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H. FOSTER BAIN, DIRECTOR

LESSONS FROM THE GRANITE MOUNTAIN SHAFT FIRE, BUTTE

BY
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First edition, June, 1922.

PREFACE.

It is not the general practice of the Bureau of Mines to publish reports of individual mine disasters, but the combination of circumstances that resulted in the shaft fire described in this paper were so unusual and unexpected and the loss of life so great that it has seemed desirable to make an exception and utilize the dramatic interest of the story to point the moral of how great a loss of life may result from a single act.

The Granite Mountain shaft was unusually well protected against fire, and the cable that, accidentally ignited, set fire to the shaft was being put into place to furnish a further safeguard to the safety of the miners, and yet it brought about the death of 163.

The apparently tardy appearance of this report is due not only to the fact that the Nation was at war when the accident happened, but also because the funds available for publishing the reports of the bureau have in recent years been insufficient to allow prompt publication. Furthermore, it seemed not undesirable to allow enough time to elapse for so distressing an event to take on something of an historical character before attempting its discussion. It is to be hoped that the lessons of the tragedy will be as helpful as the account of the heroism displayed in the work of rescue is inspiring. Also, due appreciation must be expressed of the action of the officials of the North Butte Mining Co. in cooperating in every way in the effort to get at the facts, and in acquiescing in the publication of a detailed account of a tragedy that they naturally must prefer to have discussed as little as possible.

H. Foster Bain,
Director.

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LESSONS FROM THE GRANITE MOUNTAIN SHAFT FIRE, BUTTE.

By DANIEL HARRINGTON.

INTRODUCTION.

On the night of June 8, 1917, the flame of a carbide lamp accidentally set fire to the uncovered and frayed insulation of an armored power cable near the 2,400-foot level of the North Butte Mining Co.'s Granite Mountain shaft. How this insulation accidentally became exposed is explained on page 15. The highly flammable oiled fabric set fire to the shaft timbers, and as this is a downcast shaft the fire spread with great rapidity, soon filling the mine workings with smoke and gas. At the time 410 men were working underground, 247 of whom escaped by various means, but most of the 163 remaining were probably overcome soon after the fire started, and perished. Only two men were actually burned. The cause of the disaster was purely accidental. The immediate effect was the unexpected reversal of normal conditions; the ultimate effect was great loss of life and the destruction of the main hoisting shaft, putting it temporarily out of service. The work of rescue and fire fighting continued eight days. The following pages present an attempt to draw some practical conclusions and suggestions from this disaster.

The property of the North Butte Mining Co. consists of about 220 acres in the northeastern part of the Butte district, Montana. Next to the Anaconda Copper Mining Co. it is the largest producer of the district. In 1916, the year before the disaster, there were 1,160 men employed. The output was 560,947 tons of ore, which yielded 24,498,181 pounds of copper, 1,047,063 ounces of silver, 1,712 ounces of gold, and 412,953 pounds of zinc. The profit was $2,479,595. The total development work for that year was 21,694 feet. During the first half of 1917, the year of the accident, the daily tonnage of ore averaged 2,000, an increase of 400 tons over that of the year 1916.

As shown in Figure 1, to the north of the North Butte is the Black Rock claim of the Butte and Superior, to the south and west are the High Ore, Badger, Bell-Diamond, and Modoc claims of the Anaconda, and to the east is the Tuolumne.

ACKNOWLEDGMENTS.

The officials and employees of the North Butte Mining Co. were very courteous and did everything possible to assist in the investigation of conditions in the North Butte mine before and after the fire and during the period of rescue and recovery work; particularly is this true of Mr. Robert Linton, president, and Mr. N. B. Braly, general manager of the company, who before, during, and after the fire have shown a spirit of cooperation and a desire to adopt the best measures for safeguarding the health of their employees. Ventilation had been given especial attention.

Likewise, officials of the Anaconda Copper Mining Co. were generous in affording facilities for studying conditions in connection with fires in other Butte mines. To the safety department of the Anaconda company, particularly the first-aid and mine rescue stations, too much credit can not be given for consistent, efficient, sustained, and generous effort toward lessening the loss of life and hastening recovery work through its well-organized and equipped mine rescue service. The North Butte Mining Co., the Butte and Superior Mining Co., the Elm Orlu Mining Co., and other mining companies of Butte also contributed safety men and equipment.

SHAFTS AND CONNECTIONS OF NORTH BUTTE MINE.

The main shaft of the North Butte, called the Granite Mountain, is 3,740 feet deep, and has a downcast air current. It was and is a modern and completely equipped shaft. The other main shaft, an upcast, is the Speculator, which is 800 feet from the Granite Mountain and 3,000 feet deep. Subsidiary shafts are the Gem and Rainbow. The former is about one-quarter mile northeast of the Speculator and the latter is 1 mile northeast of the Granite Mountain. Plate I is a panorama of the North Butte territory, showing the exteriors of the Granite Mountain and Speculator shafts.

The various levels of both shafts were connected and cages operated in both to each of those levels. No men were working between the 800 and 1,800 foot levels.

There was an engine on the 2,800-foot level, and a cage, independent of the other cages, operating between the 2,800 and 3,600 foot levels. At the time the fire broke out only three men were working below the 3,000-foot level.

On the 2,000-foot level was a connection with the Rainbow shaft. Also at various levels there were connections with other mines. Details of these connections and escapeways are given on pages 42 to 45, together with an account of their use and the results during the fire. Plate II shows the connections on the 2,200-foot level.

The Granite Mountain shaft has two main hoisting compartments, each 4 feet 6 inches by 5 feet inside timbers, and a third compartment 7 by 5 feet. In the third, a "chippy," or auxiliary cage, works in a space 4 feet 6 inches by 5 feet, and the remaining 2 feet 6 inches by 5 feet is utilized by air pipes, water pipes, and electric power lines.

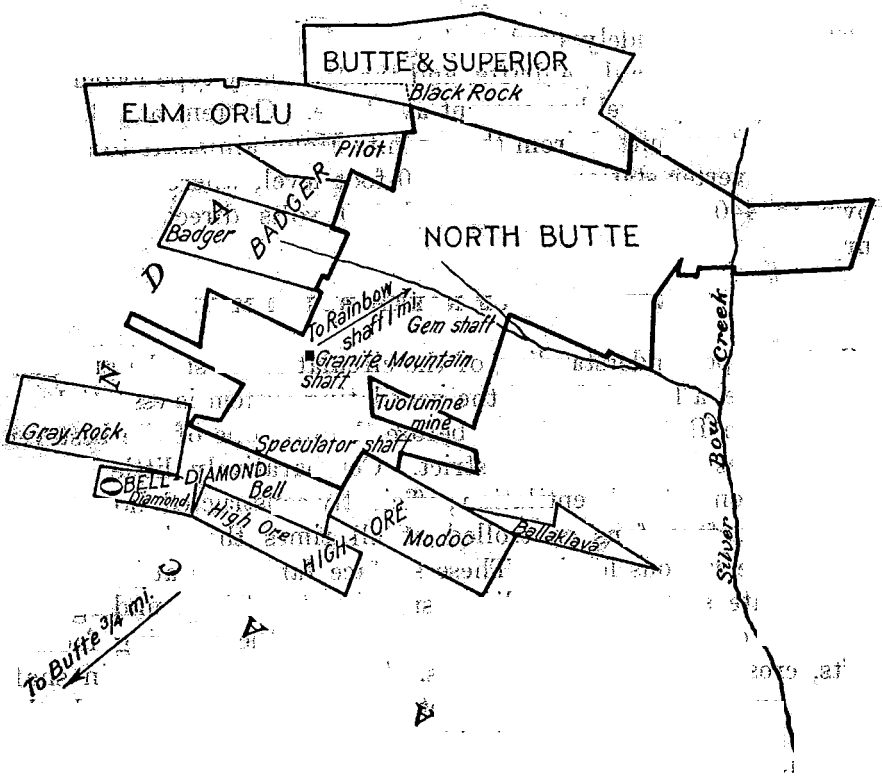


FIGURE 1.—Plan of part of the Butte mining district.

The chippy compartment is separated from the main compartments of the shaft by a solid partition of timber to prevent rock from skips in the main compartments from reaching the chippy compartment. The chippy cage is used for handling men and material, and is operated by a separate hoist. Concrete skip-pockets or bins have been constructed on the 800, 1,800, 2,000, 2,400, 2,600, 2,800, 3,000, 3,200, 3,400, and 3,600 stations of the Granite Mountain shaft. The self-dumping skips loaded from these pockets have a capacity of 7 to 8 tons of ore or waste each. At the shaft collar the

skips can be changed in three minutes to 4-deck cages, capable of holding 40 men. The stations along the Granite Mountain shaft are approximately 24 feet wide, 12 to 16 feet high, and 30 to 50 feet long, and were well protected with arched sets 10 by 10 or 12 by 12 inch sawed timber, since changed to concrete. The stations are well lighted electrically, have sheet-steel floors, and are supplied with city (Butte) water piped from the surface. The shaft is completely equipped with electric signal devices, also a hand signal.

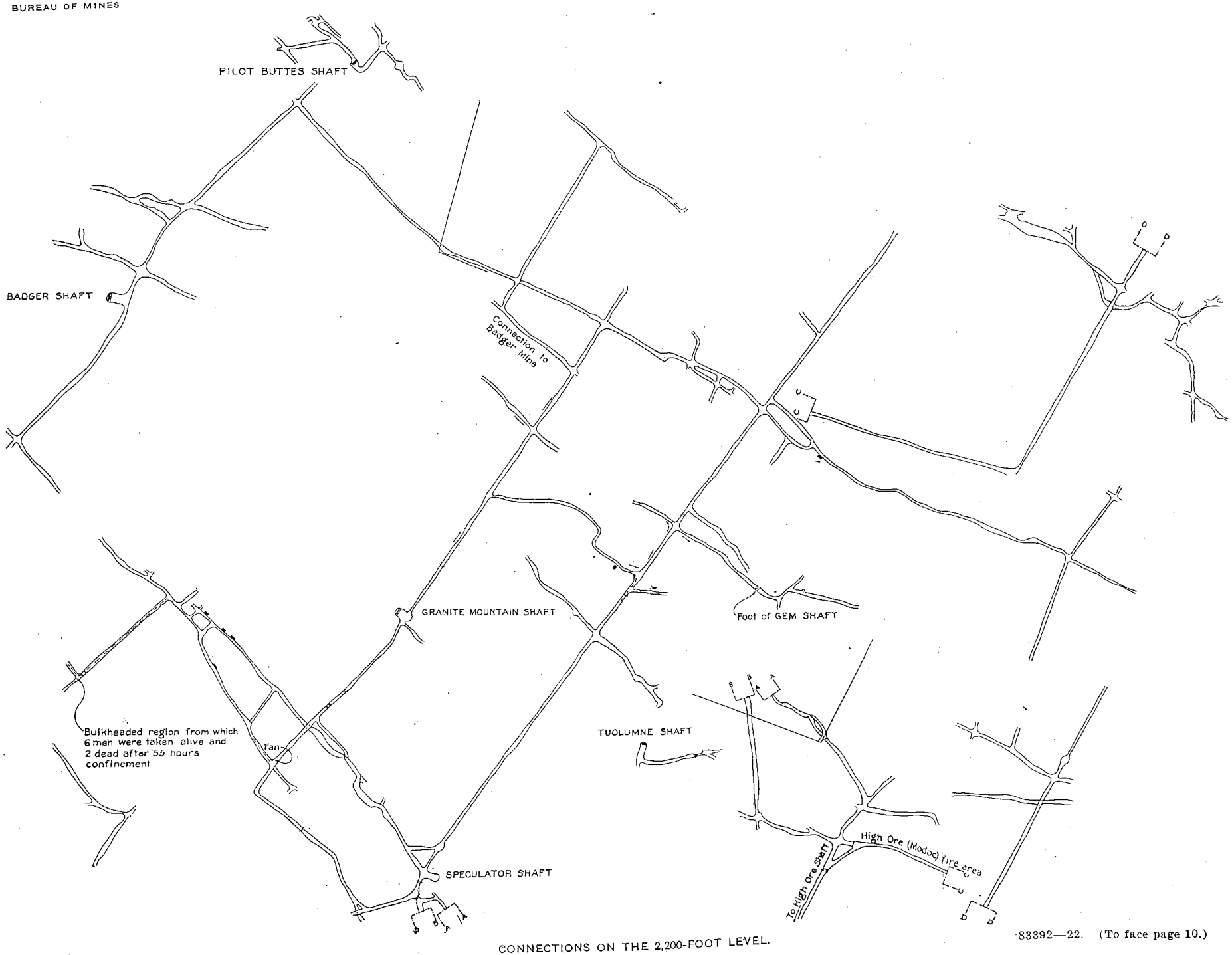
Carbide lamps replaced candles throughout the mine in the spring of 1916. The men buy their own lamps at cost price, and the company supplies the carbide.

Electricity is widely used underground for lighting and power at stations, main-haulage drifts, and the 15 trolley-type locomotives. Practically every level has current available. Current at 2,300 volts pressure is transmitted from the Granite Mountain shaft to a transformer-converter station on the 2,600-foot level, where it is stepped down to 440 volts alternating and 250 volts direct for various purposes.

VENTILATION OF NORTH BUTTE MINE.

For a proper understanding of the circulation of smoke and gases from the fire, a knowledge of the ventilating system is essential.

The North Butte is, and was before the fire, one of the best ventilated mines in the Butte district. Comparatively little reliance was placed on natural ventilation; efficiently constructed, housed, and operated surface fans controlled at all times the air circulation through the various levels. These surface fans were augmented by an elaborate system of auxiliary small motor-driven underground fans with canvas pipes for conveying air to the working faces in drifts, crosscuts, stopes, and raises. The Granite Mountain shaft, with an area of about 70 square feet clear of timber, pipe, and other obstructions except cages and skips, was the main downcast, consequently it was the main source of intake air, though at times the North Butte mine drew air from the Badger mine on the 1,800, 2,000, and 2,200 foot levels, and from the High Ore mine at various levels, but especially from the 2,200 to the 2,800. When cages and skips were not running, the Granite Mountain shaft delivered somewhat less than 60,000 cubic feet of fresh air a minute into the mine workings, chiefly on the 2,200, 2,400, 2,600, 2,800, and 3,000 foot levels. On the 3,000, a No. 6 Sirocco fan, direct-connected to a 30-horsepower motor, delivered air at velocities of 3,000 to 5,000 feet per minute through a 16-inch canvas pipe in the pump compartment of the Granite Mountain shaft, to the working faces of crosscuts on the 3,200, 3,400, and 3,600 foot levels. The return air went into the



CONNECTIONS ON THE 2,200-FOOT LEVEL.

