DEPARTMENT OF COMMERCE
HERBERT HOOVER, Secretary

BUREAU OF MINES
D. A. LVON, Acting Director

REVIEW OF
SAFETY AND HEALTH CONDITIONS
IN THE MINES AT BUTTE

BY

G. S. RICE and R. R. SAYERS

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PREFACE

The Bureau of Mines began its investigations of accident prevention and of conditions relating to the health of miners in the mines of Butte, Mont., after a general reconnaissance of health and safety conditions in metal mines throughout the United States. This general preliminary survey, made in cooperation with the Public Health Service, was begun soon after the establishment of the bureau in 1911 and was followed in 1915 by an intensive investigation of the effects of siliceous dust on the health of miners in the Joplin district. Also in 1913 and 1914 one of the bureau engineers engaged in ventilation studies made observations at Butte.

No other metal-mining district now being worked in the United States can show such intensive mining in a small area, and probably in none have the mine operators to cope with more difficult mining conditions. High rock temperatures in the deep workings, heavy ground requiring extensive timbering with consequent danger of disastrous mine fires, and in addition the potential danger to health by dusts produced in mining siliceous ores must all be met.

The intensive investigations at Butte were begun in 1916 with the cordial cooperation of the various mining companies and continued at intervals by Daniel Harrington, mining engineer, under the general supervision of the chief mining engineer, George S. Rice, and in cooperation with Dr. A. J. Lanza, of the Public Health Service. In 1917 Doctor Lanza was assisted and later succeeded by Dr. R. R. Sayers, of the Public Health Service.

Other engineers of the bureau staff have assisted Mr. Harrington as the need arose, and in 1922–23 G. E. McElroy, mining engineer, in cooperation with A. S. Richardson, ventilating engineer of the Anaconda Mining Co., carried on tests of ventilating ducts in one of the Anaconda mines to determine ventilation constants under various conditions. Important technical results have been achieved, of which only a part have as yet been published, though papers and bulletins on the various subjects have been issued by the Bureau of Mines.

Mr. Harrington during the winter of 1923–24 obtained data on which most of the following paper is based. He has recently left the Government employ after rendering most valuable service to both the Bureau of Mines and the mineral industry in helping to increase safety and health in mining operations. Because of Mr. Harrington having left the service and because of the termination of a 10-year period of observation at Butte by the bureau staff, it was deemed advisable to supplement Mr. Harrington’s recent data
with a general review of the Butte mine-safety and health conditions by Dr. R. R. Sayers, chief surgeon, and Mr. George S. Rice, chief mining engineer. Their report, which follows, confirms the data gathered by Mr. Harrington, and shows the enormous advances made by the Butte mining companies since the bureau’s investigations began in 1916.

At that time the records show that miners in many places in the mines worked in hot, humid air with little or no movement. Bad fires in old stopes were inclosed as well as possible by fire walls, but poisonous gases occasionally leaked through the ground. A few mines had only one shaft—that is, only one means of exit in the event of a fire or other disaster. Few of the mines had adequate ventilating fans on the surface, and these fans were not reversible. Dry drilling was general and no spraying was done; the miners were subjected to breathing siliceous dust; miners’ phthisis was prevalent and the death rate from pulmonary troubles was high.

The reader should note that Butte mining methods then were no worse nor were fewer precautions taken than in other metal-mining districts of the United States; on the contrary, they were as up-to-date, and their condition is recorded as illustrative of what then was true in the United States. Most of the mine operators had already begun, on their own initiative, to improve conditions underground. The largest company had begun to install large fans. By 1914 safety measures had assumed such importance at Butte that the vice president of this company gave his entire time to the safety department; by 1915 he had established a central mine-rescue station and had placed that work in charge of a former experienced member of the Bureau of Mines.

As the investigations of the Bureau of Mines proceeded, its findings and suggestions were imparted to the respective mine managements, compared with their own findings, and largely adopted. The advance that has been made in the 10 years through the cooperation of Government and companies, as pointed out in this report by Messrs. Rice and Sayers, has been notable—perhaps greater than that achieved by any other large mining district in the United States. The bureau is happy to have had a part in this work, but has no desire to claim credit for more than its part as a sympathetic observer and cooperator through the 10 years’ work.

To-day the largest old mine fire area has been filled with slimes and the abandoned ore is now being mined. Virtually every mine now in operation has on the surface a large ventilating fan with fireproof setting arranged for quick reversal. Numerous fireproof fire doors have been installed. Coursing the air is practiced as in coal mines, and in one large group of mines every heading and
raise is ventilated by an individual ventilating canvas tube. Hundreds of small fans have been placed for this purpose. The result is that the air in the working places has been so improved and the ground itself so cooled by the rapid ventilation that the miners can put in full working shifts without discomfort. At all mines now in operation water-injection drills and wet stopers have been put in or converted from dry stopers and the men have been generally educated to use water willingly in connection with drilling, although admittedly they do experience some discomfort through getting wet. While imperfections undoubtedly exist in the system and further improvements in drills are needed, wet drilling and stoping have been adopted in principle and in general practice. Watering the broken rock and ore is practiced, but Messrs. Sayers and Rice point out that in this practice and in the use of water sprays or water blasts, such as are used in South Africa, further improvement may be made. The mine operators interviewed have concurred in the suggestion.

For fire protection, besides the fire doors introduced, some of the downcast shafts have been smooth lined with concrete slabs, which incidentally lessen air friction; other shafts have been gunited or coated with cement, and many of the shaft stations, small-fan installations, and ventilating-door frames have also been gunited. Water lines extend to all working places and there are numerous taps for fire fighting. Fire hose and extinguishers in some mines are kept ready for use at shaft stations; at other mines these are kept on the surface. Messrs. Sayers and Rice believe that it might be advisable for all the mines to have hose and extinguishers at shaft stations, even if they do deteriorate.

All the mines now active have fire-fighting organizations with men trained in the use of oxygen-breathing apparatus. At some of the individual mines this apparatus is kept ready for use. The largest mining company has two well-equipped central fire-fighting and rescue stations with firemen in constant attendance, and it has facilities for calling out over 100 trained men in any emergency. Over 500 men in the Butte mines have been trained in the use of self-contained oxygen-breathing apparatus, and many others have been trained in giving first-aid treatment.

In view of the great advances in safety and health conditions in the Butte mines since the first survey by the bureau, the industry is to be congratulated upon the progress made, which serves as an example for other districts. Mining is inherently a dangerous occupation, but much has been done, as at Butte, to make it less dangerous than many occupations aboveground.

D. A. Lyon, Acting Director.
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Plate 1. Notice posted at shaft station as safeguard to miners facing 12
REVIEW OF SAFETY AND HEALTH CONDITIONS IN THE MINES AT BUTTE

By G. S. Rice and R. R. Sayers

INTRODUCTION

This review of safety and health conditions in the mines of Butte, Mont., is prepared from data gathered during the period 1916 to 1924, inclusive, chiefly by Daniel Harrington, who was until recently supervising mining engineer of the Bureau of Mines. His data have been supplemented by material obtained by other investigators and by the notes the authors of this paper made during their last visit to the mines in August, 1924. The recommendations resulting from the investigations conducted with the cooperation of the mining companies of the district, as made in conferences, reports, and printed papers, have undoubtedly exercised a strong influence in advancing the cause of safety and health in the Butte mines.

