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MINERS' CONSUMPTION IN THE MINES OF BUTTE, MONTANA

PRELIMINARY REPORT OF AN INVESTIGATION MADE IN THE YEARS 1916-1919

BY

DANIEL HARRINGTON and A. J. LANZA

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PREFACE.

Until 1914 miners' phthisis or miners' consumption had received little attention from mining men and physicians in the United States. Abroad it had been recognized officially for a number of years that conditions seriously menacing health prevailed among the metal miners of certain districts, seemingly because the inhaling of siliceous or flinty dust in underground work hastened the onset of pulmonary diseases.

The British Government carried out some extensive investigations in the metal mines of England and for a number of years a Government commission has been at work in the gold mines of the Rand, South Africa, investigating the so-called miners' consumption there. The reports of this commission have attracted widespread attention to conditions that may attend underground work in the Rand mines and have suggested various remedial measures that are being introduced gradually.

In this country the Federal Bureau of Mines, in cooperation with the United States Public Health Service, about 1913 made a preliminary survey in western metal mines. The result indicated that pulmonary troubles were widely prevalent among metal miners in certain districts. Subsequently the results of a special investigation in the so-called "hard rock" or "sheet ground" mines of the Joplin district, Missouri, were published in Technical Paper 105,[1] and in Bulletin 132.[2] These investigations early received the hearty cooperation of the mine inspectors, the miners, and the operators in the Joplin district, with the result that the investigators had access to all places in the district and all data. The recommendations made and adopted as a result of the investigations have greatly improved conditions in the Joplin district.

The success of the Joplin inquiry led the Bureau of Mines, in cooperation with the Public Health Service, to organize a similar inquiry into the health conditions at the copper mines of the Butte district, Montana, with special reference to silicosis and the effects on miners of the high temperatures of the deep workings. Further studies are now in progress in the metal mines of the Southwest, and plans have been made to investigate silicosis in other metal-mining districts of the United States.

The Butte investigations started in 1916 and extended through four years. Much progress has already resulted from pointing out dangerous conditions and practices and from the men and the mining

[1] Lanza, A. J., and Higgins, Edwin, Pulmonary disease in the Joplin district, Missouri, and its relation to rock dust in mines; Tech. Paper 205, Bureau of Mines, 1915, 48 pp.

[2] Higgins, Edwin, Lanza, A. J., Laney, F. B., and White, J. H., Siliceous dust in relation to pulmonary disease in the Joplin district, Missouri; Bull. 132, Bureau of Mines, 1917, 116 pp.

companies heartily attempting to apply remedies. There has been much experiment with the use of water drills for drilling upper holes in the hope of eliminating the great quantity of dust produced by the drilling of dry upper holes, and several machinery concerns have given and are giving much time and expense toward the development of a more efficient wet drill for such holes. At some mines water pipes have been placed in drifts, stopes, and raises, and men are required to sprinkle dry rock piles, ore and waste chutes, manways, and other places where the handling of rock produces considerable dust.

Most of the mining companies in Butte have engaged men to give special attention to ventilation problems, and extensive betterments have been started by several companies. One company has placed orders for ventilating equipment costing several hundred thousand dollars, and including about 325 electrically driven fans of various sizes and capacities. It is the intention of this company to double the volume of air in circulation and to have such an efficient distribution of air to the working places that the use of compressed air as a blower or ventilator at the face will be totally eliminated. Upcast shafts are being smoothly lined with fireproof plaster board for the double purpose of increasing air flow and decreasing fire risk, and downcast shafts are being concreted or treated with gunite.

It is hoped that all of the mining companies in Butte will make equal efforts to allay the dust nuisance, the principal cause of miners' consumption. To increase the volume of ventilating current will be an equal factor for betterment by preventing pulmonary and kindred diseases and increasing the capacity of the workers.

Other measures designed to better health conditions in the Butte mines remain to be taken, and their completion requires most of all the active, hearty interest and cooperation of both miners and the mining companies and the moral support of the general public.

In this report only the general results of the investigation are given, because the subject is important enough to warrant immediate attention. The details of the work are reserved for a later and more extensive report.

On behalf of the Bureau of Mines, I cordially thank the mining companies, the mining public, and the miners of Butte and vicinity for the many courtesies extended. The authors of this report had at all times the heartiest cooperation from all people whose aid or advice they sought and were given the utmost freedom of access to all mines and to any sources of information needed in connection with the investigation.