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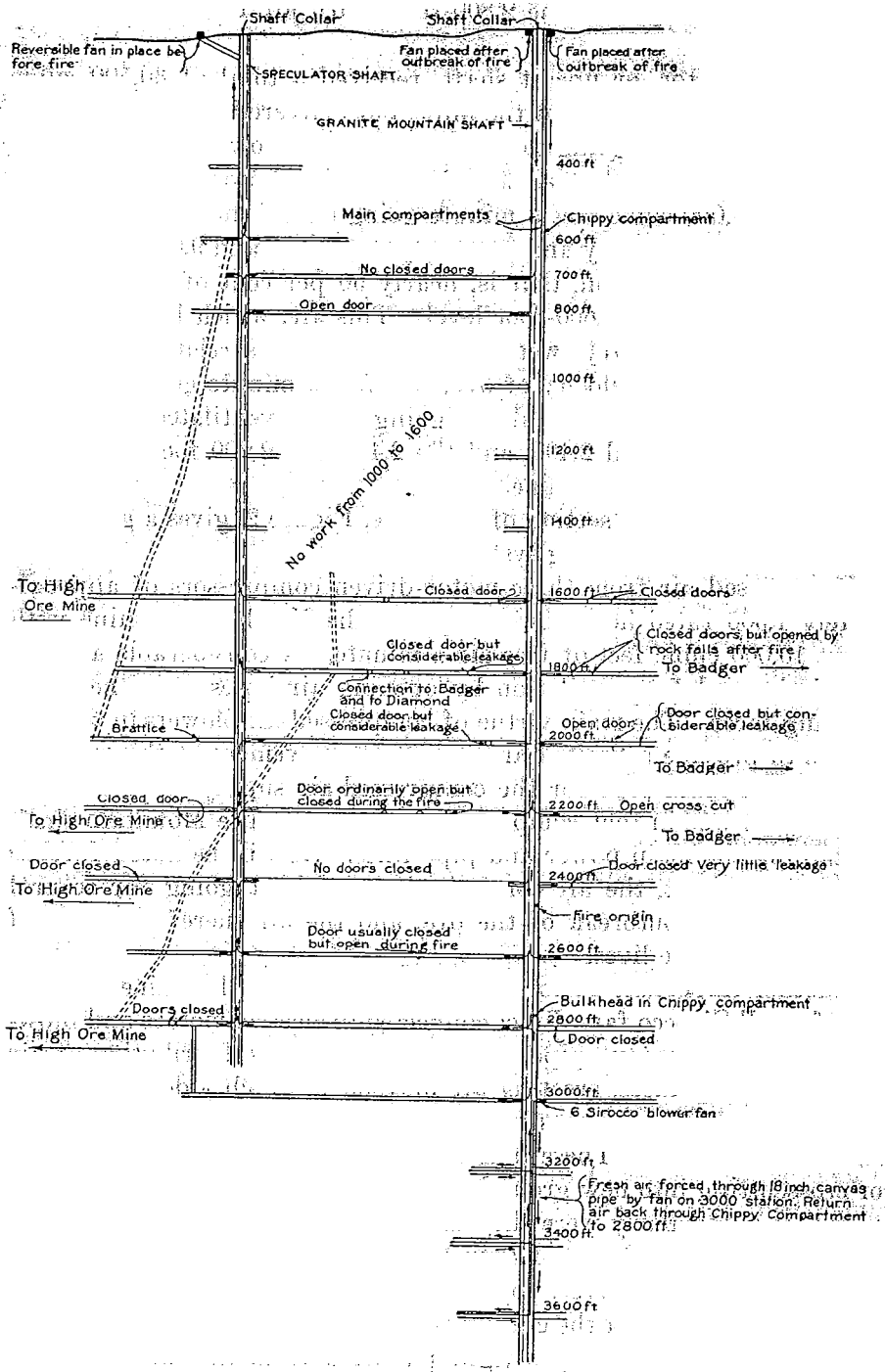


FIGURE 2.—Section of Granite Mountain shaft.

chippy compartment of the shaft, which was bulkheaded above the 2,800 and discharged on the 2,800 the return air from the crosscuts named.

The Speculator, or upcast shaft, received a total of 30,500 cubic feet of air from six levels of the mine, but delivered only part of this at the surface, some going to the Gem and Rainbow shafts.

The 2,600-foot level acted largely as a distributor of fresh air to the mine, 14,000 cubic feet a minute going out of the Granite Mountain shaft in an easterly and northerly direction, and 9,000 cubic feet in a southerly direction, that is, nearly 50 per cent of the total air left the shaft at the 2,600-foot level. This air, which left the shaft at a temperature of 51½° wet bulb, 58° dry bulb, a relative humidity of 65 per cent at a velocity of over 300 feet a minute going east and north and over 200 feet a minute going south, ventilated the stopes between the 2,600 and 2,400, and the 2,400 and 2,200 foot levels, the most active parts of the mine.

The accompanying section of the mine, Figure 2, gives a good general idea of the ventilating system.

Compressed air from three motor-driven compressors of approximately 1,500 rated horsepower supplies the North Butte mine with about 10,000 cubic feet of free air a minute. A considerable amount of this is used for ventilation by opening air hoses at or near the working faces. The main virtue of compressed-air blowers in ventilation is to provide a limited amount of air movement at the working place. The main pipe for the compressed-air supply for the North Butte mine was in that compartment of the Granite Mountain shaft containing the main power and pipe lines. As will be noted further on in this report, the air compressors were kept going for several hours after the outbreak of the fire, and the air therefrom assisted materially to save lives.

Another important factor in the ventilation of this mine was the use of small Sirocco fans direct connected to electric motors and blowing air through canvas pipe. These fans acted as distributors of air to the working faces, creating air movement which aided in removing stagnant air and fumes from blasting and in immediately evaporating perspiration. These fans were most generally used in drifting or crosscutting into new ground where no natural air circulation was possible; particularly were they used in the lower parts of the mine where rock temperatures of over 100° F. were encountered, to make these places comparatively comfortable at all times.

It will be noted that the chippy compartment of the Granite Mountain shaft was divided by a tight partition from the surface to the bottom of the shaft; that this shaft was the main source of intake air, although probably 8,000 to 10,000 cubic feet of air a minute was

released through compressed-air drills; and that although at times surrounding mines contributed much air to the North Butte mine (the strong suction from North Butte fans preventing other mines from taking air from the North Butte), at the time of the fire there was little or no interchange of air with other mines except possibly the Badger and Diamond mines south of the Granite Mountain shaft on the 1,800-foot level. The Granite Mountain shaft delivered practically no air to the mine until the 2,200-foot level was reached; the 2,400 received but a small quantity from this shaft; and the 2,600 distributed large quantities from the shaft north, east, and south. The 2,800 also took a considerable quantity southerly, much of it having been used in the levels below the 3,000; the 3,000-foot station of the Granite Mountain acted as distributing point for intake air into the 3,000-foot workings, as well as to the 3,200, 3,400, and 3,600.

It will also be noted that at the 1,600, 1,800, and 2,000 foot stations doors had to be placed in openings leading to the Granite Mountain shaft to prevent the hot, humid mine air from rushing into this shaft and vitiating the fresh intake air. This condition promoted the rapidity with which the poisonous fumes were distributed on the night of the fire. The fact that the crosscuts between the Granite Mountain and Speculator shafts on the 700, 800, and 2,400 foot levels were practically neutral as to air movement, and that the doors in these crosscuts were generally left open, also had an important bearing on the distribution of fumes during the fire. The section of the mine shows a large number of doors. One type has a spring-latch door lever with approximately 100 feet of rope attached on each side of the door, and along the drift. This device is to enable motormen on locomotives to open the doors without stopping or requiring assistance. During the fire, pieces of rock fell on these ropes and thus opened the doors, allowing smoke to circulate. Considerable air also leaked through the opening for the trolley wire through the door frames at the top.

It should be remembered that the Speculator shaft, although essentially a natural upcast, acted largely as a distributor of hot and humid air into various levels; it depended on the difference in temperature and humidity of its air as against the temperature and humidity of the downcast air for the tendency of the air to ascend rather than to descend. The movement of the cages and skips in the shaft, which created eddies, tended greatly to neutralize the ability to upcast. Moreover, as the hot and the practically saturated air from the lower parts of the mine neared the surface it cooled and condensed, and much water dropped back in the shaft, which at times almost converted the shaft into a downcast and always prevented the entrance of much air from the lower levels into the shaft.

A reversible No. 11 Sirocco fan, connected to a 75-horsepower 440-volt, alternating current motor on the surface at the Gem shaft, and a similar arrangement on the surface at the Rainbow shaft, both acting as suction fans, pulled upward of 50,000 cubic feet of air a minute from the North Butte, and probably 8,000 to 10,000 cubic feet a minute of additional air left the mine through the Speculator shaft as natural mine upcast.

The housing of a No. 15 Sirocco fan at the surface near the Speculator shaft was being reconstructed at the time of the outbreak of the fire in order to make the fan reversible. The fan itself, with an electric motor, was in condition to start at any time, and the construction of a temporary canvas brattice in less than 45 minutes made possible the blowing of air down the Speculator shaft, which greatly facilitated recovery work and forced gases back into the Granite Mountain shaft.

Analyses of samples taken from 35 different places in the mine prior to the fire, and of samples of returned impure air from three shafts are given.

Analyses of air in the North Butte mine.

	Normal air in all parts of mine.	Return air.		
		Gem.	Rainbow.	Speculator.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Oxygen	20.49	20.16	20.25	20.47
Nitrogen	79.27	79.53	79.45	79.37
Carbon dioxide	0.23	0.31	0.30	0.16
Carbon monoxide	0.00	0.00	0.00	0.00
Methane	0.00	0.00	0.00	0.00

The average wet bulb temperature in the 35 places sampled was 79° F., and the relative humidity 94 per cent. Although a few of the working faces, such as stopes and raises, are uncomfortable, the air in the North Butte mine is considered good. Under normal operating conditions about 50,000 pounds of 40 per cent dynamite is used monthly, equal to about 900 pounds a shift on 28 days.

CAUSE OF THE FIRE.

In order to provide better protection against a possible fire in the Granite Mountain shaft the North Butte company had started to pipe the shaft and place in it at frequent intervals sprinklers, to be controlled by valves from the surface or from various levels. It was decided to place small tanks at intervals of every few hundred feet down the shaft in order to reduce and equalize the pressure. Several of these tanks had been placed, much of the pipe had been installed in the shaft, and the system was practically complete except for the plac-

ing of a tank at the 2,600-foot level. As previously mentioned, the main electrical transforming station was on this level, about 50 feet from the shaft; and partly as a fire-prevention measure it was planned to move this station several hundred feet back from the shaft to a place already prepared before the fire, where a minimum of timbering was necessary. The old electric station near the shaft was then to house one of the water equalizing tanks.

Preparatory to moving the electric station, a crew of four electricians, three rope-men, two shaft-men, and one hoist-man early on the morning of June 8 started to lower 1,200 feet of lead-armored cable into the shaft, to be used in extending the main transmission wire to the newly prepared station. The cable weighed 5 pounds a foot, or 3 tons for the whole. The method used to lower it in the shaft was customary in the district. The rope on the chippy cage was detached and put in the pipe compartment adjoining, and the cable was lashed to it by 4-foot lengths of hemp rope, placed every 10 feet for the first 500 feet of cable and every 5 feet thereafter. On account of the probability of crushing the cable no positive clamps with bolts were used.

After about 16 hours' continuous work the lower end of the cable had come opposite the 2,600-foot level, and was ready to be taken into it, when the lower 200 feet of the cable was seen to be somewhat coiled around the hoisting rope. In order to remove these twists the hemp lashings were being removed from about 200 feet of the lower end, when the men noticed that the cable was slipping. The men had scarcely reached safety on the station before the cable fell, tearing away some of the hemp lashings, but slipping most of them and leaving some attached to the rope and some to the cable. This happened at 8 p. m.

The cable in falling tore away the brackets fastening the air and water pipes to the timbers, and lodged in the pump and auxiliary hoisting compartments from about the bulkhead in the auxiliary compartment just above the 2,800-foot level to about 50 feet below the 2,400-foot level. In its fall of several hundred feet, the cable struck against the timbers and other obstacles on its way down, and approximately 50 per cent of the lead armor was torn off, which exposed and frayed the oil-impregnated cambric and jute insulation beneath. Of the cross section of the cable, fully half was oil-impregnated, highly flammable material. After an inspection of the cable, the electricians decided that its use as a conductor was at an end, and that the removal of the tangled mass from the shaft would require much time and labor. As it was then almost midnight, and the men had worked continuously for 18 hours, they notified the assistant foreman of the situation and went home.

On account of the breaking of the water pipes a number of contractors who were drilling in crosscuts below the 3,000-foot level went home early, about 11 p. m., thus probably saving their lives.

At 11.30 p. m. the assistant foreman, a shift boss, and two shaft men went down on the auxiliary cage to a point 50 feet below the 2,400-foot station to try to find an end of the cable to attach to the cage and so pull it up. The two foremen of the four men stood on shaft timbers to see whether an end was available, and in doing this the flame of a hand carbide lamp was brought into close contact with the frayed, oil-soaked insulation. A blaze started immediately, and spread so quickly that it forced the four men to the 2,400-foot station.

Although there were several men on this level, and all took measures to extinguish the flame, the extremely flammable nature of the cable insulation and the dryness of the shaft timbers caused the flame to spread so rapidly that within five minutes of the initial ignition the hot gases had converted the chippy compartment of the shaft with a velocity of downcast air over 700 feet per minute into an upcast, and rapidly filled the 2,400-foot station with smoke to such an extent that all the men were driven from the station in less than 15 minutes after the fire started. After this the smoke started south along the 2,475 south crosscut toward the Edith May stopes, and then toward the Speculator shaft.