DESCRIPTION OF BUTTE MINING DISTRICT

For the benefit of those readers not familiar with mining developments at Butte, a brief description of matters that bear on this review follows:

In the Butte area there is a granitic uplift cut by numerous faults and several groups of veins which intersect and make in certain zones a network of mineralized veins with dips that range from 60° to vertical. The general country rock is hard granite and in some places the vein matter is disintegrated granite. The veins carry copper, iron, zinc, or lead minerals, which are sulphides below the oxidized zone, and yield silver and some gold. Pyrite is common. The zinc-bearing veins are chiefly in the northern part of the district.

METAL PRODUCTION OF DISTRICT

The following table gives the total metal production of the Butte mining district up to the end of 1922:

Metal production of Butte district

<table>
<thead>
<tr>
<th>Metal</th>
<th>Quantity</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>8,152,406,826 pounds</td>
<td>$1,274,890,968</td>
</tr>
<tr>
<td>Zinc</td>
<td>1,607,860,611 do</td>
<td>142,915,499</td>
</tr>
<tr>
<td>Silver</td>
<td>376,104,727 ounces</td>
<td>276,985,724</td>
</tr>
<tr>
<td>Gold</td>
<td>1,564,738 do</td>
<td>32,346,006</td>
</tr>
<tr>
<td>Lead</td>
<td>188,194,808 pounds</td>
<td>8,423,485</td>
</tr>
<tr>
<td></td>
<td>1,735,460,682</td>
<td></td>
</tr>
</tbody>
</table>

At the time this review was written the production of the Butte district, as shown by the table above, had exceeded one and a half billion dollars in about 40 years of underground working. Thus the claim that the Butte hill was the richest compact mining area in the world was well founded.

The levels in the deepest mine have already reached 3,800 feet below the surface and mineralization continues. As in every metal-mining camp, mines have started in outlying places, flourished for a time, and then have been abandoned on account of failure to find pay ore, or they have been shut down temporarily because the price of metals was too low.

In common with mines in other districts in the United States, the Butte mines reached their greatest activity and prosperity in the years 1916 to 1918, during the World War.

In 1920, Harrington, from data obtained in the years 1916 to 1918, gave the following data on the chief operating companies:

Men employed and ore hoisted at Butte mines

<table>
<thead>
<tr>
<th>Name of company</th>
<th>Employees surface</th>
<th>Employees, underground</th>
<th>Total employees</th>
<th>Daily tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaconda Copper Mining Co.</td>
<td>1,600</td>
<td>9,000</td>
<td>10,000</td>
<td>17,000</td>
</tr>
<tr>
<td>North Butte Mining Co.</td>
<td>150</td>
<td>1,300</td>
<td>1,450</td>
<td>2,500</td>
</tr>
<tr>
<td>Butte &amp; Superior Mining Co.</td>
<td>200</td>
<td>1,300</td>
<td>1,500</td>
<td>1,800</td>
</tr>
<tr>
<td>Elm Oriel Mining Co.</td>
<td>75</td>
<td>300</td>
<td>375</td>
<td>630</td>
</tr>
<tr>
<td>East Butte Mining Co.</td>
<td>75</td>
<td>600</td>
<td>675</td>
<td>575</td>
</tr>
<tr>
<td>Davis-Daly Mining Co.</td>
<td>50</td>
<td>200</td>
<td>250</td>
<td>225</td>
</tr>
<tr>
<td>Other companies</td>
<td>100</td>
<td>400</td>
<td>500</td>
<td>339</td>
</tr>
<tr>
<td></td>
<td>2,250</td>
<td>13,100</td>
<td>15,350</td>
<td>23,000</td>
</tr>
</tbody>
</table>

The city of Butte at that time was said to have about 80,000 inhabitants. The loss of markets for metals and the depression in prices caused a shutting down of many of the mines and a migration of miners, until in 1924 the population was about 40,000.

Some of the mines which had been closed resumed operations in 1922. In August, 1924, when the authors of this paper visited the

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mines listed in the above table, the 12 mines of the Anaconda Co., the Butte & Superior, and the Elm Orlu mines were in operation; the East Butte mine had a small force on development work; and the North Butte and the Davis-Daly (recently acquired by the Anaconda Copper Mining Co.) were shut down. The total number of mine employees in the district was approximately 10,000.

Figure 1 shows the headworks of a Butte mine.

METHODS OF MINING

The general system of mining at Butte is square sets with back filling. The rill system is employed wherever the veins are not too wide and the walls are strong enough. About one-third of the present production of the Anaconda mines come from rill stopes.

The Elm Orlu Mining Co. also uses rill stoping where the ground is suitable. The Butte & Superior uses the system in copper veins but the zinc veins have to be mined chiefly by square sets and filling. The rill system has sometimes been criticized as more dangerous than mining with square sets but accident records of the Butte mines do not justify this view. In fact, many experienced Butte mining men consider that when the ground is suitable, the rill method provides the better protection for the men.

HANDLING OF ORE

The ore is moved by chutes in square-set stopes and on an inclined floor in the rill stopes. These methods are described in detail by
H. R. Tunnell in one of a series of discussions on Butte mining published in 1922.

Some hand tramming is done and a small percentage of the ore is hauled by horses or mules, but most of the haulage is done by electric locomotives. Trolley locomotives were first introduced about 1908. Generally the trolley wire is well guarded by inverted wooden troughs, as shown in Figure 2. About 1914 the Butte & Superior Co. introduced storage-battery locomotives, shown in Figure 3. These are rapidly supplanting the trolley type in all the mines of the district, because they are better adapted for use on twisting roadways and lessen the danger of shocks and electrocutions; also they

![Electric trolley locomotive. Note guard for trolley wire](image)

eliminate the difficulty of maintaining the trolley wire in heavy ground and the serious hazard of timber fires from short circuits of the trolley wire or from trolley sparks igniting doorframes or the protective troughs of the trolley wires.

Ore is hoisted in skips that generally are hung below cages with two or three decks; the latter are used to lower and hoist men and to transfer ore cars or cars with supplies. The ore is loaded from pockets below the station floors. In more recent installations there are secondary or transfer measuring pockets, which expedite the loading of the skips and tend to prevent the spilling of ore down the shaft.

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Most of the shafts have three or four compartments which are smaller than is desirable for hoisting purposes and for ventilation; however, it must be recalled that the majority of the shafts were started many years ago, and the smaller requirements of that day fixed the present limits. Hoisting equipment differs widely in different mines. In the early days flat ropes and reels were largely used, and some of them are still in use. More recent hoisting plants have round ropes and cylindrical drums. The early hoists were run by steam; later compressed air was employed for many of the hoists, and a number of these are still in use. All the more recent hoists are electric. The Butte & Superior main hoist was, and perhaps still is, the largest electric hoist in the world. It is driven by a 3,000-horsepower motor, and employs the Ilgner and Ward-Leonard system of balance and control.

**MINE FIRES**

The Butte mines have had many serious fires; those in the interior workings in stopes have been most costly, but attended by little or no direct loss of life. On the other hand, two fires in downcast shafts were most disastrous—one in the Pennsylvania mine in 1916 cost 21 lives, and the other in the Granite Mountain shaft of the North Butte mine in 1917 cost 163 lives. The former was thought to have been caused by ignition of timber by a candle flame; the
latter resulted from the falling of a large new lead-protected cable while it was being hung in a downcast shaft. The fall stripped the insulation from cable and a carbide lamp set fire to the oiled insulation.