H. FOSTER BAIN,
Acting Director.

A PRELIMINARY REPORT OF AN INVESTIGATION OF MINERS' CONSUMPTION IN THE MINES OF BUTTE, MONT., MADE IN THE YEARS 1916–1919.

By DANIEL HARRINGTON and A. J. LANZA.

The writers, Dr. A. J. Lanza, of the United States Public Health Service, and Daniel Harrington, of the Federal Bureau of Mines, were detailed to investigate the prevalence and causes of miners' consumption in the Butte district. This investigation began in June, 1916, and was carried on more or less continuously until late in 1919. Four of the largest mines of the district were examined in detail, the investigators going into every working place, from the surface to the lowest level, including drifts, crosscuts, stopes, and raises. In addition to this detailed examination of 4 mines, more than 20 other mines were examined somewhat less thoroughly.

GENERAL STATEMENT.

It has long been recognized that workers in hard-rock metal mines are subject to diseases of the lungs. Extensive investigations in England, in British possessions, and in the United States appear to have revealed these facts: (1) That the so-called miners' consumption or miners' phthisis is produced by the mechanical irritation of the lungs by particles of dust of rock containing free silica; (2) that dust is dangerous in proportion to the amount of free silica or other hard, sharp, insoluble material it contains; and (3) that the particles of dust small enough to enter and remain in the lungs measure less than 10 microns, or 1/2500 of an inch in longest dimension.

Miners' consumption is mechanically produced, is neither contagious nor infectious, develops slowly, and by the production of scar tissue gradually impairs the function of the lungs. The length of time necessary to produce the disease depends on the length of time the miner has worked in rock yielding hard, sharp, insoluble dust, the amount of silica in the dust to which he has been exposed, the steadiness with which he worked (from month to month and year to year), the intensity of application of the man to his work, the actual nature of the work he has done underground, and to a great extent on the general conditions under which he works.

Miners' consumption may in itself produce disability and death. As a matter of fact, this disease so predisposes a man to various infections of the lungs and bronchial passages that few victims escape such infection. Pneumonia and tuberculosis are especially likely to occur, and the vast majority of miners with a considerable dust damage to the lungs contract tuberculosis and ultimately die of it, particularly if exposure to the dust continues. In such cases, tuberculosis runs a more rapid course than in the ordinary individual.

It is also recognized that as the larger mining camps become more crowded, with consequent gradual deterioration of housing conditions, the probability for tuberculosis infection increases, and the infection tends to become more and more prevalent and to occur earlier in cases of miners' consumption. The menace to the life of the miner and the menace to the community in general, from the spread of tuberculosis to the miners' family and associates, becomes more evident from year to year. This is attested by the experience of physicians and investigators in South Africa, Australia, the Joplin district, and also in Butte and elsewhere.

MINE EXAMINATIONS.

In the Butte investigation the following data were obtained at each working place:

Dust readings were taken to determine the amount of dust by weight per 100 liters of air the dust subsequently being analyzed; wet and dry bulb temperature readings, from which the humidity could be obtained; air movement, if any, and where possible, air measurements; and samples of air were collected at working places and sent to the bureau laboratory at Pittsburgh, Pa., for analysis.

In addition, record was made of the dampness of the place, the general feeling of comfort or discomfort, the material being handled, the nature of the work performed, the number of men involved, and other like data. In all, approximately 1,000 working places underground were visited and more than 10,000 readings taken. In general, dust samples, air samples, and other data were collected as close as possible to the place where the man, or men, were working and especial care was taken to have the dust sample represent as nearly as possible the air breathed by the workmen under ordinary working conditions, the sampling tube being placed as close as possible to the workman's head. Practically all the readings were taken on the day shift when conditions as to dust are probably subnormal. On the night shift, because of there being more hoisting and mucking and handling of ore and waste, the amount of dust stirred is at a maximum.

The result of the underground inspections disclosed that Butte mines in general were more dusty than the dangerously dusty mines of the Joplin district, Missouri. However, the Joplin dust is much more dangerous than the dust found at Butte, probably because it is approximately 90 per cent silica, practically all of which is free, whereas the Butte dust is composed of about 75 per cent silica, of which 50 to 60 per cent is free. In general the dust of free silica is harder and sharper and more dangerous to the lungs than the dust from silicates or combined silica. Miners' consumption in the Butte districts seems to be of a less pernicious type than that in the Joplin miners, largely because of the difference in dust and because of the Joplin miner working at far greater tension than the Butte miner. The average amount of ore handled per underground employee per shift in the Joplin mines in 1915 was approximately 10 tons, as against 1½ to 3 tons in the Butte mines, the average being less than 2 tons per man per shift.

