Dawson, N.M.
Arvas, Nick	"	Single	
Kamp, Martin	Austrian	"	
Stamos, Paul	Greek	"	
Tomasoni, Frank	Italian	"	
Kapich, Pete	Austrian	Married	Pueblo, Colo.
Vucinich, Pete (1st papers)	Montenegro	Single	
Scopelitia, Gust	Greek	Single	
Simpson, Aaron	Negro (U.S.)	Married	Springfield,Ill.
Tozzi, Ernesto	Italian	Single	
Papas, Nick	Greek	Married	Greece
Rounika, Frank		Single	
Zanoni, Alessandro	Italian	"	
Leeming, Geo. W.	American	"	E.LasVegas,N.M.
Martini, Filini (Out)	Italian	Married	Italy
Kapich, Mike	Montenegro	Single	
Scopelitis, Cross	Greek	Married	Greece
Lira, Anton	Italian	Single	
Guiseppe, Tomasi		Married	
Markis, Geo.	Greek	Single	
Herrera, Higinio	Mexican	Married	Dawson, N.M.
Geromino, Antonio	Italian	Single	
Romero, Francisco	Mexican	Single	
Chiboukis, Evagelos P.	Greek	"	
Retsias, Nick J.	"	Married	Greece
Cassai, Luigi	Italian	Single	Italy
Scantalis, Antonios	Greek	Married	Dawson
Palumbo, Angelo	Italian	"	"
Litchford, Claud	American	Single	"
Alamillo, Marcial	Mexican	Married	"
Volanis, Nick	Greek	Single	
Perovich, Nick	American	"	
Barranco, Jesus	Mexican	"	
Alamillo, Anacledo	American	Married	Dawson
Stavovich, Mike	Montenegro	Single	
Gatti, Odorino	Italian	Married	Dawson
Nardini, Frank	Italian	Married	Dawson
Dallas, John	Greek	Single	
Lorenzo, Jim	Italian	Married	
Karamougis, John	Greek	Married	
Papis, Floryan	Austrian	Married	Rockville,Colo.
Liguzos, George	Greek	Single	
Santi, Pacifico	Italian	"	
Psyhas, George K.	American	Married	
Vulanovich, Elia	Montenegro	Single	
Pokorn, Jozef	Austrian	"	
Graves, Earl	American	Married,	Cherryville, N.M.

NAME	CITIZENSHIP	CIVIL STATUS	FAMILY RESIDENCE
Mullins, Ben H.	American	Married	
Gayovich, Mike	Montenegro	Single	
Janakas, John	Greek	Married	
Stoynoff, John	American	Single	
ZAnoni, Tony	Italian	"	
Marlar, Ben	American	"	
Gatti, Gennaro	Italian	Married	
Kallas, Georgis	Greek	Single	
Gomez, Cruz	Mexican	"	
Aguilar, Alex	American	"	
Morrison, Harry	"	Married	Cherryville, N.M.
Cortez, Joe	Mexican	Single	
Gomez, Santiago	"	"	
Dominguez, Julian	American	Married	Las Vegas, N.M.
De Abila, Felix	Mexican	Married	
Gallegos, Fermin	"	"	Koehler, N.M.
Cordova, Panfilo	"	"	Los Angeles, Cal.
Valpando, Fileberto	American	"	Raton, N.M.
Pinedo, Juan	Mexican	"	Dawson, N.M.
Archuleta, Julian	American	"	" "
Gardea, Felix	Mexican	Single	
DeLaLuz, Manuel	"	Married	Dawson
Rodriquez, Cruz	"	"	Carthage, N.M.
Marachino, Gios	American	"	Dawson
Curzi, Nazzarene	Italian	"	
Pellegrini, Baldo	American	Single	
Bonaventuri, Frenche	Italian	Married	
Kobana, Anton	Russian	Single	
Necas, Carlo	American	"	
Gomez, Isadora	Mexican	Married	Dawson
Sena, Ben	American	Single	
Rosales, Miguel	Mexican	Married	Dawson
Cruz, Juan	"	Single	
Maestas, Jose Anastacio	American	Married	Dawson
Duran, Gregorio	Mexican	"	"
Torres, Martin	"	Single	
Davies, William S.	American	Married	
Calderian, Gabino	Mexican	Single	
Ybarra, Manuel R.	"	"	
Ybarra, Manuel	"	"	
Gonzales, Andrey	Mexican	Married	Dawson