Mr. Harrington studied these fires after taking part in the rescue work. His report on the North Butte fire has been published by the bureau. The lessons learned from these disasters caused the leading mining companies to make many improvements in methods of ventilation and fire protection. So far as practicable under the conditions surrounding the shafts (nearly all of which were put down many years ago) and the air connections to adjacent mines, the hoisting shafts were made downcast; and some downcast shafts, either hoisting or air shafts, were lined with concrete or were gunited. Main ventilating fans were placed on the surface at upcast shafts and were made reversible. Water lines, fire hose, and extinguishers were installed more generally, and the fire-fighting organizations were enlarged and improved.

**STOPE FIRES**

One of the most serious problems that has confronted the Butte district has been the occurrence of fires in the workings; these fires, no matter how started, work up into the heavily timbered stopes unless they are caught at the very start. The principal fires in the inner workings enumerated by Harrington are the Anaconda mine fire, burning continuously since 1889, the Leonard-Tramway-West Colusa fire, burning continuously since 1906, and the Mountain View fire, long fought, sealed, and probably "dead."

When fighting with hose and water has failed because of the seat of the fire becoming inaccessible by reason of falls of burning timber and of ground, the area is isolated as rapidly as possible by fire stoppings which must be built under difficult conditions—heat, smoke, and fumes requiring the constant use of breathing apparatus.

When the stopes extend up through several levels, complete sealing of the fire area is difficult, and at some fires has proved impossible because ground movements continually crack the pillars and walls and thus permit air to leak into the fire area. The fire smolders, gives off sulphurous fumes as well as heat, makes that part of the mine very difficult to work, and causes the loss of ore in pillars. Moreover, there is always a possibility of such a fire breaking through the barriers because of sudden movements of ground. The fire area must be kept under patrol and work must be constantly done, such as repairing stoppings and plastering.

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fresh cracks in the walls and pillars. For this work the cement gun has been employed with great advantage. This method of putting on cement-sand coatings was first used underground by the Bureau of Mines at its experimental mine in 1913–14, and was recommended to mine operators for fire fighting and for the prevention of weathering of mine walls. The Anaconda company further developed methods for application in moving ground, such as the erection of brattice cloth in front of, but not attached to, the wall or pillar; and then, after chicken wire fencing is pinned in front of the brattice cloth, a thick coating of cement sand is applied with the gun, and thus makes a tight reinforced cement-sand coating which is strong enough to be self-sustaining and does not crack until there is a considerable movement of ground.

COLUSA MINE FIRE

The longest and most serious stope fire was that which burned continuously from 1906 in parts of the Leonard-Tramway-West Colusa mines in spite of every effort to seal off and extinguish it. Finally in 1916 the mine officials decided to fill the area with slimes from the Butte & Superior mill, beginning on the bottom level affected, after strong bulkheads provided with drain pipes to carry off the water had been erected. The slime filling continued over six years and was finally successful in extinguishing the fire, thus affording opportunity to recover valuable ore in the pillars and adjacent areas—a notable achievement. One million tons of solid material or 4,000,000 tons of liquid slimes had been forced into the burning and caved stopes, chiefly through diamond-drill holes from higher levels. In all, 200,000 feet of diamond drilling was done. Underground the work had to be carried on in the presence of terrific heat and often of sulphurous fumes that required the use of self-contained breathing apparatus. The work was made possible by a system of ventilation carefully arranged to cool the places where the men worked and to carry off the fumes. The methods employed are fully described in a paper by H. J. Rahilly,² mining engineer of the Anaconda Mining Co. and a former employee of the Bureau of Mines.

ELM ORLU MINE FIRE

Since Mr. Harrington’s last visit a fire started in the Elm Orlu mine, August, 1924, in the level below an old extensive stope not far from an upcast shaft. Had it not been fought vigorously and efficiently from the start by trained crews from the Anaconda central stations and the Elm Orlu crews, it would have resulted disastrously.

RESULTS OF PROTECTIVE MEASURES

From 1917 until this recent fire there were no serious fires at Butte, although the mine managements report many incipient fires that did not become serious, largely because of the precautionary measures taken against the starting of fires, the systematic methods in vogue for quickly locating any fires that might start, and the prompt and effective steps taken to extinguish them immediately. The authors of this report in going about the mines noted that, although considerable fireproofing has been done and probably is being done as rapidly as conditions permit, the amount of it that can be done in mines like those at Butte is insignificant in comparison with the amount of heavy timbering exposed which can not be protected in moving ground. The most that can be expected is the fireproofing of downcast shafts and stations and the space around electrical installations that are not flame proof, and the erection of fire doors at the entrances to all shaft stations and at other critical points.

CAUSES OF MINE FIRES

Mr. Harrington considers that the fires in the Butte district have been caused chiefly by the ignition of timbers by either candles, electric cars, or carbide lights, but believes some of the fires were possibly of spontaneous origin. In other districts fires have been started by explosives used in driving drifts through crushed timbered stopes or drifts. In 1916 the general use of candles was practically discontinued in Butte mines and thus the most dangerous source of ignition was eliminated. A few fires have been caused by carbide lamps. Where timber is decaying, only a moment's exposure to the hot acetylene flame may cause ignition.

ELECTRIC LAMPS FOR MINERS

Mr. Harrington believes that miners' lamps with open flames should be replaced by permissible storage-battery lamps, the use of which would eliminate the possibility of ignition by miners' lights. The Anaconda company has taken the matter under advisement and is now trying out some permissible electric cap lamps. The chief objection to these lamps, however, is that the storage battery of the lamp catches when the wearer climbs through manholes and restricted places in raises. It is hoped that this objection will disappear as the men become accustomed to the presence of the batteries on their belts and as a little more care is exercised in providing for clearance room in manways.

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*Spontaneous firing of decaying crushed timber has been suggested as possible, but because of the high moisture content is improbable. The crushing and sliding of rich sulphide ores in stopes frequently causes such rapid oxidation of fine particles that fire results.*
SMOKING

Butte mine operators have fully recognized that smoking by men underground may be the cause of fires. One company has rigid rules against smoking; another company does not forbid smoking because it believes that if smoking is forbidden some men will smoke in spite of the rule, and, as a foreman approaches, will flip a cigarette or empty a pipe where the burning tobacco may fall on timber.

Mr. Harrington holds that smoking should be positively forbidden underground. The authors are convinced that the only way such a rule can be made effective is to search men for matches and tobacco when they enter a mine, as is now done at well-managed gaseous coal mines. However, until electric lamps are generally adopted, it is hardly possible to eliminate matches; and tobacco is easily concealed in food carried in. Although the authors of this paper believe that smoking should not be done underground in timbered or gaseous mines, they are in doubt as to the advisability of trying to enforce such a rule by penalty until open lights have been discarded.

ELECTRICAL HAZARDS

The increased use of electricity underground for haulage, general power, and lighting purposes in the Butte, as well as in other mines, has undoubtedly increased the hazard of electric shock and the hazard of fires starting from short circuits or electric sparks. If open lights are eliminated and smoking is stopped, electricity will be practically the only cause of igniting timber, except as spontaneous combustion may originate in sulphide ores.