By midnight the skips were changed at the surface to the 4-deck cages, but by this time the "squawker," an auxiliary electric signal at stations, and the shaft signals had been burned out. In addition the signaling system on the lower levels of the Speculator shaft was also temporarily out of commission, due to retimbering the shaft.

Events were rapid, as smoke started to come from the Speculator shaft at 12.10 a. m., or in less than half an hour from the start of the fire in the Granite Mountain shaft.

The 2,000 and 1,800 foot levels of the Granite Mountain were filled with smoke by 12.10 a. m. Doors at the 2,000-foot level were temporarily blocked, and the smoke coming on that station from the chippy compartment was to a large extent short-circuited, and then entered the main downcasting compartments, flowing into the 2,400, 2,600, 2,800, and 3,000 foot levels. The same short-circuiting took place on the 1,800-foot level. After this happened, distribution of smoke to the lower levels was rapid.

Before 1 a. m., gases had penetrated to the High Ore, Diamond, and Badger mines, necessitating the removal of the night shift at work. Two men were overcome while attempting to erect a brattice on the 1,800-foot level of the Diamond within 50 feet of the station.

A peculiar feature of the disaster was that the fire in the shaft did not reach the 2,800-foot level, though the shaft timbers were well scorched 10 feet above the station.

The upper levels, that is, the 400, 600, 700, and 800, were also quickly filled with smoke, particularly the 700 and 800, where 31 men perished.

METHODS OF ESCAPE.

The men had been warned of the fire by the smoke and by various foremen, especially Sullau and shift bosses, who covered considerable ground at much risk. A number of men escaped through the Diamond mine on the 2,200, through the High Ore on the 2,400, and through the Badger on the 1,800 and 2,000 foot levels. Two groups of men bulkheaded themselves in the 2,254 and 2,471 crosscuts, and all but six were saved. Another group did likewise, but perished. (See pp. 24 to 31.) No men were working between the 800 and 1,800 foot levels. Of 57 men working on the 400, 600, 700, and 800 foot levels near the Speculator shaft, 32 managed to reach the 600 and 400 foot levels through manways, and were hoisted to the surface. These were the only men taken out alive during the fire through either this or the Granite Mountain shaft. Those in the bulkheads and other live men were eventually brought to the surface by rescue parties. The fatalities totaled 163.

On two different occasions prior to June 8, 1917, the men had been rushed out of the North Butte mine and hoisted through the Granite Mountain shaft, to escape gas that had broken in from the Modoc mine fire. As several bodies were found on different stations of the Granite Mountain shaft and in crosscuts leading to the shafts, it is probable that when these men first detected the odor of gas and smoke, they started for the Granite Mountain shaft directly into the fire, thinking that the gas and smoke came from the Modoc fire, which was still burning.

COMBATING THE SMOKE.

As a result of the prompt decision of the general manager of the North Butte, Mr. N. B. Braly, the fans at the Rainbow and Gem mines, then acting as suction fans, were reversed to blowers by 12.15 and 1 a. m., respectively. The Gem fan had already been stopped shortly after midnight, which tended to prevent the spread of the gases through the mine. The fan at the surface of the Speculator shaft was started as a blower soon after 1 a. m. This was to clear the Speculator shaft of fumes and force them up the Granite Mountain. Within 90 minutes of the start of the fire in the electric cable these three fans were blowing 100,000 cubic feet of fresh air a minute into the mine, all tending to force the smoke out of the workings and up the Granite Mountain shaft. The shaft was allowed to burn freely for five hours in order to create a suction, car-

rying gases to the surface, and when water was eventually turned on, care was taken not to convert the shaft into a downcast and again fill the mine with smoke. Within 48 hours of the outbreak, two motor-driven fans, placed in the 2,800-foot level connection of the North Butte and High Ore mines near the latter's shaft, were blowing 10,000 cubic feet of good air a minute past the 2,800 Speculator station. This was done to shorten the distance traveled by rescue parties. Two large Sirocco fans, each driven by 75-horsepower motors, were lent by the Anaconda company, and placed at the surface over the Granite Mountain shaft within two days after the start of the fire. These fans removed over 50,000 cubic feet of gases a minute acting as suction, and aided greatly in freeing the mine of gas; also they enabled more water to be used in preventing the spread of fire in the shaft. The Gem and Rainbow fans were reversed to suction fans after June 10.

RESCUE WORK.

The following notes will show the prompt measures taken in rescuing the imprisoned men, carrying out men in whom some life may have remained, and recovering dead men. They also show the value of first-aid training, to what extent it was in vogue in the Butte district, and how the United States Bureau of Mines assisted and influenced this training and the work of rescue.

The first attempt at rescue work was by Messrs. Goodell and Burns, shortly before 1. a. m. on the night of the fire. They both wore Draeger oxygen apparatus. They went to the 700-foot level through the Speculator shaft and removed two bodies from workings at that depth.

At 1.15 a. m., R. J. Cole, safety engineer for the North Butte company, and another man, wearing Draeger apparatus, went through much smoke and gas to the 700-foot station of the Granite Mountain. They passed several bodies.

At 1.15 a. m., J. L. Boardman, in charge of first-aid and mine rescue work for the Anaconda company, arrived at the North Butte and turned in a general call for all the rescue men and equipment in the district. On account of gases overcoming men in the adjoining Diamond, Badger, and High Ore mines, apparatus was diverted to them, especially the Diamond. About 110 North Butte men were hoisted alive from the Badger, many of whom were more or less affected by gas. Some were given artificial respiration and sent to the hospital. Men wearing the Draeger apparatus made several long trips in smoke and gas and saved many lives by assisting partly exhausted and overcome men to safety. Several of the apparatus men were themselves affected and taken to hospitals. The Badger

mine was a base for exploring the 1,800, 2,000, and 2,200 foot levels of the North Butte for several days. About 60 men escaped through the 2,200 and 2,400 foot levels of the High Ore mine in comparatively good condition. Draeger rescue squads, under T. Oaas, foreman of the High Ore, made this a base for exploring the lower workings of the North Butte. An apparatus crew from the Tramway mine, coming from the High Ore on June 10, found the 2,254 bulkhead (described on page 27) and rescued 6 live men on June 11. Later on the High Ore base was transferred to a point near the North Butte's Speculator shaft, after two fans had been set up to force in fresh air.

Although recovery work was in progress at practically all periods after 1 a. m. June 9, through the Badger, High Ore, and Speculator shafts, employing men with and without apparatus, the main force of trained men of the Butte district did not arrive until after daylight on June 9. The work was then organized. It is unlikely that any more men could have been rescued alive, as those who perished must have been overcome soon after the fire started.

WORK OF BUREAU OF MINES RESCUE CARS.

Shortly after 2 a. m., Daniel Harrington, an engineer of the Bureau of Mines, and recorder of these events, arrived at the mine. Before 3 o'clock, telegrams had been sent to the bureau mine rescue cars at Red Lodge, Mont., and at Colorado Springs, Colo. The former, car No. 5, arrived shortly after 3 p. m. C. A. Allen was in charge, and had with him foreman miner J. J. Forbes and first-aid miner J. C. Dickinson, also a cook and a stenographer. The car was equipped with 12 sets of Fleuss apparatus, 9 sets of Draeger apparatus, an abundance of soda, flash lights, and batteries, for this, its maiden experience at disasters. Forbes, who had much experience, was assigned to alternate with Mr. Boardman in taking general supervision of apparatus and testing of apparatus, on the surface; Dickinson was assigned to night duty underground leading and directing apparatus crews; Mr. Allen remained on the car to direct car work and to be in reserve in case of emergency. Car No. 2 arrived about 8 a. m. on June 11 with C. A. Herbert in charge. He had with him foreman miner Chisholm, volunteer rescue men F. W. Price and Duncan Penwell, of Colorado Springs, with a stenographer and a cook. This car had 11 sets of Fleuss apparatus, and a supply of soda, oxygen, flash lights, and batteries, all of which were in use less than 2 hours after the arrival of the car.

Apparatus crews were early sent to close and seal doors on all drifts leading to the Granite Mountain shaft; much admirable work was done as the smoke was very dense in places. On the 1,800, 2,000, 2,200, and 2,800 foot levels, the gases issuing from the Granite Moun-

tain for some days after the fire started were essentially smoke, saturated with steam, and the apparatus men had to be guided as to direction largely by feeling rails, as the use of eyes even with goggles was practically out of the question.

The early and strenuous work of the apparatus men in closing and sealing doors, together with the fact that the mine had been equipped with ventilating fans capable of either forcing or exhausting the air, and the prompt using of the fans, resulted in clearing the mine workings of gases sufficiently to allow 25 men to escape from the 2,471 bulkhead on June 10.

By noon of June 9, or 12 hours after the outbreak of the fire, there were available for use over 50 sets of apparatus, and at least 30 apparatus wearers were employed underground on each of the 8-hour shifts. The 400, 600, 700, 800, and 1,800 foot levels were well explored from the Speculator shaft and about 30 bodies were recovered; the 1,800, 2,000, and 2,200 were explored by apparatus men from the Badger and six bodies were recovered; and the 2,200, 2,400, and 2,800 were entered by apparatus men from the High Ore who took out 15 bodies.

By night on June 10, less than 48 hours after the fire began, the Speculator shaft had been freed of gas, the 2,400 had been cleared to such an extent that the 25 men behind the 2,471 bulkhead walked unaided and without apparatus a distance of over one-fourth of a mile, and were hoisted through the Speculator shaft to safety. Moreover, 80 bodies had been recovered; a systematic exploration of drifts, especially blind ends, had been made; blueprints had been given to the heads of rescue parties; and account was kept of progress. All apparatus wearers were checked into and out of the mine, with time of entrance and exit and destination of exploring party; and a reserve rescue force fully equipped was on hand to go to the aid of any party that overstayed its time.

On arrival of Car 2 from Colorado Springs on the morning of June 11, with 11 sets of Fleuss apparatus, the following number of sets were available for use:

Fourteen sets Draeger 2-hour apparatus, 1907 type, owned by A. C. M. Co.;

Thirty-six sets Draeger 2-hour apparatus, 1911 and later types, owned by A. C. M. Co.;

Four sets Draeger 2-hour apparatus, owned by North Butte Mining Co.;

Six sets Draeger 2-hour apparatus, owned by Butte & Superior Mining Co.;

Nine sets Draeger 2-hour apparatus, owned by United States Bureau of Mines;

Twenty-three sets Fleuss 2-hour apparatus, owned by United States Bureau of Mines.

This gave 69 sets of Draeger and 23 sets of Fleuss, or 92 sets of 2-hour apparatus, with an abundance of repair parts and supplies,

and in addition about 12 sets of one-half-hour apparatus. The oxygen consumption was very heavy, but the supply was practically unlimited at the Anaconda and Tramway rescue stations of the Anaconda company, where electrically driven oxygen pumps were used to fill bottles. Two Ford trucks delivered empty oxygen bottles to the two filling stations and the filled bottles, as well as other supplies, to the Bureau of Mines rescue cars and to the apparatus bases at the High Ore, Badger, Diamond, and Speculator mines. Extra men were placed at work making apparatus repairs, filling oxygen bottles, and cleaning Fleuss bags. Fresh apparatus was supplied with little or no delay, except that the popularity of the Fleuss apparatus, which was new to the Butte district, and lack of extra Fleuss bags caused some delay in emptying, cleaning, and refilling bags for those who insisted on having that type. It is stated that there were 75 sets of apparatus actually in use at one time during the recovery work, and there was scarcely a period during the first four days of the work when at least 50 sets were not in use.

Although about half of the bodies had been removed by June 10 and much territory had been explored, by far the most difficult part of the recovery work remained, namely, the removal from remote parts of the mine of the bodies of about 80 men and of 7 horses, now in an extremely advanced stage of decomposition, and the exploration of many miles of drifts in the lower part of the mine, and of raises, stopes, and manways. It was decided to defer this work until air circulation could be restored and much of the poisonous gases cleared out, and to use half-hour apparatus, as the narrow openings in the North Butte manways, although commendable from the standpoint of safety in operating, would not permit safe passage to wearers of the bulky types of oxygen-breathing apparatus.

After the drifts had been thoroughly explored and bodies removed, the Gem and Rainbow fans were, therefore, again converted into suction fans; and the raises, crosscuts, and stopes were explored by men wearing half-hour apparatus of various types. Few bodies were found in the workings above the levels, as practically all the men had been warned and were overcome while attempting to escape on the levels; however, three were found in the 2,439 manway about 75 feet above the 2,400-foot level and Ben Tregonning, a shift boss, was found in a manway above the 3,000-foot level. The mine workings were thoroughly explored and the recovery work was completed by June 16, with about 155 bodies recovered. Several bodies were later found in cleaning falls on the 2,000 and 2,200 foot stations and in other parts of the mine, which brings the total fatalities to 163 as far as can be ascertained.

The Granite Mountain shaft was caved in some places badly from the 1,600 to the 2,600 level. The 2,000 station was completely caved and filled with débris; the shaft was filled with water and débris from 3,700 to the 3,000 foot level. This shaft was repaired with structural steel and reinforced concrete. A view of the new fireproof construction is shown in Plate III. The two main hoisting compartments are on the left and the chippy compartment on the right.

USE OF OXYGEN BREATHING APPARATUS.