NAME	CITIZENSHIP	CIVIL STATUS	FAMILY RESIDENCE
Ybarra, Secundino	Mexican	Married	Dawson
Gonzales, Leandro	American	"	Antonchico,NM.
Masiaz, Wenaslado	Mexican	Single	
Green, J. Austin	American	Married	Texico,N.M.
Fimpel, E.C.	American	"	" "
Lawson, William H.	"	"	Dawson
Marez, Jesus	"	"	Roy, N.M.
Wilson, John	"	"	Gardner,N.M.
McNeish, Thomas	"	Single	
Cenotto, Burley	"	Married	Dawson
Duke, Carl	"	"	Albuquerque
English, Albert E.	"	"	Dawson
Kerr Alec	"	"	"
Estes, Clifton C.	"	"	Plainview,Tex.
Holmes, W.R.	"	"	Roy, N.M.
Trujillo, Al	"	"	Dawson
Maricich, Rode	Austrian	"	"
Trujillo, Fred	American	"	"
Gasparac, Matt	Austrian	Single	
English, Albert	American	"	
Mondragon, J. A.	Mexican	Married	Dawson
Howard, James	American	Single	Bristol, Tenn.
Trujillo, Roy	"	"	Pictou,Colo.
Montoya, Antonio	"	"	Mora, N.M.
Cartazar, Alonzo,	Mexican	Married	Dawson
Santilla, Pete	American	Single	
Delost, Joe	Austrian		
Costa, Christ P.	Italian	Single	
Brissili, Luigi	"	Married	Dawson
Charette, George	American	Single	
Chavez, Pat	"	Married	Dawson
Capen, Louis	Montenegro	"	"
Oblock, Tony	American	Single	
Velasquez, Marselino	Mexican	"	

APPENDIX No. 1.

This appendix is copy of report of an explosion hazard study by the U. S. Bureau of Mines of a coal mine in Southern Colorado, having conditions somewhat similar to those at Dawson, the coal being coking, dry, and friable, with thickness, dip, etc., somewhat as in No. 1 Mine at Dawson, and having somewhat more methane than at Dawson.

ROAD, RIB AND TIMBER DUSTS COLLECTED IN DAWSON NO. 1 MINE, FEBRUARY, 1923

Lab.No.	Kind of Dust	H_2O (As Received)	Vol. (As Received)	F.C. (As Received)	Ash (As Received)	Ash + H_2O (As Received)	$\frac{V}{V + F.C.}$ (As Received)	Sizing Thru 20-mesh grams	Sizing Thru 20-mesh %	Thru 20-mesh 48	Thru 20-mesh 100	Thru 20-mesh 200	Thru 200 mesh On 250 %	Thru 200 mesh On 325 %	Thru 200 mesh Thru 325 %	Thru 200 mesh Tota
89651	Timber	2.7	14.7	19.0	63.6	66.3	.436	833	61.7	78.5	60.6	45.7	.1	6.8	93.1	100
52	Road	2.5	19.8	22.2	55.5	58.0	.472	954	62.6	63.1	42.2	26.0				
53	Road	2.7	25.1	33.1	39.1	41.8	.422	975	63.4	67.7	41.5	20.3				
54	Road	2.5	32.7	13.9	50.9	53.4	.702	956	62.0	64.6	39.8	23.5				
55	Road	2.4	18.1	18.2	61.3	63.7	.500	1193	69.5	70.4	45.2	24.4				
56	Road	3.0	28.5	33.6	34.9	37.9	.459	908	64.5	57.4	36.6	22.6				
57	Road	6.3	27.1	30.7	35.9	42.2	.468	762	63.8	58.8	38.2	20.6				
58	Road	2.9	30.6	34.9	21.6	34.5	.467	857	64.3	56.2	34.2	20.7				
59	Road	2.1	27.2	30.4	40.3	42.4	.473	1015	68.2	61.2	35.0	14.0				
		27.1	223.8	236.0	413.1	440.2	4.409									
Average		3.01	24.86	26.22	45.9	48.88	.489				41.47	24.2				
33022	Face Coal	1.85	37.13	46.35	14.67	16.52	.445									

89651 Taken at old parting. Timber caps and crib and other timber for a distance of 200 lineal feet.

52 Main entry, 2300' from mouth of mine and 50' outby 4th north entry.

53 Main entry, 1900' from mouth and 25' inby rock dust barriers.

54 Main entry, 1600' from mouth, at point where timbers were knocked out at parting.

55 Main entry, 1500' from mouth, outside of old parting.

56 Main entry, 950' from mouth and 25' inby manway.

57 In manway, 925' from mouth; north side at intersection of manway and main return.

58 Main entry, 900' from mouth, opposite stopping on south side.

59 Main entry, 400' from mouth of mine, opposite stopping on south side.

33022 End of main entry, Sept. 15, 1919, by W. T. Lee, U.S.G.S.