Formerly, as Mr. Harrington reports, electrical equipment underground at Butte, in common with similar equipment elsewhere, was installed in a slipshod and dangerous way and many fires of electrical origin occurred. In recent years all of the operating companies have been making improvements and overhauling their electrical equipment. Descriptions of the work being planned and done by the Anaconda company are given in separate papers by E. M. Norris and C. D. Woodward. In their visits to the mines the authors of this paper noted that the underground electrical installations were in general fully up to the best American mining practice in respect to armored cables, taps on power lines, and protection at switchboards and in transformer

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stations. The trolley wires usually were well boxed to prevent electric shock to men traveling the roads or loading ore into cars from chutes. However, although timbering in the vicinity of the small blowers used in ventilation was protected from fire by guniting, this protection was not always as well done as is desirable at such critical places. If a fire does start from a hot bearing or from a shorting or burning out of the motor and ignites the insulating material, it is liable to be rapidly fanned into a serious blaze and set fire to near-by timber.

GUNITE AND CEMENT IN FIREPROOFING

The use of gunite for fire protection has been extensive in the Butte mines wherever there are electric cables. Harrington reports that the Anaconda company has gunited over 40,000 linear feet of shaft, many shaft stations, fan stations and electric stations, as well as thousands of feet of drifts or tunnels. Other companies are also using gunite, and this commendable practice may be considered general in Butte mines. The Anaconda company has also developed a method of lining timbered air shafts with concrete slabs so as to obtain a smooth surface as well as fire protection. Richardson has shown that in the shafts so lined the friction of the air has been reduced enough to increase greatly the ventilating capacity of the shaft. According to Harrington the Anaconda company has 26,000 linear feet of air shaft so lined.

The authors believe that the practice of lining air shafts is most excellent, and is second only to making the air shafts circular and lining them with massive concrete. The Granite Mountain shaft, after the disastrous fire in 1917, was smooth lined with solid concrete, and was said to have then delivered 50 per cent more air than before the fire; presumably this figure is based on the air current being actuated by the same pressure head. Naturally, such massive smooth concrete linings can not be put into old narrow rectangular shafts without great difficulty.

Although it was evident from the recent inspection that much remains to be done in fireproofing in Butte mines, and much more is planned to be done by the companies, taking the district as a whole, fireproofing there has probably advanced as far as in any other important mining district in the United States.

FIRE DOORS AND VENTILATING DOORS

Fire doors are used extensively in Butte mines; some of them are of iron and are hung on concrete frames; some of the doors are of reinforced concrete which is better because iron doors, when exposed

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to great heat are likely to warp. The doors are placed at critical points and some are at the entrance to shaft stations.

The authors believe it would be wise to have fire doors at or near the entrance to at least all used shaft stations and that these doors should have latches made so that the door, after closing, would remain closed if the ventilating currents were reversed or a strong puff of wind was set up by a heavy fall of ground. The latches should be turned by long levers that would insure ability to open from either side. Similar latches are recommended for ventilating doors. A striking case of the importance of such provision was furnished by the recent Elm Orlu fire, during which, when the ventilating current was reversed to clear the hoisting shaft of smoke and permit direct attack on the fire, the latches kept the ventilating doors closed. It is a general and commendable practice to make the more important ventilating doors double with a space between so that one door may always be closed when cars or men are passing. Some doors are provided with arrangements for pulling the door open from a distance—as by a trip rider on an approaching trip of cars. At one mine there were split doors, one-half opening each way so that the doors could be easily closed or opened in a high-pressure current—an excellent arrangement.

FIRE-FIGHTING AND RESCUE CREWS

In each of the mines are crews of fire fighters trained in the use of breathing apparatus. Two central rescue stations, with foremen constantly in attendance, not only serve the Anaconda Mining Co., which established and maintains them, but the men are ready to go at once to any of the mines of the district. These stations have about 100 sets of permissible oxygen breathing apparatus and complete fire-fighting material. About 100 men have been organized into crews and are ready to respond quickly to telephone calls. At least 500 men in the district have received rescue training and could be called on in the event of a disaster.

Both the rescue stations and the crews trained in the use of breathing apparatus, although established for duty at disasters threatening life, are in effect fire-fighting crews. Even coal-mine districts, where rescue crews have the added possibility of being called on for rescue service after gas and coal dust explosions, have found fire-fighting alone justifies the maintenance of the crews.

Moreover, the two purposes, rescue and fire fighting, are not separable; an initial blaze may in a few minutes threaten life, as happened in both the Pennsylvania and the North Butte fires. Undoubtedly the prompt action of such crews has kept numerous incipient fires from getting beyond control and endangering lives.
WATER LINES

As already mentioned, water lines extend throughout the various mines now in operation. One of the indirect advantages of adopting wet drilling is that water lines do extend to each working place and must be kept in constant use. Pipe lines for fire fighting alone are liable through nonuse to be out of order and the water pressure too high or too low. The system, used extensively at Butte, of tanks 200 feet apart vertically, or connected so that they may be by-passed to make the pressure head 400 feet, provides a range of water pressure that is excellent yet not too high for one man to handle a water hose in an emergency.

Some of the mines in the Butte district keep fire-fighting hose at each shaft station; others keep it on the surface near the hoisting-shaft collar. The authors believe that it would be wise for all mines to keep the hose at shaft stations. Admittedly, hose may deteriorate more in a humid atmosphere underground, but if kept in a self-draining trough, its deterioration becomes insignificant in cost.

OTHER PRECAUTIONS

Some of the mines have carbon tetrachloride extinguishers at electric stations and chemical hand fire extinguishers at shaft stations. One mine has adopted the desirable practice of putting at each shaft station a notice, in large type, giving concise instructions on what should be done in case of fire. (See Pl. I.)

The authors believe it would be well to have posted at each shaft station an outline map showing the position on that level of the shafts, drifts, and tunnels that lead to exits; also the normal direction of ventilating currents, position of fire doors, ventilating doors, fire hose, and telephone. Care should be taken to keep the map free from information unessential in the event of fire.

The greatest confidence is deservedly felt at the Butte mines in the splendid rescue and fire-fighting organizations, but it appears to the writers that in addition an excellent plan would be to have the shift bosses and station tenders hold monthly meetings to study fire problems and determine what should be done before the arrival of the higher officials or the rescue crews if a fire starts in the mine.

The precautions the largest mining company takes to prevent fire are fully described in a paper by E. M. Norris.\textsuperscript{12}

DUST AND VENTILATION INVESTIGATION

Practically all stope drilling in the metal mines of the United States up to 1916 was dry; neither sprays nor water hose were then

generally available for that work. (See Figure 4.) Up to that
time, dust had not been generally recognized in this country as a
serious menace to the health of miners. The breathing of rock dust
in large enough amounts and for long enough periods of time often
results in or predisposes to diseases of the respiratory system, in-
cluding silicosis, bronchitis, and tuberculosis. Silicosis (miners’
phthisis or miners’ consumption) is the most important disease
caused by breathing rock dust containing a high percentage of free-
silica or quartz.

That silicosis is produced or is as-
associated with the breathing of rock
dust has been
known by many
men of centuries,
as the literature
indicates.

DEATH RATE FROM
SILICOSIS IN FOR-
EIGN COUNTRIES

Silicosis is known
to be generally
present in a great
many of the hard-
rock mining dis-
tricts of the world.
The disease was
studied in West-
ern Australia by
Dr. J. H. L. Cump-
ston[13] whose re-
port was made in
1910. He said that the death rate due to respiratory diseases among
all nonminers (males) over 15 years of age was 167 per 100,000,
whereas among miners the rate was 539 per 100,000. The death
rate due to tuberculosis among nonminers (male) over 15 years of
age was 96, whereas among miners it was 192 per 100,000.