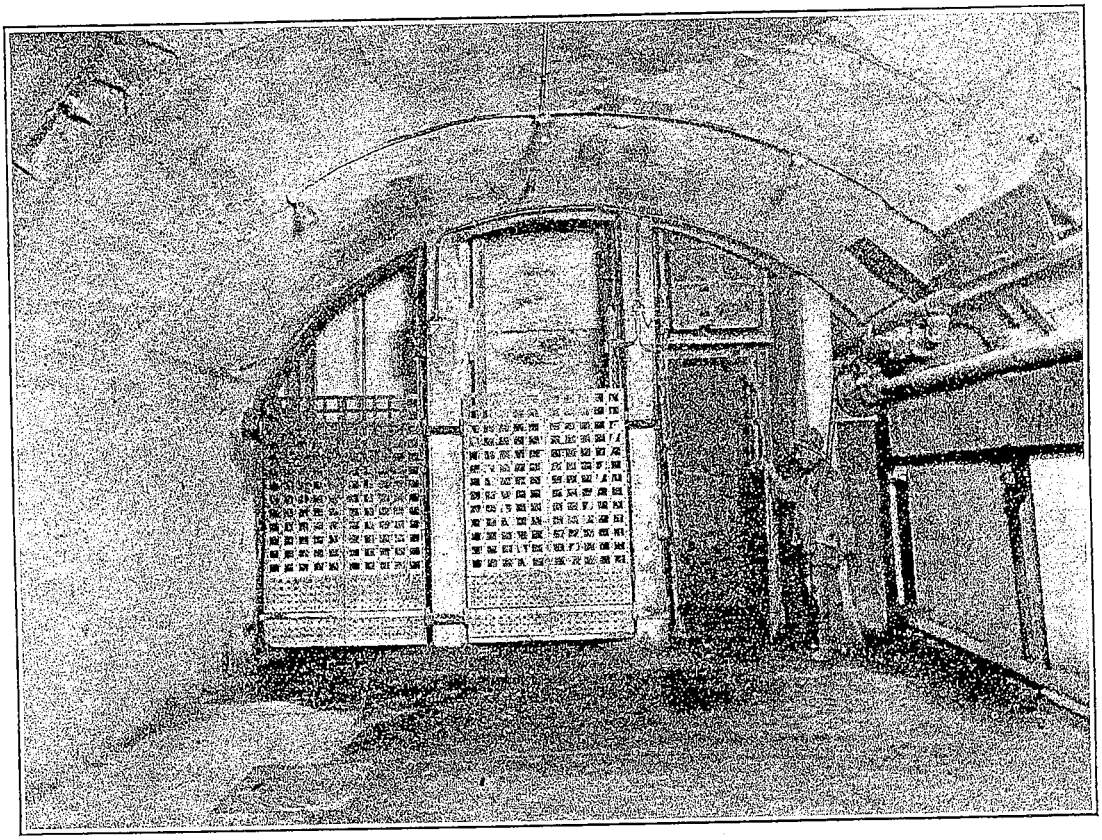
During the eight days of rescue and recovery work, over 175 different persons wore apparatus, and of these, 90 had received Bureau of Mines training. On account of the magnitude of the disaster and the great area to be explored, and because the need was urgent to complete the work with all possible speed, apparatus had to be worn by at least 15 previously untrained men in order to use them as guides. Many trips of 5,000 to 7,000 feet or over, in noxious fumes, were made during the first few days of the work, and in some of these trips the men climbed over or around strings of 10 or more ore cars, and went considerable distances in smoke and steam so dense that a sense of direction was maintained only by feeling the track rails.

The following supplies were used in connection with apparatus and apparatus work:

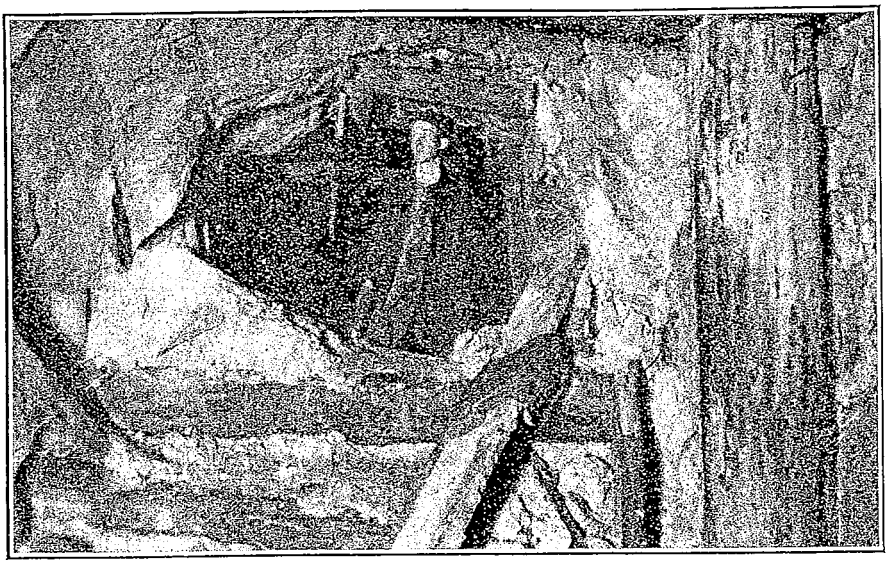
800 two-hour Draeger regenerators.
200 one-half hour regenerators.
600 pounds of Fleuss soda.
7,500 cubic feet of oxygen.
225 flash-light cases (3-cell Ever Ready).
1,000 flash-light batteries (3-cell Ever Ready).
175 pairs of goggles.
20 Draeger breather-bags with covers.
15 Draeger finimeters.
15 Draeger reducing valves.

with a large supply of mouthpieces, tubes, nose clips, and other small accessories.

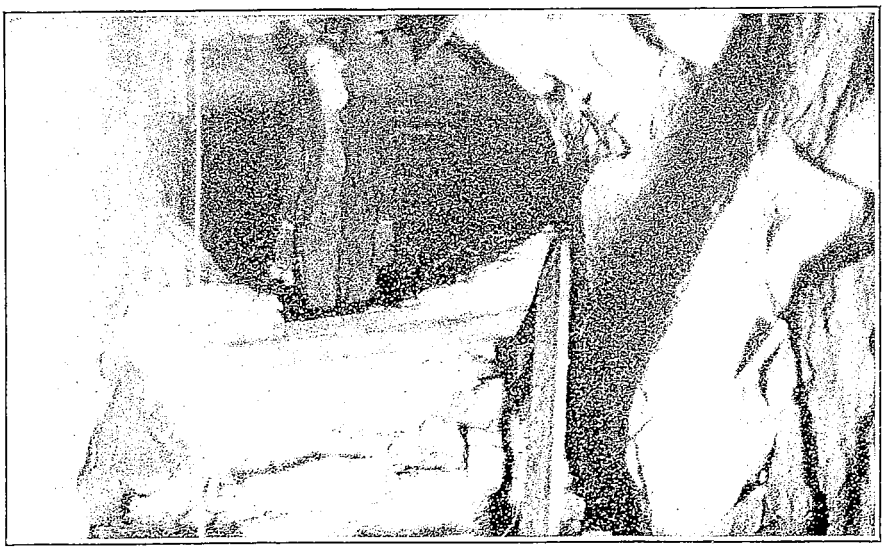
The North Butte Mining Co. carried on its payroll 119 names of men who wore apparatus for a total of 974 shifts, about one-third of the shifts being six hours long and two-thirds eight hours. Most of these men were paid time and a half, or about $7.12 a shift. In addition to these, several members of the operating staffs of the High Ore, Badger, and other mines worked as apparatus men and took an active part in the rescue work. Apparatus wearers during the rescue and recovery work at the North Butte disaster were employed previous to the fire as follows: Anaconda Copper Mining Co., 107; North Butte Mining Co., 25; East Butte Copper Mining Co., 4; Butte & Superior Mining Co., 2; Bureau of Mines, 8; and previous employment unknown, approximately 30. Of the 107 apparatus men from



CONCRETE SHAFT AND STATION IN THE GRANITE MOUNTAIN SHAFT, AS RECONSTRUCTED AFTER THE FIRE.



A. BULKHEAD IN THE 2254 CROSSCUT, BEHIND WHICH EIGHT MEN WERE ENTOMBED FOR 55 HOURS. NOTE METHOD OF PLACING STRINGERS IN CONSTRUCTING THE BULKHEAD.



B. BULKHEAD IN THE 2254 CROSSCUT. PHOTOGRAPHED FROM OUTSIDE THE BULKHEADED AREA.

the Anaconda, the number from the individual mines was as follows: Tramway, 42; Pennsylvania, 13; Leonard, 10; Mountain View, 6; Badger, 6; Original, 5; Poulin, 5; High Ore, 4; Diamond, 3; West Colusa, 3; Berkeley, 2; Neversweat, 2; Anaconda, 1; East Colusa, 1; Stewart, 1; Silver Bow, 1; Moonlight, 1; and St. Lawrence, 1.

Of the total of 163 bodies, at least 125 were recovered by the use of apparatus; the 6 men taken out alive from the 2,200 bulkhead owe their escape to the use of apparatus; and the 25 men who reached safety after 36 hours' imprisonment behind the 2,471 bulkhead would undoubtedly have perished had not apparatus wearers placed brattices and sealed doors in drifts and crosscuts leading from the Granite Mountain shaft on various levels from the surface down, thus preventing poisonous gases from the burning shaft and stations from continuing to penetrate into the mine workings and giving the downcasting fans at the Speculator, Gem, and Rainbow shafts an opportunity to clear the mine of the gases which had previously filled the workings. The use of apparatus in the Badger mine on the night of the fire and until daylight of the following morning in assisting the almost exhausted men from the 1,800 and 2,000 foot exits from the North Butte mine to fresh air in the Badger mine, and in giving artificial respiration to many of these men at the surface, undoubtedly saved many lives. Although the North Butte pay roll carried the names of 119 persons working with apparatus underground for a total of 974 shifts, the actual number of shifts worked by apparatus wearers was at least 1,300. When it is considered that all of this work was done within eight days, that over 30 miles of drifts and crosscuts, and at least 15 miles of stopes, raises, and manways were explored, and 155 bodies recovered and removed, largely in an atmosphere impregnated with poisonous gas, such as carbon monoxide, and frequently with dense tar-laden smoke, all without the loss of a single rescue worker, and with fewer than 20 part or total prostrations of apparatus wearers, the record is a remarkable one. Figure 2 (p. 11) gives an idea of some of the workings. Credit for this work could be distributed to a number of sources, but the largest amount is due to the Anaconda company for the use of its well-equipped and efficiently maintained mine rescue and first-aid organization and equipment. Moreover, by giving the services for actual work of such experienced men as Messrs. Boardman, Nighman, Carrigan, Rahilly, Barraugh, Smith, Ethier, and others, the Anaconda conferred an extremely valuable favor on the North Butte Mining Co., and on all connected with the recovery work.

The work of the two Bureau of Mines cars during the disaster is best indicated by the fact that 150 charges of soda were used in connection with the 23 sets of Fleuss apparatus in the six days that the cars were engaged on the work, and for the first three days

after the arrival of the cars there were very few shifts when all of the 23 sets of Fleuss apparatus were not in use. In addition to these, 9 sets of Draeger apparatus belonging to the Bureau of Mines were in operation a large part of the time. Messrs. Chisholm and Goldbloom on car 2 were kept busy on repair work, assembling and testing machines, and issuing supplies; Messrs. Forbes and Dickinson took regular shifts in charge of apparatus and apparatus work at the Speculator shaft and underground, and these two men, together with Messrs. Allen, Herbert, Harrington, Lanza, Penwell, and Price (who accompanied car 2 from Colorado Springs) wore apparatus underground daily, and frequently several times daily for several days, assisting in the work of exploration and restoring ventilation, as well as in the removal of the 25 live men on the 2,400-foot level on June 10, of the 6 live men on the 2,200-foot level on June 11, and of the recovery of bodies on various levels.

Employees of the North Butte mine who were inexperienced in the use of the apparatus appeared to have more confidence in the Fleuss than in the Draeger, largely because of the by-pass, as the Draeger machines used had no by-passes. Although 150 charges of soda were used and the apparatus was worn largely by inexperienced men, there were no cases of prostration or trouble in connection with Fleuss apparatus, except that Messrs. Allen and Forbes, of car 5, were partly overcome in rescuing the six live men on the 2,200-foot level on June 11, because they remained underground working on the helpless men after their supply of oxygen was exhausted.

EFFORTS OF ENTRAPPED MEN.

The following incidents show what may be done by entrapped men who keep their wits about them and act promptly.

ON THE 2,400-FOOT LEVEL.

Two parties, totaling 29 men, who had come from various points on the 2,400, 2,600, and 2,800 foot levels, met on the 2,400-foot level, and, being unable to get out by any exit, decided to build a bulkhead in the 2,471 crosscut. This was upon the advice of Manus Duggan, a nipper who was well acquainted with the mine. The time was between 12.30 and 12.45 a. m., an hour or so after the fire started.

Duggan instructed the men to carry into the crosscut with them saws, axes, shovels, chute lagging, canvas pipe, nails, one partly filled keg of water, and other materials. He chose a point about 250 feet from the face of the drift for the erection of the bulkhead, which gave approximately 9,000 cubic feet of pure air with a temperature of

81½ degrees wet bulb, 84½ degrees dry bulb, and relative humidity of 87½ per cent. The place was practically without timber, clean, and dry. A Leyner drill had been set up 35 feet from the face of the crosscut by men who had been working there on the night of the fire, so compressed air was available, as well as a small quantity of city water in the "submarine" or Leyner tank. The bulkhead was started 150 feet from the 2,401 crosscut, which under ordinary ventilating conditions received air going northward from the Speculator shaft, and on the night of the fire received little or no smoke until some came out of this shaft; hence, although the 2,471 crosscut had been ventilated previous to the fire by a fan placed on the 2,401 crosscut, with several hundred feet of canvas pipe into the 2,471, yet the cutting off of electric power at about 12.10 a. m. caused air circulation in the crosscut to be almost totally destroyed by the time the men entered it. Moreover, there was no smoke in the 2,401 until after the bulkhead was well started and probably nearly finished; hence, the men within the 2,471 bulkhead had absolutely pure air at the time of entering that section and on completion of the bulkhead.

Duggan and a man named Stewart supervised the construction of the bulkhead. A form was erected somewhat similar to the manner of building a concrete brattice, with about 8 inches between the face of the boards, which were placed horizontally. The 8-inch space was filled with fine dry dirt, and the holes chinked with canvas pipe and clothing. Four men at a time were employed, and it was completed in less than an hour. A hole near the side of the crosscut was left in such manner that it could be used to test the outside air and then closed by filling with a man's jumper. The outside air was thus tested several times and gas found in each test, the first time being about an hour after completion of the bulkhead. After being closed in, the men took turns rapping on the air pipe and track rails near the bulkhead to attract outside attention, and each man upon completing his turn at rapping or at keeping the bulkhead tight would go back toward the end of the crosscut thus keeping the air well stirred up and mixed. The air in the compressed-air pipe near the drill close to the end of the crosscut was at full pressure, but Duggan was afraid the compressed air contained gas, and stationed a man to prevent the opening of the compressed-air valve.