Raises proved to be the dustiest places in the Butte mines, because of lack of ventilation and the dry drilling of upper holes. Drilling requires a larger percentage of total time in raising than in any other kind of work, because little or no time is spent in mucking. Stopes rank next to raises in dustiness, possibly because of lack of ventilation, the use of dry drills, and the mucking of dry ore, with practically no effort made to allay dust. Drifts and crosscut faces are the least dusty places, because drifts and crosscuts drain off most of the water encountered, and practically all drifting and crosscutting is done by wet drills; the water from the drilling prevents dry dust from settling on the floors and partly wets down the muck piles. Also drifts and crosscuts are comparatively free from dust that the drill holes are almost horizontal rather than vertical, as in raises and stopes. Main air courses at chutes are generally very dusty, as are main downcast-shaft stations, especially where the ore is hoisted in skips.

Men running dry drills have by far the dustiest jobs underground. Men pulling ore from chutes and running locomotives on hauling roads rank next. Then come muckers, timbermen, and miners using wet drills. Other occupations were not noted in detail, as comparatively few readings could be taken.

In general the dustiest part of the mines was that just below a depth of about 500 feet from surface; the lower workings were damper, while in the upper parts of the mines, close to surface, conditions were more or less affected by the weather.

The tests showed that the total quantity of air circulated underground was sufficient for the needs of the mines and analyses of considerably more than 100 samples of air from working places showed that the atmosphere of working places was not particularly impure

except in a few abnormal instances, and that in general the proportion of oxygen is adequate and the proportion of CO_2 is not excessive. However, as in most metal mines there is comparatively little circulation of air at the working faces in drifts, crosscuts, raises, and stopes. In practically all classes of places the velocity of the air was so slow that the air very soon took the temperature of the surrounding rock. At depths of 2,000 feet or more below the surface this warming of the air becomes serious as the rock temperatures generally exceed 80° F.; and such temperatures and the high humidities that prevail have a marked depressing effect, reducing the amount of work men can perform unless the air velocity is considerable. In general, the Butte mines are not wet, but the rock carries moisture, so that that irrespective of the humidity of the atmosphere above ground, the mine air quickly absorbs so much moisture that a humidity of less than 75 per cent is rare below the 2,000-foot level, and the humidity generally is between 85 and 100 per cent. With temperatures below 75° this high humidity is of comparatively little importance and if the air circulates rapidly enough, relatively high humidities can be endured where temperatures are considerably above 80°.

One of the serious health hazards of the Butte mines is that in winter an underground worker, with his clothing saturated with perspiration, faces a transition from an underground temperature of 80° F. or over to one of 15°, 20°, or even 30° F. below zero on coming out of the mines, and frequently must walk several hundred feet, exposed to the cold and wind, to the "dry" or washhouse. In addition, at some mines, under certain circumstances as, for instance, when a new or inexperienced timekeeper is on duty, a miner must stand in line in the open air 5, 10, or 15 minutes in order to give his time at the timekeeper's window. These conditions are unduly severe and tend to cause pneumonia and kindred diseases which are so prevalent in Butte in winter.

RESULT OF PHYSICAL EXAMINATIONS OF MINERS IN THE BUTTE DISTRICT.

PREVALENCE OF MINERS' CONSUMPTION.

Dr. Lanza examined from December, 1916, to February, 1918, 1,018 bona fide miners. These men presented themselves for examination at the office of the Butte Anti-Tuberculosis Society after notice had been given verbally and by printed card that all miners who would come to the office at certain hours would be examined free of charge. No examination was made of all of the miners of the Butte district or all those of any particular mine. Of those examined a large proportion knew or thought they were infected when they presented themselves for examination; conversely a large proportion who did not think they were infected did not present themselves. Of those examined 432, or 42.4 per cent, showed definite signs of dust injury to the lungs. Practically all of these men were either still working or had quit within the previous two or three months.

The results of the examination were classified, as follows:

There were 194 cases of early miners' consumption; 120 of these had worked in Butte mines longer than five years; 7 were also tuberculous.