More work on the study of silicosis has been done in South Africa
than in any other country, because a far greater number of men are
exposed, in a limited region, to the effects of rock dust containing a
high percentage of silica. For the years 1908–9, the Miners’ Phthi-

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phthisis: Milroy Lectures, 1913.
sis Commission of South Africa considered that in any one year approximately 1,000 men out of a mining population of 12,000 would reach the stage of definite incapacity. In the year 1921–1922, 434 cases of simple silicosis developed among South African miners.

PREVALENCE OF SILECOSIS IN UNITED STATES

In 1913 Dr. S. C. Hotchkiss, detailed to the bureau from the Public Health Service, made a survey in the United States which indicated a most serious prevalence of phthisis or silicosis in certain of the western metal districts. The first intensive investigation of this subject, however, was made at Joplin in 1914 by Dr. A. J. Lanza, detailed to the Bureau of Mines by the Public Health Service, and Edwin Higgins, mining engineer. This investigation showed a most alarmingly high mortality from pulmonary disease among miners of that district.

In 1916, with the cooperation of mine operators at Butte, an extended investigation was begun in the Butte mines by Dr. A. J. Lanza and Daniel Harrington to determine the prevalence and the methods of preventing miners’ phthisis or consumption. They obtained definite proof that miners’ consumption was prevalent but, owing to the general reluctance of miners to being examined, the exact proportion of men affected could not be determined. They say in their reports that 42 per cent of the 1,018 men who presented themselves for examination had miners’ consumption, but “it can not be concluded from the above figures that 42 per cent of the Butte miners have consumption. It is, however, possible to say that a large number of miners who have worked for any considerable time in the mines may have the disease.”

Attention is called to the excellent work being done by the Butte Tuberculosis Society. This society reports that in 1919 there were, including the coroner’s cases, 223 deaths due to tuberculosis, which indicates with reasonable certainty that there were 1,115 active cases; in 1921 there were 85 deaths due to tuberculosis and silicosis among the men and 6 due to tuberculosis among the women and children; in 1922 there were 104 deaths due to tuberculosis and silicosis among the men and 8 due to tuberculosis among the women and children; and in 1923 there were 137 deaths due to tuberculosis and silicosis among the men and 11 among the women and children.


These figures show a great preponderance of tuberculosis among men in the district. Although during the last three years there has been some increase in the number of deaths, even the highest rate, that of 1923, is much less than that of 1919. The increase in 1923 over the two preceding years may be due to some extent to the increased number of men working.

As Mr. Harrington has pointed out, in the Butte mines the extensive workings, the large number of veins, and the numerous connections to old stopes make effective ventilation difficult. Most of the ore comes from below the 2,000-foot level and much of it from around the 3,000-foot level. The deepest level at present is the Stewart 3,800-foot level.

**MINE TEMPERATURES**

Rock temperatures differ considerably in different parts of the district at the same altitude. The variation is possibly due to hot circulating waters. In the central part of the district the temperature gradient is high—much higher than in the gold mines of the Mother Lode or the copper mines of the Lake Superior region. Harrington states that the rock temperature is 100° F. at the 3,000-foot level. In 1921 Sayers and Harrington found that the water temperature in the Stewart 3,800-foot level was 113°, the rock temperature 108°, and the air temperature 107° F., with a relative humidity of 100 per cent. At the time of the visit of the authors in 1922, water standing in a drill hole at the face of the heading had a temperature of 105°. The air temperature in the heading at that time was 92° F. and the air was saturated; but the temperature of air issuing from the canvas tube ventilating the place was but 88° F., and at the shaft only 75° F., so the ground is evidently being cooled by the ventilation.

H. M. Wolflin, a mining engineer of the bureau, in a study of ventilation in the Butte mines in 1913 and 1914, found many hot working places not only in the neighborhood of the fire areas but in the headings and raises. In occasional visits one of the authors of this paper also observed this condition. The air temperature in the deeper workings, where the rock temperatures were naturally high and fully saturated with moisture, approached blood temperature. Under these conditions the miners went back frequently to rest where there was some natural circulation of air.

**VENTILATION**

Often in blind headings the air was vitiated by powder fumes that were not entirely removed by blowing out with compressed air. In fact, compressed air coming from the drill exhausts and
bleeding from the compressed-air line was the only general mechanical method of ventilation in metal mines in which dangerous gases other than powder fumes were rare. In other words, there was no systematic "coursing" of the air as required in coal mines and as is now general in the Butte mines.

It soon became evident to the bureau investigators that the question of health of the miners was closely related to the question of ventilation. Doctor Sayers and Mr. Harrington found that high temperature and humidity probably lowered the vitality of the workers and reduced their efficiency at least 50 per cent. It was determined that powder fumes and dust could be removed to a certain extent by better ventilation with fresh air.

STUDIES TO IMPROVE VENTILATION

Accordingly, Mr. Harrington devoted much attention to methods of improving ventilation and its effect on temperature and humidity in the working places. This study was carried on while the ventilation methods were being rapidly improved by the mining companies. His published report on this subject gives details of these studies.

IMPROVEMENTS MADE

In 1910 the Anaconda Mining Co. began installing ventilating fans. In 1916 the same company appointed a ventilating engineer who, with the help of safety engineers appointed for each mine, began systematic testing and planning for better general ventilation and the improvement of local ventilation by canvas tubing. Meanwhile other companies in the Butte district had begun improvements in ventilation—notably the North Butte Mining Co. which developed the use of canvas tubing with special jointing simultaneously with a similar development by the Anaconda Co.

The extensive use of canvas tubing in place of the more cumbersome metal and wooden box pipes, which in use become leaky at the joints, and the development of connections for the canvas tubing and of methods for taking them down and putting them up again quickly are the notable contributions which Butte operators have made to the ventilation of tunnels and metal mines.

Harrington points out that in 1917 some mines at Butte had but one shaft and practically no mechanical ventilating equipment, and that few main fans were reversible. Now all the mines have at least

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two shafts, and practically all the mines have large, capacity, quickly reversible, well-housed fans placed on the surface where they are not liable to damage by a mine fire. When the main fan is placed underground often there is a recirculation of mine air; this can not happen when the main fan is on the surface. This change marks a most commendable improvement—one unsurpassed in any other metallic mining district in the country.

In February, 1924, according to Mr. Harrington, there were in the Butte district about 35 operating mines, which employed in all not more than 7,000 men underground, and not more than 3,000 to 4,000 at any one time. To ventilate these mines there are about 40 electrically driven fair-sized to large-capacity main fans on the surface, which have a total delivery of about 2,750,000 cubic feet of air per minute and use electric motors of nearly 4,000-horsepower capacity. There are about 20 fairly large underground booster fans and over 250 small electrically driven blowers for ventilating blind headings and raises through use of tubes—mainly canvas tubes 12 to 16 inches in diameter. Some of the tubes are 8 inches in diameter, but these are being discarded for larger tubes. Men can now work without serious discomfort in places that were formerly "hot boxes."

In 1923 the Anaconda company used 120,000 linear feet of flexible tubing, the life of which averaged five and one-fourth months.