The bulkhead was finished shortly after 1 a. m. During construction and for some hours thereafter lights were freely used, some of the men playing cards, others writing letters, others restless and walking around. Some of the men finally became alarmed at the possibility of oxygen depletion, and restricted the use of carbide lights to four and later to but one light. At the end of 24 hours of confinement, neither match nor carbide lamp would burn, although

repeated attempts were made to obtain a light from dry matches or the patent igniter on the lamps. Although the place was comparatively warm with dry bulb temperature of 84½°, the men appear not to have removed clothing to any great extent, nor to have suffered particularly until after 24 hours, when breathing became labored. During the last 10 or 12 of the 36 hours of confinement, the water supply was exhausted, and several of the men, especially some foreigners whose English was limited, began to be hysterical and to threaten suicide, and demanded breaking of the bulkhead. Duggan, Stewart, and a few others tried to reassure them and resorted to several subterfuges to encourage them. About 1 p. m. on June 10, or almost exactly 36 hours after closing themselves in, some of the men were practically overcome and all were suffering through lack of food and water, and difficulty in breathing, so Duggan and a few others broke the bulkhead and started into the crosscut without lights.

On entering the inclosed region the men had had approximately 9,000 cubic feet of pure air, and the oxygen consumption of 29 men for 36 hours at the minimum figure of 0.9 cubic foot of oxygen per man per hour would be 940 cubic feet, or about 10 per cent of total air content, leaving but a little more than 10 per cent of oxygen cut of the original 20 per cent. This 10 per cent of oxygen left in the air was about the minimum for sustaining life, especially when accompanied by nearly 10 per cent of carbon dioxide, which must have been present. These figures must be correct, as it is known that a carbide lamp will ignite and burn in 13 per cent or more of oxygen, but their lamps would not ignite. The men kept moving about while behind the bulkhead, and occupied all parts of the confined area, thus mixing the pure with the impure air and diffusing both the oxygen and carbon dioxide, which accounts for the fact that some of the men were not totally overcome, as was the case with all the men who were in the bulkhead territory on the 2,200-foot level. Although none of the men were actually overcome and all were fully conscious at all times, several had to be given assistance in walking the 1,300 feet to the Speculator shaft to be hoisted. Of the 29 men that were in the bulkheaded crosscut, 4, including Duggan, took the wrong direction after breaking through, and were overcome by gases and died.

It is possible that the comparative immunity from absolute exhaustion of these men, as against the almost total collapse of men bulkheaded on the 2,200-foot level who likewise used practically all the available supply of oxygen, may be explained by the fact that the men on the 2,400 had a dry place with relative humidity 87½ per cent, whereas the men in the 2,200 had a wet place with approximately 98 per cent relative humidity.

ON THE 2,200-FOOT LEVEL.

A shift boss, J. D. Moore, and seven men on the 2,200-foot level were forced to retreat to the 2,254 crosscut, where they constructed an air-tight bulkhead to shut out the gas. This crosscut was somewhat over 400 feet long, with a 50-foot drift off westerly. The men who were driving the drift had evidently been working on the night of the fire and had a Leyner drill set-up near the face, and a submarine or 50-gallon tank partly filled with water within 30 feet of the face. The place was very warm and humid, with a wet bulb temperature of 84½° F., dry bulb 85° F., relative humidity 98 per cent. A small electrically driven fan on the Edith May drift had supplied air circulation through a 16-inch canvas pipe. When the eight men arrived the fan was not running, as all power had failed at about 12.10 a. m., yet the air was evidently still circulating, as survivors state that smoke and gas followed them into the crosscut to such an extent that they were able to complete the bulkhead only by stationing one man blowing air from a hose to keep back the gas.

When the men were retreating toward the 2,254 crosscut, Moore instructed them to carry along picks, saws, hammers; axes, boxes of wedges, and kegs of water, which they found along the drift, also some boards from the trolley guard and nails, and on nearing the end of the crosscut they tore down a considerable length of the 16-inch canvas pipe which had been used for ventilating. A narrow place in the crosscut, about 80 feet from the end, was chosen for the brattice or bulkhead, thus giving about 80 feet of crosscut and 50 feet of drift, with approximately 6,500 cubic feet of air inclosed. In constructing the bulkhead, which consumed several hours' time, round posts were placed across the floor, and a shorter piece of round timber was wedged along the top of the crosscut immediately above the timber on the floor, with other timbers between these two and also wedged to the sides. Before placing the middle timbers, inch boards standing vertically were nailed to the outside of the two round timbers, on the inside of which boards the canvas pipe was nailed. When the supply of canvas pipe was exhausted the men used their clothing. After the inch boards and canvas were placed, the timbers were placed and wedged and the spaces between filled with mud, of which there was a plentiful supply at the face of the crosscut. Plate IV, *A* and *B*, shows views from both sides of the bulkhead after it had been partly torn down. Before completion of the bulkhead, an attempt was made to go out into the crosscut for more nails and for an additional supply of canvas pipe which was to be had less than 75 feet from the bulkhead, but the gas was so strong outside the bulkhead that this trip had to be abandoned. The survivors were a unit in the opinion that they would have been unable to finish the bulk-

head had it not been for the use of the jet of compressed air to force back the gas.

On completion of the bulkhead, a thorough search was made for leaks, and it was found that gas was coming into the confined territory several feet back of the bulkhead through a loose piece of pipe with ends both inside and outside of the bulkhead. This pipe was plugged and was used from time to time by Moore to test the quality of the outside air. In order to conserve the oxygen supply, but two carbide lights were used as soon as the men were confined behind the bulkhead; when the bulkhead was completed all lights were extinguished except a candle used by Moore and a man named Marthey in writing letters. When Moore's candle burned down, one carbide lamp was kept burning for about an hour, and then the entire party was in darkness. Moore, who was weaker than the others, presumably having inhaled much gas before meeting his companions, stationed himself permanently at the bulkhead and the other seven men took turns at rapping on the air pipe as a signal to any possible rescuers on the outside. It appears that compressed air failed to flow in any considerable quantity after about 4 a. m., at which time apparently the main air pipe in the Granite Mountain shaft must have at least partly collapsed. Ordinary drilling pressure on compressed air failed about this time, but some air continued to flow from the hose until at least 7 a. m., or about two hours after completion of the bulkhead.

Moore made notes constituting a sort of diary during the first 8 or 10 hours of confinement. He wrote a letter to his wife, dating it 6/8/17, giving information as to the fire and gas and of his efforts to warn his men. Another letter dated 6/9/17, 5 a. m., stated that they had practically abandoned hope. At 7 a. m. he wrote that all were alive, but the air was getting bad and that only a small piece of candle was left. His last notation was at 9 a. m., 6/9/17, when he wrote that they were in the dark. This was at least 48 hours before the bulkhead was broken.

Survivors agree that within five hours after completion of the bulkhead (or about 10 a. m.) many attempts were made to light matches, and, although a dull red glow could be obtained, the flame would be extinguished almost immediately. It was stated that the matches used were from moisture-proof metal containers and were not damp. The men also state that attempts to light carbide lamps with patent igniters were fruitless, and it is the opinion of the men that the air was so bad that flame on neither match nor carbide light could be supported. This latter opinion can be corroborated on only three suppositions: 1. That during construction of the bulkhead, although compressed air was used to force the gas back, some of it may have reached the region back of the bulkhead by eddies. In any case, the

air must have been deficient in oxygen and contained an excess of carbon dioxide caused by complete combustion. If carbon monoxide was present, it must have been in a minute quantity. 2. That a considerable quantity of gas may have entered the bulkhead area through the loose 2-inch pipe on the floor, previously mentioned, though this is not probable. 3. That when the compressed air failed at about 4 a. m., and a small amount of air under little or no pressure continued to flow until at least 7 a. m., this low-pressure air may have been gas forced into the broken main supply pipe in the burning Granite Mountain shaft.

Against any of the above suppositions, it is reasonably established that the air originally in the bulkheaded territory was practically normal, from the fact that a candle burned freely until at least 7 a. m., or several hours after the brattice was first closed and at least three hours after it was completed. Moreover, the drift within the bulkheaded region had been worked on the night of the fire and was ventilated by a fan and by compressed air escaping from the Leyner drill. It is possible that the men grouped themselves near the bulkhead, and that the futile attempts to light matches and carbide lamps were made near the escaping gas from the 2-inch pipe under the bulkhead; but it is improbable that the deficiency of oxygen in the general atmosphere behind the bulkhead was large enough to fail to support combustion of a carbide lamp (which would be 13 per cent or less) at 7 a. m., on June 9, and still allow eight men to continue to exist for 50 hours; yet six men actually did live the 50 hours, and the two dead men (Moore and another) had probably been dead but a short time when the others were found.

The discussion on the amount of oxygen needed to support life in the previous bulkheading incident applies to this one also. The confined area contained 6,500 cubic feet of air whose oxygen content was 455 cubic feet above the minimum required to sustain life. This amount should last eight men about 65 hours, provided there was sufficient circulation to bring about a uniform mixture of the air within the bulkheaded region. However, after the 65 hours, the general atmosphere, even if uniformly mixed, would have contained 13 per cent of oxygen and upwards of 6 per cent CO_2 which would occasion labored breathing; and further diminution of oxygen to 10 per cent would undoubtedly have produced death. The men were behind the bulkhead about 55 hours, and claim to have no remembrance of having made any considerable movement after having been there 24 hours. As they were all found grouped together on the floor near the bulkhead and in the drift within about 30 feet of the bulkhead and were probably in a semicomatose condition for at least 24 hours previous to being rescued, it is entirely probable that

due to lack of movement tending to mix the pure with the impure air, the mixture instead of being of uniform quality throughout the bulkheaded territory had considerably less than 13 per cent oxygen and more than 6 per cent CO_2 near the bulkhead and in the drift where the men were found, and had considerably more than 13 per cent oxygen and less than 6 per cent CO_2 at the face of both drift and the crosscut. This is corroborated by the fact that although a carbide light held near the top of the bulkhead by one of the rescuers while tearing it down was extinguished by the first air coming from the interior, yet immediately upon removal of sufficient of the bulkhead to allow men to enter, two apparatus wearers readily went to the face of both drift and crosscut, using light from the carbide lamp. The men stated, however, that the flame was comparatively feeble.

When reached by rescuers two of the eight men were dead and the other six men were unconscious. According to a statement by Dr. A. J. Lanza, five of the six miners rescued from the 2,200-foot level were taken to a local hospital. They appeared to be suffering chiefly from exhaustion and lack of food, and four were able to leave the hospital the day after entering; one, who was in the worst shape, remained in the hospital about four days. Facilities were not at hand to examine the blood spectroscopically, but a careful microscopic examination of the blood showed marked and similar changes in the blood of all five, but no effects that could be ascribed specifically to carbon monoxide poisoning. Rather the blood examinations indicated the effects of oxygen insufficiency, together with probable effects of starvation.

ON THE 2,600-FOOT LEVEL.

Some of the men tried to bulkhead themselves in a drift on the 2,600-foot level, about 300 feet southeast of the Speculator shaft, but 19 were found dead behind this bulkhead. They had failed to take into consideration a manway between the 2,600 and 2,800 foot levels back of the bulkhead, and moreover, the drift was in broken ground, stoped through from below and backfilled with loose material through which gas could readily come from below.

ON THE 700-FOOT LEVEL.

A fourth case of presence of mind is that of two men—Boyce and Camitz—who, after trying to penetrate the fumes on the 700-foot level, retreated to the breast of a comparatively cool but wet drift, turned on the compressed air, pulled their jumpers over their heads and threw themselves face downward on the wet floor with the compressed air blowing close to their heads and under their jumpers. From time to time they tried to leave but always encountered gas. Upon failure of compressed air about 5 a. m., they left the face of

the drift, going directly to the Granite Mountain shaft and passing several dead bodies within a few hundred feet of the face of the 742 drift, from which they had originally fled. At the shaft station they encountered some apparatus men who led them to the Speculator shaft, from which they were hoisted to the surface, considerably weakened by breathing gases, but able to walk at all times.

CONCLUSIONS AND SUGGESTIONS.

From the general conditions at the North Butte mine and the happenings at the fire, a number of practical suggestions can be derived for all metal mines, which are briefly as follows:

METHOD OF SECURING HEAVY CABLES.

When the cable in the Granite Mountain shaft fell, it tore away some of the hemp lashings, but slipped through most of them, and left some of the lashings attached to the chippy rope and some to the electric cable. It appears that a positive clamp could have been attached to at least the upper 8 or 10 feet of the cable even if the clamp should crush and destroy that length of cable; such a clamp would undoubtedly have helped greatly to prevent slipping of the cable, especially if it were tightened so as to exert effective pressure on the copper stranded cables rather than on the lead armor. The lubrication or tarring of the chippy rope may have also prevented effective service by the hemp lashings.

DANGER FROM ELECTRIC CONDUCTORS IN SHAFTS.

In view of the fact that several fires in shafts within the past few years have originated from electric wires and cables and that the use of electricity underground is being extended rapidly, companies should remove these conductors from shafts used for hoisting or ventilation purposes and place them in drill holes. This is done in both coal and metal mines in many parts of the United States, also in at least one mine in Butte. Although moving ground might make difficult the maintenance of a drill hole in some districts, yet there are few mines in which a block of ground can not be found that does not move, or that does not move as a whole; and in the latter case provision could be made to take up the movement by some expansion arrangement varying the length of the cable. The drill hole could be intersected by crosscuts at the working levels to take off current, and the cables could be supported at these points. Such crosscuts should always be separated from the remainder of the mine by close doors as nearly air-tight as possible, as accidental wrecking and ignition of a cable such as the one in the Granite Mountain shaft might give off sufficient poisonous fumes to cause a disaster, unless provision

were made to confine the fumes. From experiments made, the writer of this report is of the opinion that the combustion of the wrecked cable in the Granite Mountain shaft, with distillation of gases from parts of the cable retaining the lead armor, gave off sufficient poisonous fumes, high in carbon monoxide, to have caused the entire loss of life, even had the cable been contained in an absolutely fireproof shaft. At least 150 of the 163 men killed showed the cherry-red blood and knotted veins of neck and side of head characteristic of carbon monoxide poisoning.