There were 128 cases of miners' consumption, moderately advanced; 107 of these had worked in Butte mines longer than five years; 8 were also tuberculous.

There were 110 cases of miners' consumption, far advanced; 107 of these had worked in Butte mines longer than five years; 48 were also tuberculous.

TABLE 1.—*Data on Butte miners examined for miners' consumption.*

[Number examined, 1,018; number afflicted, 432, or 42.4 per cent.]

State of the disease.	Miners' consumption.		Tuberculosis.		Worked in Butte mines over 5 years.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
Early	194	44.9	7	3.6	120	61.8
Moderately advanced	128	29.6	8	6.3	107	83.6
Far advanced	110	25.5	48	43.3	107	97.3
Total	432	100.0	63	14.6	334	77.3

As the table shows of 432 cases of miners' consumption, 44.9 per cent were in the early stages; 29.6 per cent moderately advanced, and 25.5 per cent far advanced. Only 3.6 per cent of those in the early stage and 6.3 per cent of those in the moderate stage had tuberculosis, but 43.3 per cent of the far-advanced cases were tuberculous. Of the 432 miners having miners' consumption 77.3 per cent had worked more than five years in Butte mines; 61.8 per cent of those in the early stages of miners' consumption and 83.6 per cent of those in moderately advanced stage, and 107 out of 110, or 97.3 per cent, in the far-advanced stage had been engaged in mining in Butte more than 5 years.

The Canadian laws make three years the minimum time a man must have worked in a district in order to establish a claim for miners' compensation at that place. Hence, at least 334 out of 1,018, or 32.8 per cent of all miners examined in Butte by Dr. Lanza would be entitled, under the Canadian law, to compensation, due to miners' consumption, and an additional 14 or nearly 1½ per cent would be entitled to compensation due to tuberculosis alone.

There were 26 miners, not included in the above, who had tuberculosis with no definite signs of dust injury; 14 of the 26 had worked five years or more in Butte.

An examination of the death records on file in the office of the secretary of the State board of health in Helena shows that during the year 1915, 122 Butte miners died of tuberculosis and 54 of pneumonia and other respiratory diseases; in 1916 there were 126 deaths from tuberculosis and 46 from pneumonia; and in 1917 there were 169 deaths from tuberculosis and 47 from pneumonia, all miners. The record does not include those cases in which the death certificate may have been incomplete or inaccurate or those who, as frequently happened, went to some other place to die. How many of these contracted their disease in Butte and how many in other mining camps can not be ascertained. The death certificates rarely distinguish between miners' consumption and tuberculosis. How significant is the death of 169 miners in Butte in 1917 from tuberculosis, as shown by records at the State capitol at Helena, is shown by comparison with record of other regions. In 1917 approximately 14,000 men were employed underground in Butte mines, and with 169 deaths from tuberculosis for the year the rate per 100,000 was 1,207; the tuberculosis death rate of Michigan for a recent 10-year period was 97.4 per 100,000; hence the tuberculosis death rate of Butte miners was nearly thirteen times as great as that of Michigan.

During 1917 the visiting nurses of the Butte Anti-Tuberculosis Society cared for 300 cases of tuberculosis, practically all miners and mostly unable to work; of these more than half died during the year, in Butte or elsewhere.

It can not be concluded from the above figures that 42 per cent of the Butte miners have miners' consumption. It is, however, possible to say that a large number of the miners who have worked for any considerable time in the mines may have the disease. The recent disagreement between companies and miners, with the consequent migration to and from Butte, have made impossible accurate figures on this point. Many miners with 10 years' actual service underground in Butte show evidence of miners' consumption. Men were occasionally examined who had been underground in Butte 20 years or more, but usually, on questioning, they were found to have largely followed some of the less dusty occupations, as shaft sinking, pipeman, etc., or to have carefully avoided working in very dusty places; or they have been accustomed to spend a considerable part of the year on farms, in the mountains, etc. It was noted that many of the better class of miners, especially the English-speaking ones, said that they were in the habit of avoiding, whenever possible, working in very dusty places.

As a result of making physical examinations and of underground experience, certain conclusions have been formed that can not be set into figures as above, but seem equally true.

PROGRESS IN DUST ABATEMENT AND BETTER VENTILATION.