Nearly every mine in the Butte district has at least one man whose attention is given largely to ventilation. Mr. Harrington says that one mining company operating a fairly large mine has at all times three men—and much of the time four or five—wholly engaged on ventilation work; and the management feels well repaid for this expenditure, because the lower temperature in working places through effective ventilation has decreased labor turnover immensely, and it is also said "that in decreased decay of timber alone the ventilation expenditure is saved."

FAULTY DISTRIBUTION OF AIR

Mr. Harrington expresses the opinion that at present the main defect in the ventilation of Butte mines is the faulty distribution of air. He believes that in order to obtain full benefit from the liberal expenditures for ventilating equipment it would be well to give more attention to bringing the available underground air currents to the active working places. One of the most effective ways of doing this would be to seal abandoned places, drifts, raises, and stopes, as well as other places not in use.

This recommendation by Mr. Harrington seems sound in principle. Evidently a large volume of air per man employed, 250 to more than 400 cubic feet per minute, is entering the mine—an
amount larger than that entering most coal mines. In coal mines, however, there is better opportunity to circulate the air to the working faces than in metal mines. But at Butte a certain amount of air is needed to lower the rock temperatures, and the cooling can be done practically only by rapid currents of comparatively cool air.

STUDIES OF MECHANICS OF VENTILATION

In 1922-23 G. E. McElroy, mining engineer of the bureau, in cooperation with A. S. Richardson, ventilation engineer of the Anaconda Co., made a study of the mechanics of ventilation by tubes and small blowers to establish fundamental factors in such ventilation. Three reports,\textsuperscript{19} prepared by Mr. Elroy and Mr. Richardson, have been issued by the Bureau of Mines.

Mr. Harrington obtained comparative data on the lowering of temperature and humidity in working places between 1916, when the first investigation was made, and 1924, when improvements were in effect. His statement follows:

The effect of the improvements made in ventilation is clearly shown at one mine which, in 1916, had in 87 working places an average air temperature of 82.4\degree F. and an average relative humidity of 85.2 per cent, but in 1924 had in 81 working places an average air temperature of 71.6\degree F. and an average relative humidity of 81 per cent. Here is an average reduction from 1916 to 1924 of about 11\degree in dry-bulb temperature and of over 4 per cent in average relative humidity. Moreover, in 1916 the air in the working places was stagnant and impure, whereas in 1924 nearly all the working places were ventilated by comparatively fresh air.

In another mine in 1916 the average air temperature of all places, about 40, where work was being done was 80\degree F.; in 1924 the air temperature in the working places, also about 40, had been reduced to 66\degree F.—an average reduction of 14\degree.

In still another mine in 1916 there were few, if any, working places with moving air; the air temperature in nearly every working place was above the rock temperature of 78\degree F. (some readings at faces reached 87\degree F.), the relative humidity in no working place was below 90 per cent and in most was above 95 per cent; in 1924, 109 working places in this mine had an average temperature of 69.8\degree F. and an average relative humidity of 88.4 per cent. In 1916 the working places were almost undurable, because the air was stagnant, had high temperature and humidity, and was low in oxygen. In February, 1924, there was fresh moving air in practically all places, and working conditions approached the ideal of comfort as closely as those in any metal mines ever visited by the writer.

In 1923-24 a survey of 676 working places in 16 mines showed an average dry-bulb temperature of 75\degree F. and an average relative humidity of 81 per cent.

A similar survey, about five years before, of 586 places in 14 of the 16 mines showed an average dry-bulb temperature of 81° F. and an average relative humidity of 87 per cent. These average reductions of 6° in dry-bulb temperature and of 6 per cent in relative humidity combined with the definite movement of air in many, if not most, of the working places have improved the comfort of miners enormously.

All working places visited in 1924 by Mr. Harrington and the authors were found well ventilated in contrast to conditions some years earlier. In a few places, however, the full benefit in preventing silicosis is not attained from the good ventilating equipment, because not enough care has been taken to select a clean supply of fresh air. For example, a booster fan which was ventilating several working places drew its supply from near the downcast shaft where the dumping of dry ore from cars into ore bins was producing much dust, some of which was carried back to the working places. This condition could have been prevented by the selection of a clean source of air or by wetting the ore. Attention was called to the condition, and it has probably been corrected. It is cited as an illustration of the care that should be taken in planning ventilation.

Besides lowering the underground temperature and being of great advantage in the control of mine fires, should they occur, good ventilation is one of the chief factors in eliminating dust and thus preventing silicosis. The other two factors in the prevention of this disease are wet methods of mining and physical examination of all employees. As mentioned in the discussion of mine fires, the mining companies at Butte have adopted the wet method and have piped water to nearly all working places in the mines. Mr. Harrington has called attention to the fact that the dry drilling of upper holes is one of the most prolific sources of the dust which impairs the health of the miners.

During the past few years dry stopers have been practically replaced in the Butte mines by wet stopers, of which there are over 1,000; three-fourths of this number are hand-rotated and one-fourth self-rotated. One of the mining companies has converted 700 dry stopers into hand-rotating wet stopers. To serve these drills about 250,000 feet of water lines have been laid, and over 40,000 feet of water hose have been placed in the mines.

Blasting, another dust-producing operation, is usually done only at the end of a shift. In some mines, however, some firing is permitted during the shift, and the elimination of this would be advantageous. In many of the working places the rock is wet down with hose after blasting. In some mines and on some levels very little water is used for this purpose. Wetting down the walls and floor is also practiced, but not universally.
WATER BLASTS

Water blasts, or atomizers, using water pressure aided by air pressure which breaks the water up into fine clouds of mist are especially useful in wetting down roofs, sides, and floors of a mine as well as ore piles. Owing to the immense number of minute drops of water in the mist, dust in the air is wetted and settles out more quickly. A water blast should be turned on immediately before shot firing and should be continued for at least 30 minutes—that is, until all rock and surfaces are thoroughly wetted. The water blast should be within 50 to 100 feet of the face to be blasted and should be protected from flying rock by a shield made of iron about half an inch thick and from 12 to 15 inches square. The water blast is not in use in the metal mines of the United States but probably will be tried out to determine its practicability under Butte conditions. Various types used in other countries are shown in the accompanying figures.

PHYSICAL EXAMINATION OF MINERS

Even with the wet methods of mining and ventilation carried out as they have been up to the present time, silicosis, while it has no doubt been lessened, has not been entirely eliminated. It is unlikely that even most faithful observance of these practices will eliminate it in America any more than in other countries. It has been found that physical examination of miners to determine the presence of respiratory diseases (especially tuberculosis) and the taking of proper precautions in each case are necessary for the elimination of the disease. Such examinations have been required in Australia, South Africa, and Great Britain. The law in those countries specifies that an applicant must be examined before he is allowed to begin work in certain mines or in certain trades (Great Britain), and that the examinations of the workmen must be made at regular periods of 6 to 12 months thereafter. These periodical examinations are extremely important. The first examination is made to determine whether the applicant has any diseases, especially a respiratory one, which would make him susceptible to silicosis or tuberculosis. Any man suffering with silicosis should not be employed where he will have to breathe dust, especially silica dust, though this limitation is no bar to his working in other places. In general, he should not be employed underground; if he has tuberculosis he should not be allowed under ground at all. Men with tuberculosis develop silicosis much more rapidly than do normal men; the tuberculosis progresses more rapidly when they are exposed to silica dust; and the men themselves are a menace to their fellow workmen. Moreover, men having silicosis are very susceptible to tuberculosis. It is
**Figure 5.**—Detail of a water blast with an iron tee: a, ¼-inch nipple; b, ¼ to ½ inch reducing bushing; c, ½ to ¾ inch reducing bushing; d, ¾-inch pipe; e, water; f, air.