It would seem that in general cables should not be placed in downcasting shafts, and if the bore-hole method is not feasible, upcasting shafts should be used. The placement of electric cables in upcasting shafts would necessitate unusual precautions for waterproofing the cable and for prevention of accidents due to electrical leakage, but fire risk and danger from fire fumes would be practically eliminated. Where it is necessary to carry wires and cables in a downcast or neutral timbered shaft, the compartment containing the conductors should be fireproofed by using metal lath and plaster, or metal lath and concrete, or by the gunite method.

REVERSING AIR CURRENTS.

When a mine has two shafts, and the one downcast is afire and filling the workings with smoke, every effort should be made by fans and other means to convert this shaft into an upcast. This was promptly done at the North Butte, which was well supplied with reversible fans.

FIREPROOFING THE MAIN SHAFT.

It is highly desirable that the main hoisting shaft of every deep mine be lined with concrete. If this is done at the time the shaft is sunk the cost should not be excessive, and, if the mine has a long life, may in the end prove cheaper as subsequent repairs are eliminated. In some formations, especially where there is shifting ground, concrete may not be practicable, but in such shafts the timbers should be fireproofed and smooth lined by coating with cement, which can be easily and thoroughly done by using a cement gun.

CONNECTIONS BETWEEN MINES.

From the viewpoint of Butte mining men and the Montana State laws, the North Butte mine was perfectly safe as regards means of escape in case of fire. The exits are described on page 43. It is the opinion of the writer that the practice of making numerous connections with adjoining mines is dangerous. The main objects of such frequent connections, a practice almost universally commended by

Butte miners as well as mine managers and safety men, are: 1, Exits in case of disaster; 2, an aid to ventilation; and 3, for drainage purposes.

Connections between mines should only be for drainage purposes and for gaining admission to existing mine fires for the purpose of extinguishing them. Existing connections should be closed with air-tight doors, preferably of steel or concrete on concrete frames and with edges sealed by concrete. Doors should not be hung inside of concrete frames, but should be placed flush against the smooth outside surface in order not to be readily affected by settlement of the ground. Where doors can not be made air-tight the doorway should be sealed with 2 to 3 inches of concrete, and picks and hammers should be kept on each side of the door, with signboards giving directions as to the thickness of the concrete.

For the purpose of supplying adequate ventilation, and in order to permit the safe removal of employees at times of disaster, every mine should have at least two fully-equipped shafts from surface to lower stoping level, and all levels should be connected with both shafts.

Every drift, crosscut, or other opening leading from any shaft, whether upcast or downcast, wet or dry, timbered or concreted, should be supplied with concrete or other fireproof doorframes with fireproof doors and with minimum opportunity for leakage, and so equipped as to be kept closed positively without reliance on air pressure which may at any time be reversed; a dependable latch or system of weights, rope, and pulleys, or both, could be used. In general, drifts or crosscuts between downcast and upcast shafts should be closed by two doors at least, with positive action to insure against the short-circuiting of air currents in ordinary working periods and of gases in times of fire; it is important that these doors be closed positively and automatically, that they be as free of leakage as possible, and that they be kept closed at all times. Doors dependent on ordinary air pressure for being kept closed are very dangerous, as they will certainly fail in case of reversal of air currents. Where possible, these doors should be placed sufficiently far apart to act as airlocks opening but one door at a time, the distance apart to be approximately 25 or 50 feet where only men travel; where trips of cars are handled, the distance should be sufficient to contain the maximum length of trip between the doors with ample clearance between the end of the last cars and the doors.

SUITABLE AND FREQUENT SIGNBOARDS.

It is important that plainly visible signboards, preferably of enamel paint on tin or other metal, be erected to show direction to

exits to other mines, to the manways which are in condition for travel, and to the main shafts. Many mines employ from 20 to 45 per cent new men every month, and as most of these men are unfamiliar with the mine it is suggested that the use of signboards be extended, so that the name or number of all important drifts and chutes shall be clearly marked. Great care should be exercised at all times in placing danger signs in manways or other workings that are unfit for travel. So far as possible, men should be instructed by shift bosses or other officials of the mine as to the position of hoisting shafts and exits to other mines. During the North Butte fire, the shift bosses appear to have acted quickly and effectively, and they deserve much credit. However, in a large fire, signboards in the smoke-filled region could not be easily read or seen after the first few minutes of the fire; and it has been noticed that miners frequently deface the signs underground, making them illegible. Such defacement should be punishable by instant dismissal of the offender.

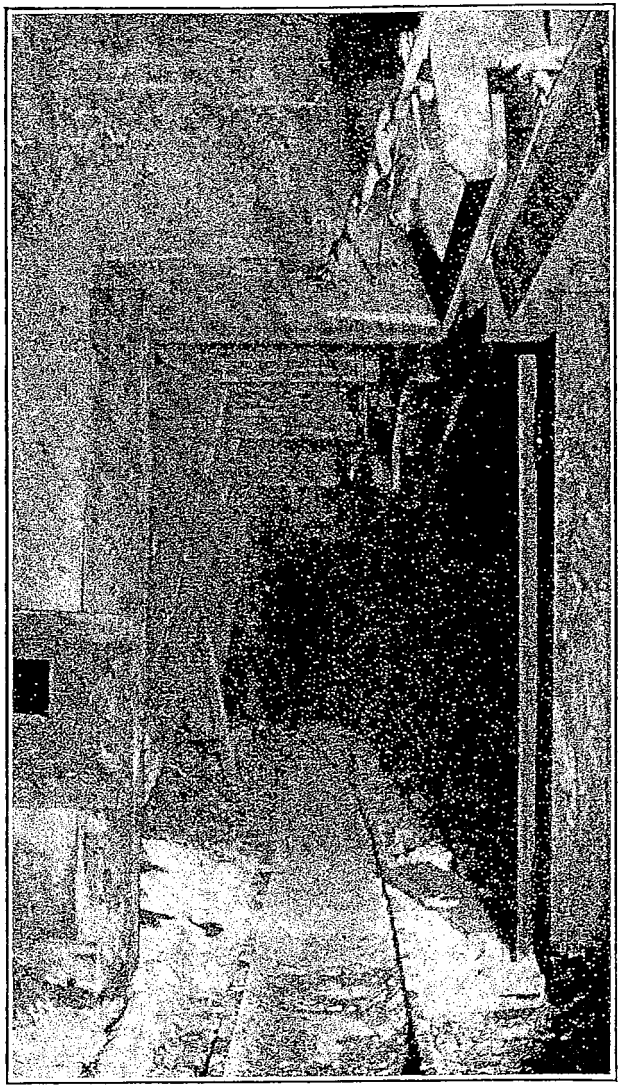
PLAN OF LEVEL AT EACH SHAFT STATION.

On every shaft station there should be a plan of the level, showing exits to other mines, safe manways to levels above and below, and direction of air currents. These maps should be placed in a cupboard or box with a glass cover and always kept up to date and in readable condition, and should be under the direction of the safety engineer. Such maps could be made of material aid in the conduct of ordinary mine operations, especially ventilation, by indicating doors to be kept closed; in time of disaster there would almost certainly be some person with sufficient intelligence to read the map and thereby find safe manways and exits.

LEAKAGE OF GAS THROUGH DOORS.

The spring-latch door-lever, with approximately 100 feet of rope attached on each side of a door and alongside of a drift, should be abolished for a more positive system of keeping doors closed. This device reduces the time and effort of opening doors for motors, but it is extremely dangerous in time of fire, as a small rock fall from the side or back of the drift on the rope will open the door. This occurred on several levels during the Butte fire, with disastrous consequences on the 1,800 and 2,000 foot levels. All mine doors should be fitted with some arrangement by which they close automatically when released. The door shown in Plate V was closed immediately after the fire, but was opened by rock falls during the fire.

The large opening left in the concrete doorframe (as shown in Plate V) to accommodate the support for the spring lever allows much leakage of air in normal times and of poisonous gases in time



CONCRETE DOOR FRAME ON THE 1,800-FOOT LEVEL, WITH A HOLE ON THE LEFT FOR THE DOOR-ACTUATING DEVICE AND A HOLE OVER THE DOOR FOR THE TROLLEY WIRE AND THE WHEEL ON THE TROLLEY POLE.

of fire. This leakage undoubtedly greatly hampered men on the 1,800 and 2,000 foot levels. Escape of gases through the opening in concrete doorframes was undoubtedly augmented by leakage through the trolley slot above the door. This trolley slot is generally about 20 to 30 square inches, and inspection after the fire showed a considerable deposit of tarry matter in the trolley slot from smoky fumes. It is recommended, therefore, that some method be devised to decrease the area of the trolley slot in doors or doorframes. There could be a break in the trolley line at the doorframe, as in street-car systems and in some mines.

SIGNALS.

The Granite Mountain shaft had practically four systems of signals, but all of these were carried within the shaft and failed within 15 minutes after the outbreak of the fire in the shaft. Similarly, at fires in other metal mines, the signal system quickly failed. The following conclusions may be drawn from these accidents:

(1) The safest method of handling signal wires is through a drill hole with branch wires to each shaft station.

(2) Whether electric signal wires, telephone wires, and cables are carried in shaft or in drill hole, there should be a pull bell in every shaft, the rope whether of steel or of vegetable fiber to be renewed from time to time, even if little used, and the system to be tested frequently.

(3) Where there are two separate hoisting shafts, each should be fully equipped with signals, and provision should be made at intervals from surface to lowest level for obtaining current for signals in one shaft from the other shaft. This could be done by connecting the two shafts underground by wires and switches on several levels with switches thrown out in ordinary times. This is not to be interpreted as advocating the connection of the signal wires of one shaft to the signal wires of the other shaft.

(4) It would appear to be necessary and feasible to have an electric signal workable on all decks of a cage, taking very low voltage from a conductor in the shaft through a roller or wheel similar to a street-car or mine locomotive trolley system, the return to be made through the hoisting rope. A Butte man has a model of such a system, with the additional feature of automatically transmitting a signal to the hoisting engineman as soon as the cage encounters a region of missing or broken guide. Some operating mines in Utah use a similar system.

FIRE PROTECTION IN SHAFTS AND DRIFTS.

Timbered shafts not lined with fireproofing material, particularly downcasts, should have ample facility for fire protection, and, in gen-

eral, this fire protection could be extended to good advantage into mine workings. A system of water pipe through which water could be sprayed against shaft timbers, not only around the shaft horizontally at every station, but also vertically between stations and on the surface at shaft collar, is practicable. Although automatically operated sprays from fusible plugs are desirable where a shaft is not much traveled, the writer prefers perforated pipe with valves placed at the surface near the shaft, and at suitable intervals underground. All sprinkling devices or other apparatus intended for fire protection should be tested at least once a month. Sprinkling of dry downcast timbered shafts or shaft stations should be done at frequent intervals, and employees should be acquainted by suitably placed signs, as well as by verbal instruction, as to the position of valves, hose, and hose houses. If possible, water lines should be brought down both upcast and downcast shafts. A full head could be kept in the former, as it would be warm at all seasons of the year.

In order to control pressure in deep shafts, the pressure-reducing valves appear to be preferable to open storage tanks at intervals of every few hundred feet. With these valves the flow of water may be kept under control by the use of a surface supply valve. Supply tanks at underground stations may continue to flow longer or at greater volume than is desired. This is especially important when control of the direction of the air current in the shaft is desirable.

Water pipe of at least 2½-inch size with not less than 50 feet of 2½-inch hose with nozzle, should be in place at every shaft station for use in case of emergency. If the shaft is downcast, consequently carrying cold air in winter, water should not be kept in the pipe, but should be controlled by a valve in the drift back from the station. The present practice of making connections by suitably placed tees and valves to allow quick conversion of air pipes into water pipes is a good one.

Two main compressed-air lines might be brought into a mine, each by a different opening from the surface, so that if one is put out of commission the other would be available.

FIRE WARNINGS.

Although few employees of the North Butte mine were caught at working places in the stopes, raises, drifts, or crosscuts, yet this emergency shows the necessity for some method of quickly warning men in case of disaster. All surface employees at Butte, for instance, should be instructed to notify immediately by telephone or otherwise the following in case of fire or other serious disaster:

1. The mine foreman, mine superintendent, safety engineer, man in charge of rescue apparatus, and all available men trained in use of oxygen breathing apparatus, also mine electricians and rope men.

2. The State mine inspector.

3. Mine offices of all mines with which the mine is connected; a list of such mines should be always available. This matter is vital and should not be neglected.

4. The U. S. Bureau of Mines at Pittsburgh, Pa., or Washington, D. C., or, if one is near by, one of the field stations and rescue cars.

As with air and water lines, two separate main telephone wires could be led into the mine through different openings.

Inasmuch as nearly all working places are reached by compressed air, and are dependent largely upon compressed air either for ventilation or for power with which to work, it would appear that some signal could be devised using compressed air for conveying warning to miners in case of danger. The shutting off of compressed air could be quickly accomplished, and this could be made a danger signal. This is done in some California mines by means of a three-way valve. Some governing regulations would be necessary, but that should not be extremely difficult.

The introduction of some substance into compressed-air lines through the compressor or otherwise at the surface has been proposed as a danger signal; this is practicable, but would probably not be as quick as shutting off air.[1] One of the large Butte mining companies has introduced a small amount of valeric acid into the compressed-air system at the compressor on the surface. Within a comparatively few minutes a pungent but harmless odor is found by compressed-air users even in the remote parts of the mine. In a test at a Californian mine, an odor came through 7,800 feet of pipe in 8 minutes. Such a system would communicate only to users of compressed air, but it would act quickly where compressed air consumption approximates total air supply. Those thus warned would undoubtedly warn others.

ORGANIZATION OF RESCUE WORK.

All shift bosses, nippers, and samplers, and other men that are familiar with the mine workings, should be trained in the use of apparatus, provided they are pronounced physically capable after examination by a competent doctor. They should be required to wear apparatus at least 1 hour each month, thus keeping them acquainted with the apparatus and its working condition.

As many employees as possible, miners and officials, should be given training in first-aid and mine rescue. At a large mine at least 10 physically capable and mentally alert employees might be selected as permanent rescue men and paid a little extra compensation, such as 25

[1] Katz, S. H., Allison, V. C., and Egy, W. L., Use of stenches as a warning in mines: Tech. Paper 244, Bureau of Mines, 1920, 31 pp.

cents a day. No person should be allowed to wear apparatus unless trained in its use.