In passing on the harmfulness of siliceous dust, one should also consider the effect of working in hot, humid, and poorly ventilated places where such dust is found. In general, the quality of the air in the working places was good—that is, under ordinary working conditions it did not generally contain harmful gases or impurities. In most of the working places, however, there was a noticeable lack of air movement. Extensive investigations of various phases of ventilation have clearly demonstrated that the effects of poor air or bad air (as the terms are commonly used), if there is no lack of oxygen and poisonous gases are not present, are due less to the composition of the air than to its stagnation or lack of movement. In places where manual labor is done at a temperature of 70° F. or higher and there is little or no movement of the surrounding air, proper evaporation of perspiration on the surface of the body is hindered, there is a rise of body temperature, and ability to work is impaired. Obviously, as temperature and humidity increase the results of deficient air movement will also increase. In most of the working places examined in Butte the temperature was well above 70° F., little or no movement of the air was perceptible, and the humidity approached saturation. Comparatively little work in such places caused body temperatures quickly to mount from 98° F. (the normal) to 103° F. or higher—that is, to fever temperatures. The immediate effect of such conditions is greatly to decrease the working ability of the men. It is the impression of the authors of this report that in the places visited the time spent in actual work during an eight-hour shift was not in excess of four to five hours, and probably was much less. An adequate movement of air, even if it did not lower the temperature, would greatly increase the efficiency of the men. This conclusion can be proved by observations in the Butte district and in many mines elsewhere.

Besides decreasing the working ability of miners, the heat and the humidity in the working places tends to impair their vitality, by causing an increased tendency to colds, bronchitis, and to pneumonia, especially in those men who have dust-injured lungs. On the other hand, were the ventilation in the working places to be improved, so that the men would work longer and harder during the shift, without the dust conditions being remedied, there would undoubtedly be an increase in the prevalence of miners' consumption; the men, working harder would breathe more deeply and more frequently and consequently fall victims to the dust much more readily. One of the

reasons for the rapid breakdown noted among the miners of the Joplin district, Missouri, was the unusual amount of work they were able to perform (averaging 10 tons per shift per underground man, and 22 tons per shift for shovelers) in very dusty atmospheres, because of the low temperature of the mines. It is not likely that the work done in Butte mines will ever reach such high individual production, but it is obvious that if ventilation conditions are improved, the dust hazard must be reduced to a minimum, otherwise the situation as regards miners' consumption will get progressively worse.

The harmful effects of dust were noticed most prominently in men who had done much work in mines; those drilling with dry stopers or "buzzies," repairing timber, and driving motor trains came next. It was noted that men who did not work steadily—that is, who for two or three months in a year were idle or worked in the harvest fields or had other outdoor occupations were less affected by the dust than the men who worked 12 months a year underground.

As with those suffering from other chronic diseases men who drink hard stand a poorer chance of getting well and die sooner than the nonalcoholic.

A man suffering from miners' consumption in an early or moderate stage tends to recover on leaving underground work—that is, he is apt to improve and is not as shortwinded as time passes. An attack of pneumonia or a tuberculous infection, however, may bring about a fatal issue even in early cases. Where dust has done much damage to the lungs the outlook is poor, though some of these cases show remarkable improvement. Where tuberculous infection has resulted in disability, a period of two years, on the average, elapses between the time the miner quits work and his death.

Generally speaking, it may be stated that the best hope for recovery in miners' consumption, where disability has not occurred, is for the sufferer to be able to follow some outdoor occupation. The mining companies in the Butte district have for several years been using water drills in driving practically all drifts and crosscuts, and at different times during that period they have conferred with the representatives of three of the largest rock-drill concerns in an effort to have them develop and perfect a self-rotating water stoper that would be acceptable to the miner and the mine operators. Such a drill seems to have been perfected recently. One mine in the district is now fully equipped with it; several other mines have a large number, and it is giving good satisfaction. The authors of this report understand that at least one company intends to follow up this policy and equip all of its mines with self-rotating water drills for stoping.

Nearly all of the shafts in the district, and many of the drifts, crosscuts, stopes, and raises in some of the mines are piped with

water for fire protection, for supplying the water stopers, and for wetting down muck piles, floors, timbers, and chute mouths.

In most of the mines the firing of shots, except in an emergency, while a shift is at work has been prohibited for several years.