**Figure 6.**—Detail of water blast with a malleable cast-iron Y bend: a, air; b, water.

**Figure 7.**—Suggested design for a water blast made from standard pipe fittings: a, Plug welded in; b, 1-inch tee; c, 8 ¼-inch holes (a second row of ¼-inch holes back of those shown is of advantage); d, entrance of water; e, 1-inch pipe; f, gasket; g, ¾-inch pipe; h, ¼ by 1 inch bushing; i, 1-inch sleeve coupling.
therefore of the greatest importance that they do not come in contact with people having tuberculosis.

At the periodic examination any man found to be suffering with silicosis, which can usually be diagnosed in a very early stage, should be notified in order that he may seek other employment if he so desires. In order to protect the other workers no man found suffering with tuberculosis should be allowed to return to mining. In the countries where physical examinations are compulsory by law, compensation is provided for men found to have either silicosis or tuberculosis or both diseases together. In South Africa since August 1, 1916, no cases of simple silicosis have developed among 5,234 recruits who passed the initial examination and became miners on the Rand.

Physical examination is considered a very important measure for the prevention of silicosis. No preventive measure is successful by itself; a combination of all of them—wet methods of mining, good ventilation, and physical examination—is necessary for the best results. In the United States physical examination has not been introduced, and there are economic difficulties in the way of any one company or the companies in any one district or State enforcing physical examination in advance of competitors. There is also a strong
prejudice against the system among the men, despite the fact that it would be to their own interest to prevent miners from working except in places and at jobs where they would not injure themselves or others. In the long run, compulsory examinations would work to the great advantage of the men, the companies, and the communities and will, it is believed, be generally adopted in time, but united action will be necessary to insure adoption. Meanwhile good ventilation and wet mining methods are the best safeguards that can be given the men.

HISTORY OF THE SAFETY MOVEMENT IN BUTTE MINES

What has been said in this paper should not be considered as implying that the investigations of the Bureau of Mines were responsible for starting the safety movement at Butte. The leading companies of their own initiative began improvements some years before. The necessity of fighting serious fires that occurred from time to time had early led to the organization of fire-fighting crews and to the development of the Anaconda hood which was extensively used before self-contained oxygen breathing apparatus was generally introduced in this country.

In 1910 the largest company at Butte, the Anaconda Mining Co., began establishing additional means of escape in all its mines. By 1914 the accident-prevention work of this company had so advanced that Mr. C. W. Goodale devoted his entire attention to organizing safety and ventilation departments.

In 1915 a central rescue station equipped with self-contained oxygen breathing apparatus was established. The following year another central rescue station was established to divide the work so that rescue crews could reach separate groups of mines with a minimum loss of time.

Messrs. Goodale and Boardman, the latter once a member of the Bureau of Mines, say that “the Bureau of Mines began the work of training first-aid men at Butte in 1914 and 1915, and in 1916 the company added a mine-rescue and first-aid department to its bureau of safety. The Bureau of Mines and the company instructors have trained more than 2,000 men (1922) to give first-aid treatment to the injured.”

20 The Anaconda hood uses compressed air through flexible hose connecting to a compressed-air pipe line.
21 In 1909 self-contained oxygen apparatus began to be extensively used in the East by the Federal mining engineers for rescue and fire-fighting work in coal mines. In 1911 the Bureau of Mines was established and, under the leadership of the first Director, Dr. Joseph A. Holmes, the safety campaign of the bureau was extended to metal mining.
MINE-ACCIDENT INVESTIGATION

While investigating ventilation and dust conditions in the Butte mines Mr. Harrington made studies of accident prevention, of methods employed by different companies, and of improving methods already in use. His report on this subject has been published by the bureau. The following table, subsequently prepared by him, shows the accident record of 31 mines at Butte, Mont., covering the nine-year period from 1915 to 1923, inclusive:

<table>
<thead>
<tr>
<th>Year</th>
<th>Shifts worked</th>
<th>Fatal accidents</th>
<th>Serious accidents</th>
<th>Slight accidents</th>
<th>Total accidents</th>
<th>Accidents in metal mines of United States per 10,000 shifts worked</th>
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<tbody>
<tr>
<td></td>
<td>Num.</td>
<td>Per 10,000 shifts worked</td>
<td>Num.</td>
<td>Per 10,000 shifts worked</td>
<td>Num.</td>
<td>Per 10,000 shifts worked</td>
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<td>1915</td>
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<td>28</td>
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<td>301</td>
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<td>1918</td>
<td>3,401,980</td>
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<td>1.22</td>
<td>368</td>
<td>1.07</td>
<td>2,364</td>
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<td>1,144</td>
</tr>
<tr>
<td>1923</td>
<td>2,225,527</td>
<td>27</td>
<td>0.13</td>
<td>392</td>
<td>1.92</td>
<td>1,569</td>
</tr>
</tbody>
</table>

* Serious accidents are those with time loss of 14 days or over.
* Slight accidents are those with time loss between 1 and 14 days.
* Includes "nonlost-time" accidents.
* Includes only fatal and serious accidents.

INJURY AND FATALITY RATES

The following statement, prepared by W. W. Adams, mine accident statistician of the bureau, compares accidents underground in the Butte copper district with accidents underground in all metal mines in the United States during the three-year period 1920 to 1922, inclusive.

During these three years the copper mines in Silver Bow County, Mont., which are here taken as representing the Butte district, employed an average of 4,673 men underground; in three years these men performed 4,246,700 days of labor. Accidents killed 60 men and injured 4,045. The yearly fatality rate per thousand full-time (300-day) workers was 4.238, and the injury rate was 285.76. During the same years the metal-mining industry in the United States employed an average of 66,700 men in underground operations; the men worked 55,460,000 shifts in the three years. Accidents killed 814 men and injured 59,818. The annual fatality rate per thousand

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24 Unpublished report.
full-time (300-day) employees was 4.403 and the injury rate was 323.57.

Thus the fatality rate for the Butte district during the three years was 4 per cent lower and the injury rate was 12 per cent lower than the corresponding rates for all metal mines in the United States.

Falls of rock from the roof or wall caused a larger proportion of fatalities in the Butte district than in the country as a whole. The fatality rate for this class of accidents at Butte was 2.05 per thousand men employed as against 1.66 for the entire metal-mining industry, the excess for Butte being 23 per cent. The injury rate from the falls was 77.36 for Butte and 69.24 for the whole industry, the Butte excess being 12 per cent.

Haulage accidents at Butte were represented by a fatality rate of 0.428; for the United States the rate was 0.340; the Butte rate shows an excess of 24 per cent. The injury rate from haulage was 42.32 for Butte and 42.37 for the United States.

The fatality rate from persons falling down stopes, winzes, and raises was 0.340 for the United States and 0.494 for Butte, the rate at Butte being higher by 45 per cent. The injury rate from the same cause was 9.92 for the United States and 10.60 for Butte, an excess of 7 per cent for the Butte rate.

The classes of injuries for which the rates were lower for Butte than for the United States as a whole were those due to loading ore, drilling, run of ore from chutes, explosives, machinery other than drills, electricity, and shaft accidents.