Where apparatus is kept near the collar of a shaft instead of in lockers in a regular rescue station, not less than five sets should be on hand.

Electric-battery cap lamps should be provided so as to allow rescuers to have their hands free, which is impossible when carrying flash lamps. Electric lamps are used in hundreds of coal mines.

HINTS TO RESCUE WORKERS.

1. Several wearers of apparatus were overcome because they had worked too vigorously; others had removed apparatus in order to be able to work to better advantage; some had continued working after the supply of oxygen was exhausted; and some over-eager employees of the North Butte rushed into the bulkheaded region without any apparatus. The result of these indiscreet acts was that a large number of the men were overcome practically at the same time, and only prompt and effective assistance by doctors on the 2,200-foot level of the Speculator shaft prevented serious consequences.

2. Another warning is not to get excited over any incident of rescue, as this has a bad effect on the system, especially when apparatus is being worn.

3. Three days of strenuous work seems to be about the limit of endurance of most men in rescue work.

4. Apparatus should be properly assembled before an attempt is made to enter any gaseous area. Several examples of a lack of care in this regard resulted in the wearers being somewhat affected.

5. During rescue work underground all bulkheads should be examined thoroughly, as men may be behind them. If any bulkhead is not on the mine map, then presumably it has been erected by imprisoned men. The reason for every bulkhead should be known, and even a well-constructed one should not be considered as having been put up during normal operations. If the 2,254 bulkhead, which was inspected and considered too well built to be hastily thrown up, had not been reported, six men would certainly have perished.

6. Rescue men frequently forget or ignore the limitations of apparatus.

7. On long trips in gas with oxygen-breathing apparatus only machines with by-pass should be used.

8. No fewer than four men should be allowed to go into a gaseous region together.

9. When about to go down manways, make sure that there is sufficient space for the wearer and apparatus. Present-day types of oxygen apparatus should be used only as a last resort where ladder climbing is necessary, as this is decidedly dangerous work.

SAFETY BEHIND BULKHEADS.

The bulkheading incidents, in which 56 men shut themselves in crosscuts by erecting bulkheads and 31 survived, offer the following hints to others in like circumstances:

1. When entrapped by gases and forced back into a crosscut or drift in which is comparatively good air, keep in mind the thought of building a bulkhead and collect tools, timber, water, and other necessities on the way.

2. Before constructing a bulkhead, make sure that there is no manway or other connection with another level through which fumes could come. Also see that the drift is not in broken ground or stoped through from a lower level and back-filled with loose material through which gas could find its way. Even if a tight bulkhead be made and these conditions are present, the inclosed area will soon fill with gas.

3. Under these conditions, with from 8 to 29 men employed, a bulkhead may be put up in from one to four hours' time.

4. When erected, test a bulkhead for leaks by means of a candle or carbide lamp.

5. If there is a compressed-air pipe with hose attached leading into the drift and gas is coming in during erection of the bulkhead, station a man blowing air to keep back the gas.

6. Use a minimum of lights when in a bulkheaded region, as these consume oxygen.

7. The burning of the flame of a candle or lamp will show the condition of the confined air and how the oxygen is being used up.

8. Keep moving in the drift as much as possible, so as to mix the air, and do not gather in one place.

9. A bulkheaded drift 250 feet long and 6 feet high by 6 feet wide contains 9,000 cubic feet of air, and kept 29 men alive for 36 hours; and one 130 feet long and 7 feet high by 7 feet wide, containing 6,500 cubic feet, supported 6 out of 8 men for 50 hours, and would have sufficed for all 8 men for 65 hours if the air had been circulated by moving about.

AVOIDABLE ACCIDENTS.

The foremost lesson derived from the Granite Mountain fire is a repetition of a very old one. Hazards unavoidably inherent in underground mining demand eternal vigilance against every form of carelessness. Had the man whose light ignited the cable been more careful the fire would not have occurred. The best efforts of mine owners and managers, of State and Federal authorities, and of organizations to promote industrial safety are unavailing as long as

the individual workman is careless. Even had the shaft been entirely fireproof, there seems little doubt but that large loss of life would have resulted from the poisonous fumes generated by the burning of the cable insulation. Every effort to educate underground workmen in the hazards of their work and what should be done to make their operations safe should receive hearty cooperation and support from both employers and employees.

APPENDIX.

NAMES OF WEARERS OF APPARATUS.

The names of known wearers of apparatus during the fire are given, together with the name of the mine at which the apparatus wearer worked when known. Probably many others unrecorded wore apparatus, especially in the High Ore, Badger, and Diamond mines.

Name.	Mine.
Jack Adams	Leonard.
R. V. Ageton	North Butte.
F. E. Allen	Mountain View.
Thomas Baker	Badger.
Frank Balkąvitz	Tramway.
W. E. Barraugh	Leonard.
W. J. Bate	Tramway.
W. M. Best	Poulin.
Tony Bezik	Tramway.
Frank Bren	North Butte.
E. Brooks	West Colusa.
R. P. Brown	Diamond.
Frank Bunnell	Badger.
William Burns	Pennsylvania.
B. W. Byrne	Badger.
Henry Callison	
Hugh Campbell	Pittsmont.
John Campbell	Original.
Lester Carrigan	Do.
J. W. Collier	Badger.
E. E. Collins	Black Rock.
Thomas Connor	West Colusa.
W. Cook	Tramway.
Frank D. Cronin	Badger.
Harry Crosswell	Mountain View.
W. F. Crowley	Poulin.
E. Davis	Mountain View.
William Davis	Neversweat.
Cal Devoss	North Butte.
J. Devoss	Tramway.
A. Diates	
J. F. Donley	Tramway.
Ellis Drakes	Do.
George Ethier	Do.
John Fisker	Pittsmont.
Ralph Flenner	Tramway.
Charles Fredericks	Pennsylvania.
Frank Gartrell	Tramway.
Earl Gillan	Original.
Thomas Gerety	Tramway.
Harry Goodsell	Do.
Louis Grace	Silver Bow.
C. D. Grey	Diamond.
E. J. Guinan	Tramway.
W. Harris	North Butte.
B. B. Harvey	Tramwy.
T. J. Hoskin	Mountain View.
Fred Hoskin	Leonard.
Thomas Howell	Do.
Charles Huber	Tramway.
Frank Huber	Do.
L. V. Hunter	Speculator.
A. Hughes	Pennsylvania.
J. J. Kelley	Diamond.
Bill Kendall	Tramway.
L. M. Kirby	Do.
W. J. Kirby	Pennsylvania.
John Larkin	Tramway.
Alfred Larson	Moonlight.
James Leary	St. Lawrence.
Peter J. Leary	
L. Lemm	Original.
Tom LeMartin	Leonard.
Martin Lisac	Pittsmont.
T. J. Manley	Anaconda.
John Mathers	Pennsylvania.
W. E. Mathorn	Do.
William Matthews	
Evan Mattice	Berkeley.
William Maxwell	Tramway.
William Mitchell	Pittsmont.
J. R. Montgomery	Pennsylvania.
E. A. Moody	Tramway.
T. B. Mosley	Pennsylvania.
Jim McAlona	North Butte.
Charles McClellan	
W. McClements	Tramway.
M. E. McDonald	
Charles McGrail	Neversweat.
T. McKearn	Original.
Joe Neighton	Tramway.
Frank Nurin	Do.
L. H. O'Rear	Do.
Earnest Oates	Poulin.
John Pascoe	Tramway.
John Parlins	Do.
Frank Patolka	Do.
R. W. Pelton	Pennsylvania.
H. J. Pohlman	Mountain View.
Anton Popich	Pennsylvania.
William Porter	Tramway.
John Powers	Do.
Pierce Powers	High Ore.
R. J. Powers	North Butte.
James Prewitt	Pennsylvania.
C. C. Price	North Butte.
W. Pugsley	Tramway.
Charles Purtle	North Butte.
H. B. Robinson	Black Rock.
John Roba	Berkeley.
Tom Ryan	Tramway.
A. G. Ryecroft	West Colusa.
Jack Schoning	Leonard.
James Shields	High Ore.
John Shuman	Leonard.
L. Smith	Tramway.
A. J. Sommers	East Colusa.
J. H. Stobbs	Leonard.
D. P. Sullivan	Badger.
Mike Sullivan	Tramway.
Thomas Sullivan	Badger.
Tommy Sullivan	Do.
Jack Tavis	North Butte.
Ed Thibo	Tramway.
Joe Tiddy	Stewart.
Charles H. Uphoff	Tramway.
Edgar Uren	Poulin.
Chris Walker	Tramway.
Cliff Walker	Do.
Joe Watson	
W. H. Weat	Mountain View.
Dan Wells	Pennsylvania.
C. C. Whitmore	Tramway.
Mike White	Do.
Allen Wilson	North Butte.
M. D. Wilson	Tramway.
Mike Woods	High Ore.

L. D. Frink, general superintendent, North Butte Mining Co.
N. B. Braly, general manager, North Butte Mining Co.
R. J. Cole, safety engineer, North Butte Mining Co.
L. J. Coady, engineer, North Butte Mining Co.
C. C. Case, engineer, North Butte Mining Co.
H. D. Shields, North Butte Mining Co.
W. A. McMasters, North Butte Mining Co.
E. A. Fritzberg, assistant foreman, North Butte Mining Co.
H. J. Steinberg, assistant foreman, North Butte Mining Co.
John Hammill, shift boss, North Butte Mining Co.
C. A. Russell, shift boss, North Butte Mining Co.
J. McNichols, shift boss, North Butte Mining Co.
W. R. McCoy, shift boss, North Butte Mining Co.
W. D. Budelier, shift boss, North Butte Mining Co.
T. Oaas, foreman, High Ore mine.
J. J. Carrigan, assistant general superintendent, Anaconda Copper Mining Co.
E. M. Norris, foreman, Tramway mine.
H. R. Tunnell, foreman, Pennsylvania mine.
J. A. Bartlett, assistant foreman, Tramway mine.
C. E. Neighman, mining engineer, Leonard mine.
H. J. Rahilly, mining engineer, Leonard mine.
C. E. Calvert, safety engineer, Anaconda Copper Mining Co.
Dan Crowley, apparatus man, Anaconda Rescue Station.
R. B. Linton, president, North Butte Mining Co.
C. A. Allen, J. C. Dickinson, J. J. Forbes, F. W. Price, Duncan Penwell, D. Harrington, and C. A. Herbert, from the United States Bureau of Mines; and Dr. A. J. Lanza, of the United States Public Health Service.

In addition to the above, great credit is due to Ernest Sullau, the assistant foreman on shift on the night of the fire. In his efforts to warn men in various working places he walked over 3 miles underground, much of which was climbing up and down ladders, also encountering gas in several places. He was instrumental in sending at least 50 men to safety. In doing so he lost his own life, though he had ample opportunity of saving himself had be been willing to abandon his men.

Of the nine shift bosses, three lost their lives. They all acted quickly and efficiently, and appeared to have exerted almost superhuman effort to show their men the way to safety. They included McFadden, J. Hammill, J. McNichols, Goodell, Bronson, Wiegenstein, J. D. Moore, George Gorrie, and Ben Tregonning, the last three of whom were overcome.

Others who were of material assistance were John Gillie, general manager of the Anaconda company, with three of his assistant superintendents, John O'Neill, C. L. Berrien, and J. J. Corrigan; also Robert Linton, vice president of the North Butte company; State mine inspectors Orem and McGrath, officials of neighboring mines, and many doctors, including Messrs. Lanza, Maillet, McCarthy, and Rhodes. The fact that the doctors were underground without doubt saved some lives.

DETAILS OF ESCAPE WAYS FROM NORTH BUTTE MINE AT THE TIME OF THE GRANITE MOUNTAIN FIRE.

From the viewpoint of Butte mining men and Montana State laws, the North Butte mine was perfectly safe as regards means of

escape in case of fire; there were two working shafts, each with adequate signals, hoists, and cages, though unfortunately, on account of retimbering at the time of the fire, the Speculator shaft was temporarily out of commission below the 800 as to main compartments and below the 2,000 as to chippy compartment. Moreover, the open drifts between shafts on the 700, 800, and 2,400 quickly filled the Speculator with poisonous fumes.

CONNECTIONS WITH THE BADGER MINE.

The exits between the North Butte and Badger Mines were as follows: One southwest of the Granite Mountain shaft on the 1,800 with an easily opened door, behind which was fresh air for several hours after the fire, and near this door in an absolutely open crosscut was a connection to the Diamond through which fumes later on went direct to the Diamond and resulted in the death of foreman O'Neill and his companion Lorie. At least a dozen men who perished could have reached safety through this connection to the Badger had they taken it instead of going toward the Granite Mountain. There was another connection to the Badger northwest of the Granite Mountain shaft through open drifts with a raise of about 16 feet from North Butte to Badger property. The Badger company had placed a brattice in this connection of 1-inch boards, said by miners to be 3 inches, and this brattice was broken with comparatively little trouble by the fleeing men, many of whom escaped this way. There was a connection to the Badger on the 2,000 northwest of the Granite Mountain shaft on practically the same level, but through a stretch of squeezing drift and another of crosscut from which broken rock had not been removed from the floor. A brattice of 1-inch boards, said by men to be 3 inches, was also in place in this connection on Badger ground and had to be broken, but many men escaped by this exit. On the 2,200 was another connection to the Badger, northwest of the Granite Mountain shaft with the Badger drift about 30 feet higher than the North Butte. It is believed that comparatively few men escaped by this connection as the flow of poisonous gas northward from Granite Mountain shaft with a velocity of over 400 feet a minute through the open 2,275 crosscut toward this connection undoubtedly prevented many men from taking advantage of the opening. These four openings to the Badger were practically open, as the brattices in the Badger on the 1,800 and 2,000 were readily broken.

CONNECTIONS WITH THE HIGH ORE MINE.