While the upper levels of the mines in the district were being opened a considerable quantity of low-grade ore that was not of commercial grade then was left unmined. Because of the great advance in mining costs during the last few years, the better price for copper, and, particularly, the lower cost of reduction, and the increased percentage of recovery, this ore is now of commercial value. Recovery of this ore has necessitated the reopening of many of the upper levels, and hence the operation of a large number of levels at the same time. For this reason it is difficult to ventilate properly all of the working places in such mines; however, the mining companies are working as expeditously as possible to extract this low-grade ore in order to eliminate as many levels as possible and to confine mining to fewer levels. The companies intend when this ore is extracted to seal off the worked out levels with concrete so as to prevent the good fresh air from being vitiated.

Almost all of the mines have one or more upcast shafts besides the operating shaft, which at nearly every mine is the downcast, and an effort is being made to have every operating shaft a downcast.

Large, double-intake, reversible Sirocco fans, electrically driven, are installed at the collars of most of the upcast shafts. In some mines No. 11 Sirocco fans, also electrically driven, are used as boosters in the lower levels with satisfactory results, and in most mines small electrically driven fans with canvas pipe or tubing are installed in raises, drifts, and crosscuts to force the fresh air from the main air passages to the dead ends. One company purchased at one order 325 of these small fans. This company has nearly completed plans. after working three or four years on them, that will double the volume of air circulating in its mines. Nearly all of its mines are ventilated independently of adjoining mines, and an effort is being made to provide independent ventilation for the others.

One working shaft is nearly all of solid concrete, a large number of other working shafts are coated with gunite, and a large number of upcast shafts are smoothly lined with concrete slabs, thus making the shafts fireproof and at the same time reducing the frictional resistance for the air. The smooth surfacing of these shafts permits almost a doubling of the velocity of the upcast, and thus doubles the quantity of air that can be exhausted per minute by the large suction fans at the collar. One mining company has planned and has authorized continuation of this work, so that when its plans are completed every one of its working shafts will be coated with gunite and

every one of its upcast shafts will be smooth-lined with concrete slabs.

The conditions at the deeper Butte mines are difficult and intricate, and the mining companies have for many years past spent much time, energy, and money in efforts to solve the problems involved. Much progress has been made, but much remains to be done. The recommendations following are offered with full knowledge that many of them are already in effect at some mines, but with the hope that their adoption may become general.

RECOMMENDATIONS.

1. Dry drilling should be absolutely eliminated. Spraying devices should not be used with dry drills, as they are very likely to be inefficient, due largely to the fact that the cooperation of the miner is required to obtain maximum efficiency, and only too frequently this cooperation can not be relied upon. Tests of spraying devices prove that when used with judgment such devices may afford considerable protection to the driller and his associates, but investigation of the actual use of sprays has shown that the miner only too often handles a spraying device so as actually to increase the danger to himself as compared with dry drilling.

Elimination of dry drilling is largely a question of drilling fewer upper (practically vertical) holes; wet drills (Leyners and wet stopers) can readily be employed in the drilling of all holes except those pointed vertically upward or not more than 30° from the vertical. It would seem feasible to use the wet drills in all kinds of places in Butte mines, except possibly raises, and even raises have been driven in Butte with Leyners when the rock was too hard for the stopers. Where raises are of such small area that the handling of Leyners would be cumbersome water stopers can be used. Miners object to the latter because of water from the drill holes wetting their clothes, yet miners do not object to using Leyners in drifts and crosscuts, although few shifts pass without the machine men having their clothes, and especially their shoes, saturated with water. Moreover, men working in most raises in Butte have their clothing saturated with perspiration in a comparatively short time after starting work, and the wetness from drilling can not differ much from that due to perspiration. By the use of judgment in handling Leyners or water stopers the drillings from upper holes can be made a comparatively thick mud that has little tendency to fall on the driller, so that the use of wet drills for upper holes becomes largely a question of educating miners in proper regulation of water feed and of enforcing the use of wet drills.

2. All working places underground, including drifts, crosscuts, stopes, and raises should be piped with water, preferably pure city water under pressure; the successful use of water drills depends absolutely on all places being piped with water, as miners can not be expected to carry water into raises or stopes for drilling. This water could be used for drills in all kinds of places, for wetting down muck piles, the floors, and timbers before or during a shift, and especially during shoveling, and also to aid in lowering the high temperature of the mine air. Possibly wetting of muck piles might have to be discontinued during cold weather to prevent excessive freezing of ore in surface-ore bins and in railroad cars.