The following figures show the fatality and injury rates per thousand full-time workers from the main causes of accidents underground in metal mining:

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**Fatality and injury rates, by causes, at Butte, and in all metal mines in the United States**

<table>
<thead>
<tr>
<th>Causes of accidents</th>
<th>Fatality rate</th>
<th>Injury rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>United States</td>
<td>Butte</td>
</tr>
<tr>
<td>Falls or roof or ore from roof or wall</td>
<td>1.660</td>
<td>2.048</td>
</tr>
<tr>
<td>Rock or ore while loading at working face or chute</td>
<td>.675</td>
<td>.141</td>
</tr>
<tr>
<td>Timber or hand tools</td>
<td>.032</td>
<td></td>
</tr>
<tr>
<td>Explosives</td>
<td>.482</td>
<td>.423</td>
</tr>
<tr>
<td>Haulage</td>
<td>.340</td>
<td>.423</td>
</tr>
<tr>
<td>Persons falling down chute, winze, raise, or stop</td>
<td>.340</td>
<td>.494</td>
</tr>
<tr>
<td>Run of ore from chute or pocket</td>
<td>.007</td>
<td></td>
</tr>
<tr>
<td>Drilling</td>
<td>.037</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>.070</td>
<td></td>
</tr>
<tr>
<td>Machinery</td>
<td>.016</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>.480</td>
<td>.353</td>
</tr>
<tr>
<td>All causes underground</td>
<td>3.645</td>
<td>3.885</td>
</tr>
<tr>
<td>Shaft accidents</td>
<td>.757</td>
<td>.353</td>
</tr>
<tr>
<td>All underground and shaft</td>
<td>4.403</td>
<td>4.238</td>
</tr>
</tbody>
</table>
The foregoing comparisons show that although the accident rates from falls of rock or of ore, from persons falling down chutes, etc., and from haulage are higher in Butte mines than the corresponding rates for all metal mines in the United States, for other kinds of accidents they are less at Butte, and the total accident rate is less, especially the total injury rate.

MINE SAFETY AND HEALTH

The safety organizations of the Butte mines are generally excellent. A few of the mines, shut down before the authors' recent visit, were said not to pay due regard to safety; one of these mines had only one means of exit and used dry drilling.

A detailed description of the safety organization of the Anaconda Copper Mining Co. has been given in a paper by Messrs. C. W. Goodale and John L. Boardman. In general, each mine in the Butte district has a "safety engineer," who at many mines is also the ventilation engineer. He works in conjunction with the mine foreman but his report on safety is made to one of the head officials of the company.

FIRST AID TO THE INJURED

Butte mines were among the first metal mines in the country to take up the safety-first movement. First-aid teams were organized by different companies, and were trained either by the Bureau of Mines first-aid men or by the company man in charge of safety work. Each year great first-aid and rescue contests are held at Butte, and there is much high-class competition by large numbers of teams from the different mines. This training of miners, over 2,000 of whom have received instruction in first-aid and mine-rescue work, has undoubtedly saved many lives and prevented much sickness and suffering among the miners.

The Anaconda company publishes a monthly paper which gives the relative standing of the mines as to accidents which happened during the month, and presents various technical articles and items of local interest. This company also distributes to employees a pamphlet containing excellent "Safety rules and suggestions."

WASH AND CHANGE HOUSES

The Butte mines are well provided with wash and change houses which are generally well constructed and heated, and have venti-
lated lockers for drying clothes. They are equipped with shower baths and hot and cold water, and are under the charge of a caretaker. While all of them are not kept as clean as desirable, in general they are above the average wash house or "dry."

Because of the severity of winter weather it is believed that, in the interest of health, there should be covered passages between shaft collars and wash houses. A miner coming from hot or warm workings, possibly in a sweat and wearing wet or damp clothes, may be badly chilled by exposure before he reaches the "dry." This chilling may be serious to a miner who has a tendency to pulmonary weakness. Covered passages, some of which are underground just below the collar level, are provided at a good many mines in other districts. It is appreciated that such covered passages can not be easily made at all old mines, but they can doubtless be installed at many.

HOUSING AND WELFARE

The city of Butte is so large that the mining companies do not have to provide housing for their miners. Many miners own their houses. Although some of the houses leased from private owners or owned by miners are not what they should be, it is not in the direct power of the mining companies to take action for improvement. A sentiment for better homes can be created in Butte only by public education and continuous effort. Welfare is also a matter which, except in the mines, is not controlled by the companies. During the past 10 years Butte has greatly improved as a mining town, and its facilities in the way of stores, places of entertainment, and general living conditions are above the average mining town or city. It is usual in American mining districts for towns to begin as camps and progress into cities. Butte has reached the latter stage, and if there remain reminders of the old days of shacks rather than houses, it is a matter which local public pride may be expected to correct year by year.

CONCLUSIONS

Although it is realized that much still remains to be done for the improvement of safety and health among the miners of Butte, attention is again called to the advances already made—good systems of mechanical ventilation, wet drilling, fireproofing at shafts and stations and around underground electrical installations, training of many men in first aid and use of oxygen breathing apparatus, and the building of an organization to see that improvements are properly maintained.
PUBLICATIONS ON METAL MINING

A limited supply of the following publications of the Bureau of Mines has been printed. Requests for publications available for free distribution should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list of all publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the cost of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION

**Bulletin 48.** The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1914. 50 pp., 3 pls., 7 figs.

**Bulletin 80.** A primer on explosives for metal mines and quarries, by C. E. Munroe and Clarence Hall. 1915. 125 pp., 15 pls., 17 figs.

**Bulletin 204.** Underground ventilation at Butte, by Daniel Harrington. 1923. 131 pp., 3 pls., 42 figs.


**Bulletin 239.** Iron ore (hematite) mining practice in the Birmingham district, Ala., by W. R. Crane. (In press.)

**Bulletin 240.** Electric shot-firing in mines, quarries, and tunnels, by L. C. Isley and A. B. Hooker. 1925. 120 pp., 73 figs.


**Technical Paper 363.** Lessons from the Argonaut mine fire, by B. O. Pickard. (In press.)

**Miners’ Circular 10.** Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.


**Miners’ Circular 17.** Accidents from falls of rock and ore, by Edwin Higgins. 1914. 23 pp.

**Miners’ Circular 19.** The prevention of accidents from explosives in metal mining, by Edwin Higgins. 1914. 16 pp., 11 figs.


PUBLICATIONS THAT MAY BE OBTAINED ONLY FROM THE SUPERINTENDENT OF DOCUMENTS

**Bulletin 57.** Safety and efficiency in mine tunneling, by D. W. Brunton and J. A. Davis. 1914. 271 pp., 6 pls., 45 figs. 40 cents.

**Bulletin 75.** Rules and regulations for metal mines, by W. R. Ingalls and others. 1915. 296 pp., 1 fig. 35 cents.


BULLETIN 121. The history and development of gold dredging in Montana, by Hennen Jennings, with a chapter on placer mining methods and operating costs, by Charles Janin. 1916. 64 pp., 29 pls., 1 fig. 30 cents.


BULLETIN 188. Lessons from the Granite Mountain shaft fire, Butte, by Daniel Harrington. 1922. 50 pp., 5 pls., 2 figs. 15 cents.

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

TECHNICAL PAPER 95. Mining and milling of lead and zinc ores in the Wisconsin district, Wisconsin.