On the 2,200 were two drifts near the Speculator shaft leading to the same crosscut to the High Ore shaft about 600 feet from Speculator shaft. (See Fig. 2, p. 11.) The most northerly of these

two drifts was sealed with a concrete brattice in May, 1917, when fumes from the High Ore-Modoc fire persisted in going into the North Butte mine; no bodies were found in this drift or near the concrete brattice. The most southerly drift had an easily opened door in North Butte ground, and in High Ore ground a board canvas brattice, which was readily broken by 6 men who escaped to the High Ore shaft. Later on 9 men went through this exit to within 150 feet of the High Ore shaft and then, following directions on a signboard, turned into a drainage crosscut to the Bell Diamond and were hoisted from the 2,200 Bell-Diamond station. On the 2,400 was a drift south and east of the Speculator shaft, with two easily operated wooden doors in concrete frames on North Butte ground and with a drop of about 10 feet to the High Ore; and in the High Ore drift was a concrete doorframe, the door opening of which had been sealed during High Ore-Modoc fire in May, 1917, with between 3 and 4 inches of concrete and 1-inch boards as concrete form. The iron door swung toward the North Butte mine and had rusted to such an extent that the men had some difficulty in opening it on the night of the fire, and upon opening the iron door and encountering the inch boards of the 4-inch concrete form they tried unsuccessfully to force the concrete with a mine track rail. Most of the men despaired of forcing the concrete in the doorframe and retreated. Some of those who originally tried to go through the 2,400 to the High Ore later went into the Manus Duggan bulkhead on the 2,400. Some of the men returned, however, with picks and hammers and succeeded in breaking the concrete from the doorframe and at least 50 men escaped. Attention should be called to the fact that had the men failed to break the bulkhead they would still have been safe by remaining near the bulkhead, as before they entered the High Ore workings they had passed through a door in the North Butte mine which definitely excluded all of the gases from the North Butte mine fire. The distance between the above-mentioned door in the North Butte mine and the bulkhead in the High Ore mine was several hundred feet. Moreover, there was a compressed air line there from the High Ore mine. Hence, these men could have existed for several days in this airlock, even had they been unable to force the bulkhead.

The 2,600 had no connection to any other mine, but it connected both the Granite Mountain and the Speculator shafts and had several manways to the 2,400, and the 2,800. The 2,800 had two connections with a High Ore drift used also as a drainage level. In one of these connections were two doors on North Butte territory, the other, the more southerly, was sealed off by a concrete brattice in a door frame to keep fumes from North Butte mine when the High Ore-Modoc fire was at its height in May, 1917. One man was found dead near this latter bulkhead and four others in the drift, though

they might have gone to safety had they chosen the more northerly exit and barricaded themselves outside the doors in North Butte territory and inside another door frame with concrete brattice in a door opening in High Ore territory. No North Butte men escaped to the High Ore on the 2,800, and the one man found dead near the brattice and four near by in the south drift to High Ore on the 2,800 were the only men found dead in any part of the mine near a bulkhead or brattice previously placed by mine officials.

MANWAYS BETWEEN LEVELS.

There was no opening to any other mine on the 3,000, but this level was connected to the Granite Mountain shaft and to several good manways to the 2,800. The 3,200, 3,400, and 3,600 had been driven less than 300 feet from the Granite Mountain shaft in a direction toward the Speculator shaft, and on the night of the fire the men, except possibly one or two, had gone out, due to breakage of pipe in Granite Mountain shaft supplying water for use in Leyner drills. These men below the 3,000 level were all hoisted to the 2,800 level, as no men were found dead below the 3,000 level, and few if any below the 2,800 level.

Between each two levels from the 3,000 to the 1,800 were several manways and, in general, the North Butte manways were kept in first-class condition. Between the 1,600 and 1,000 no men were working. The 700 and 800 were connected to both Speculator and Granite Mountain shafts with open drifts between shafts, but had no open connection to adjoining mines. The 400 and 600 were connected only to the Speculator shaft, but the various levels from 400 to 800 had several manways in fairly good state of preservation, and some men from the 800 escaped to the Speculator shaft on the 400 on the night of the fire.

DANGERS OF INTERMINE CONNECTIONS.

In the opinion of the writer the Butte practice of making numerous connections to adjoining mines is dangerous. The main objects of frequent connections to adjoining mines, which are almost universally commended by Butte miners, mine managers, and safety men, are: As exits in case of disaster, as an aid to ventilation, and for drainage purposes. Although it is true that approximately 170 employees of the North Butte mine escaped through underground exits to the Badger, High Ore, and Diamond mines on the night of the fire, yet these men, together with many others, could have been saved had the Speculator shaft not been partly out of commission on account of repairs and had there been a more extensive system of

doors controlling the flow of air to or from both the Speculator and Granite Mountain shafts.

A large number of lives were undoubtedly lost, because on learning of presence of smoke in the mine many of the men hastened toward the Granite Mountain shaft, following the precedent set when North Butte employees were compelled on at least two occasions during the High Ore-Modoc fire in April and May, 1917, less than two months before the North Butte fire, to flee toward the Granite Mountain shaft for safety. During the High Ore-Modoc fire the North Butte mine was closed for nearly two weeks because of gas and fear of gas, and on the night of the outbreak of that fire North Butte employees were being overcome by fumes from the High Ore as their first warning of danger. Conversely, on the night of the North Butte fire employees of the High Ore mine, working on pumps at pumping stations along the High Ore shaft, some wearing Draeger apparatus, were overcome by North Butte fumes and brought unconscious to the surface. O'Neill and Lorie, of the Diamond mine, were overcome and killed by North Butte gases within 50 feet of the Diamond shaft, yet the Diamond mine is connected to the North Butte only indirectly through the Badger and High Ore. Several other Bell-Diamond employees were overcome by North Butte gases in the Bell-Diamond mine and many of the Bell-Diamond men had to be hoisted through the West Grayrock shaft. Badger mine employees, who had no reason to fear gas from the North Butte mine because the general direction of air currents was toward rather than from the North Butte, narrowly escaped disaster when the smoke from the North Butte quickly reversed the usual direction of currents.

Connections should be made between mines only for drainage purposes and for gaining admission to existing mine fires to extinguish them.

Existing connections between mines should be closed with air-tight doors, preferably of steel or concrete, on concrete frames and with edges sealed by concrete. Doors should not be hung inside of concrete frames, but should be placed flush against the smooth outside surface so that they may not be readily affected by settlement of ground. Where doors can not be made air-tight the doorway should be sealed with 2 or 3 inches of concrete and picks and hammers should be left on each side of the door with signboards giving directions as to the thickness of the concrete.

Although but one man was found dead at a concrete bulkhead or at a brattice of any kind erected by mining companies in the connections to other mines, the existence of bulkheads on the 2,400 and 2,800 levels to High Ore connection may have caused some men to retreat and later on to lose their lives. However, the bulkheads in the doorways of concrete frames on the 2,400 and 2,800 exits to the High Ore

mine were placed by the officials of the High Ore mine to protect the employees of the North Butte mine from poisonous fumes from the High Ore-Modoc fire in April and May, 1917, *which was still burning when the North Butte fire occurred.* It had been found impossible to make the standard iron doors sufficiently tight to exclude the poisonous gases and the thin concrete brattices were placed solely to give positive assurance of safety to North Butte employees who at least twice, in April and in May, 1917, had been hurriedly taken from the mine to avoid gases from the High Ore fire coming through the identical doors which were concreted later. Any loss of life due to bulkheads placed by mine officials in exits to other mines is chargeable directly to the mistaken policy of all classes of Butte miners, mining men, and inspectors in demanding a multiplicity of connections. At the time of the High Ore-Modoc fire the North Butte Mining Co., unwilling to risk the lives of employees while fire was uncontrolled in an adjoining connected mine, closed the North Butte mine for nearly two weeks.

PUBLICATIONS ON MINE FIRES AND VENTILATION.

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PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 75. Rules and regulations for metal mines, by W. R. Ingalls and others. 1915. 296 pp.

TECHNICAL PAPER 82. Oxygen mine rescue apparatus and physiological effects on users, by Yandell Henderson and J. W. Paul. 1917 102 pp., 5 pls., 6 figs.

TECHNICAL PAPER 229. Accident prevention in the mines at Butte, Mont., by Daniel Harrington. 1920. 59 pp., 2 pls.

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Rescue and recovery operation in mines after fires and explosions, by J. W. Paul and H. M. Wolflin. 1916. 109 pp.

Manual of first-aid instruction for miners, by a Committee of Surgeons on Standardization of First Aid. Revised by R. R. Sayers. 1921. 214 pp., 99 figs.

PUBLICATIONS THAT MAY BE OBTAINED ONLY THROUGH THE SUPERINTENDENT OF DOCUMENTS.

TECHNICAL PAPER 67. Mine signboards, by Edwin Higgins and Edward Steidle. 1913. 15 pp., 1 pl., 4 figs. 5 cents.

TECHNICAL PAPER 77. Report of the committee on resuscitation from mine gases, by W. B. Cannon, G. W. Crile, Joseph Erlanger, Yandell Henderson, and S. J. Meltzer. 1914. 35 pp., 4 figs. 5 cents.

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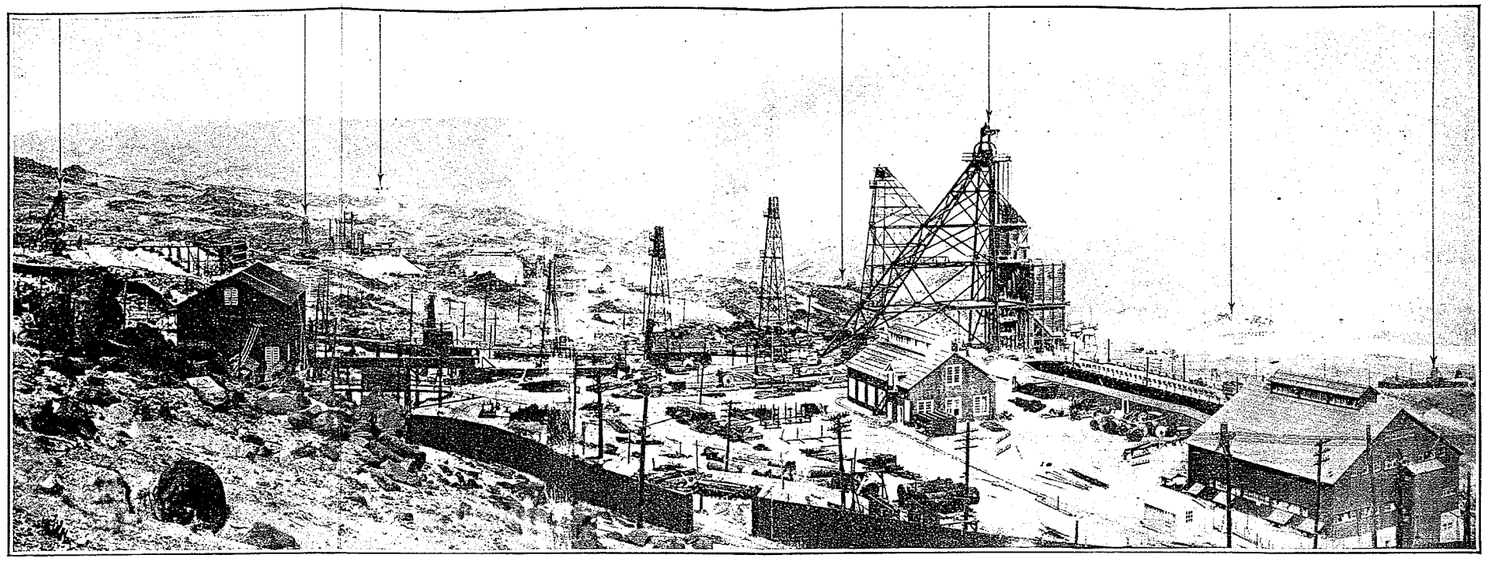

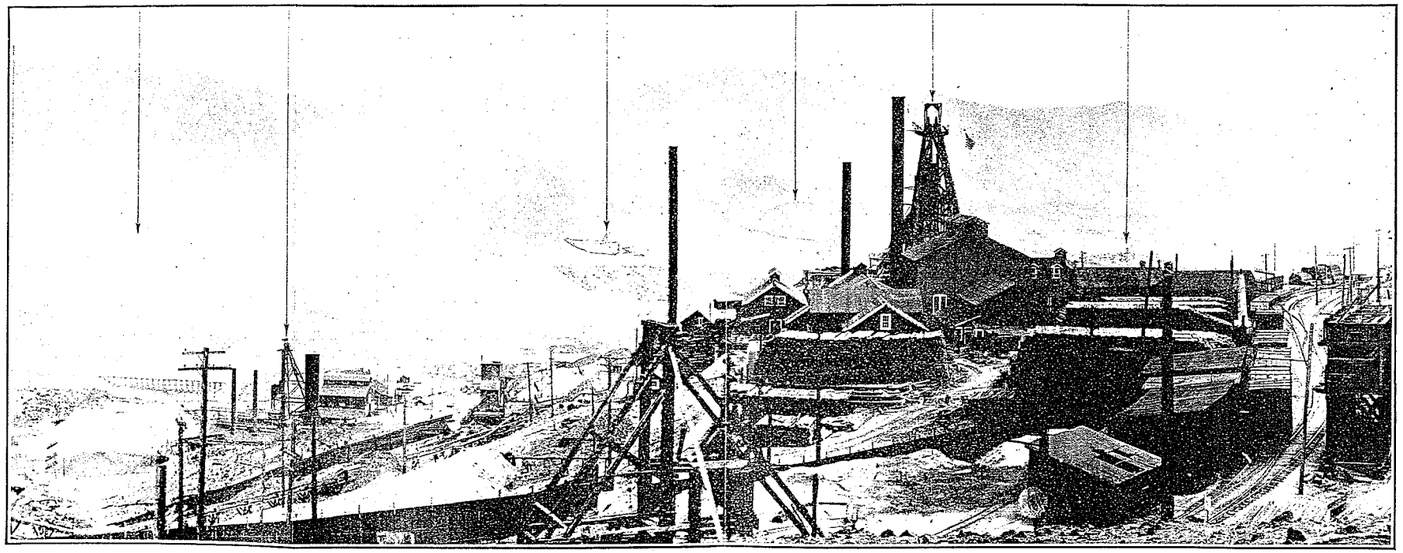

PANORAMA OF THE NORTH BUTTE TERRITORY, SHOWING THE GRANITE MOUNTAIN AND SPECULATOR SHAFTS.