Water should also be used to spray the mouths and possibly the entire length of ore chutes; skip chutes should be sprayed as well, especially where the skip chutes are at downcast shafts; where dry ore is handled in downcast shafts a complete system of water sprays should be used in air courses leading from the shaft. In addition, water should be used freely in sprinkling the floors, sides, and top or back of haulage ways, shaft stations, and manways at all times of the year.

3. All firing of shots while the shift is at work should be eliminated; if such elimination is impossible and shots are fired, no men, except possibly "fire bugs," whose work is of an emergency nature, should go into the place for at least three hours, unless the place has been well sprinkled immediately after the shot firing or before any work is done there. This is important, as the shock to the air from the firing of shots throws clouds of excessively dangerous fine dust into the air; this dust settles very slowly, especially where air movement is sluggish; moreover, some of the gases from explosives are poisonous.

4. In order to decrease the temperature and humidity of the air at working faces and to remove dust and poisonous fumes, especial effort should be made to increase the circulation of air at the places where the men are working and not to allow it to be dissipated in abandoned workings or to traverse only drifts and crosscuts that are largely unfrequented by workmen. To insure such circulation the underground work should be concentrated as much as possible, thus eliminating the large number of levels to be ventilated; all places that have been abandoned, including drifts, manways, and stopes, should be sealed off by concrete stoppings, by doors, or otherwise; downcast air should be divided into a definite number of splits and an effort made to keep the total quantity of air in each split concentrated so as to maintain as high a velocity as possible; splits for drifts and crosscuts in the Butte mine should carry 12,000 to 20,000 cubic feet of air per minute. At intervals there should be raises or

manways comparatively close to working places and cleared of obstructions, such as chutes and platforms, so as to permit air to pass with minimum friction, and all air courses should be kept clear to allow free passage of air; idle cages or skips should not be allowed to remain in shafts, nor should cars, timber, etc., be allowed to practically seal main air courses as they do in many places. Mine air should not be allowed to discharge into downcast shafts to vitiate fresh intake air, and air should not be taken from upcast shafts to ventilate parts of the mines. In other words, all possible effort should be made to concentrate air currents, cause them to flow through the working places with minimum hindrance, and then to be discharged from the mine as quickly as possible.

For deflecting air currents underground a more extended use of doors, of fireproof canvas and brattice, and of regulators is recommended. On haulage roads a type of door should be used that can be relied on to close automatically and allow minimum leakage of air. The free use of small electrically driven fans with canvas pipe is commended, provided suitable safeguards are taken to make installation fireproof; such fans and canvas pipe could force air through high raises or long drifts or crosscuts to the working face, doors and brattice being used to deflect air currents to places where men work in stopes, drifts, etc., that are comparatively close to the air courses.

If the mine is piped with city water, as heretofore recommended, water sprays could be advantageously introduced into air currents in drifts, crosscuts, etc., and into canvas or galvanized-iron ventilating pipe in order to decrease air temperatures. Comparatively small quantities of cool water sprayed into air currents have well-defined cooling effect, and this is particularly true of air being transmitted through ventilating pipes; sprays also aid in settling fine dust. The spraying, as far as practicable, should be constant rather than intermittent.

In so far as is feasible, each mine should be ventilated independently of adjoining mines and should have at least two shafts, one an upcast and one a downcast, to the lowest workings. Where possible ventilating shafts should be smooth-lined and fireproof and offer minimum obstruction to air flow. All mines should be ventilated by a fan or fans of large capacity; main ventilating fans should, where possible, be on the surface, housed in fireproof structures, and be readily reversible. Very important fans should have more than one source of power, such as steam and electricity or alternating and direct current motors, etc., so arranged as to cause a minimum amount of delay in going from one source of power to the other in case of failure of one kind of power; this is especially important at time of fire

or other disaster. Fans should be kept in operation 24 hours per day, even when full shifts are not working.

5. Provision should be made so that, at least in winter, it will not be necessary for miners coming off shift in wet clothing to stand in line in the open air in order to give their time. The timekeeper should receive the time in the "dry" or in some other building where miners waiting turn would be protected from the weather. It also seems feasible to have a fireproof runway, covered and possibly heated, extending approximately from the shaft collar to the washhouse or "dry," so that underground men emerging from the mine in winter need not be exposed to the weather.

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