PUBLIC HEALTH BULLETIN

No. 277

HEALTH AND WORKING ENVIRONMENT OF NONFERROUS METAL MINE WORKERS

FEDERAL SECURITY AGENCY

U. S. PUBLIC HEALTH SERVICE

WASHINGTON, D. C.

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HEALTH AND WORKING ENVIRONMENT OF NONFERROUS METAL MINE WORKERS

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PREPARED BY DIRECTION OF THE SURGEON GENERAL

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1942

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - Price 20 cents

ORGANIZATION

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SUBMITTED FOR PUBLICATION
SEPTEMBER 1941

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ABSTRACT

Silicosis was the principal occupational disease found by medical and X-ray examination of 727 workers whose only experience in dusty trades had been in nonferrous metal mines. A total of 66 cases of silicosis, 42 classified as first stage and 24 as second stage, were diagnosed among this group of men. The incidence of silicosis increased regularly with severity and duration of exposure. The 4 cases of silicosis found among persons with less than 10 years of employment in metal mines occurred among workers who had an average weighted dust exposure of more than 22 million particles per cubic foot of air. Approximately one-half of all persons who had worked more than 19 years in metal mines with an average weighted dust exposure of more than 18 million particles per cubic foot of air were found to have silicosis.

When the principal occupational experience of metal mine workers was taken into consideration, it was evident that the incidence of silicosis was concentrated among workers at the face (i. e., drillers, miners, and muckers). Among the group of face workers employed in metal mines for 10 years or more, 29.5 percent were found to have silicosis, while all other workers had an incidence of 7.5 percent.

Eighteen metal mine workers had reinfection pulmonary tuberculosis, an incidence of 2.5 percent. Nearly 14 percent (9 cases) of the silicotic workers also had pulmonary tuberculosis whereas only 1 percent of those not affected with silicosis had pulmonary tuberculosis.

Lead poisoning ranked next to silicosis in importance as an occupational disease of workers in the mines studied. About 20 cases of plumbism causing disability, ranging from a few weeks to 2 months, had occurred among these workers during the last 5 years. At the time of the medical examination 75 workers were diagnosed as having abnormal lead absorption (latent lead poisoning).

On the basis of the data presented, if the atmospheric dust in these metal mining operations is kept below 10 million particles per cubic foot, no disabling silicosis should occur and morbidity from lead may also be expected to decrease.

HEALTH AND WORKING ENVIRONMENT OF NONFERROUS METAL MINE WORKERS

INTRODUCTION

Silicosis and other forms of occupational diseases have long been known to occur among workers engaged in the mining of nonferrous metal ores.[1] In 1900, Betts (62) described cases of silicosis among Utah and Nevada miners which he designated chalicosis pulmonum or chronic interstitial pneumonia. Other investigations in the United States[2] as early as 1914, by the United States Bureau of Mines in cooperation with the United States Public Health Service indicated the existence of a serious problem of pulmonary disease near Joplin, Missouri. Subsequent investigations (63) in the same general mining area (tri-State district) and elsewhere (66) confirmed this fact and suggested a silicosis prevalence of 20 or 25 percent among metal mine workers.

In 1936, the Utah Industrial Commission requested the federal government to make a study of the nature and prevalence of occupational diseases in Utah industries. Following a number of conferences, the United States Public Health Service agreed to undertake such a study with the cooperation of Utah State agencies, such as the State Board of Health, the Industrial Commission, industrial organizations, labor groups, and others.

A preliminary survey made during 1937 and 1938 by the United States Public Health Service and the Utah State Board of Health showed the number of workers in various industries in the State of Utah who were exposed to certain materials and conditions which

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[1] Since a complete review of the literature pertaining to this general subject is not given here, the reader is referred to such recent works as "Silicosis and Asbestosis" (A. J. Lanza, Oxford University Press, New York, 1938); "Review of Literature on Effects of Breathing Dusts with Special Reference to Silicosis" (Harrington and Davenport, Bull. No. 400, U. S. Bureau of Mines, Government Printing Office, Washington, 1937); "Silicosis and Allied Disorders," Medical Series, Bulletin No. I, Air Hygiene Foundation of America, Pittsburgh, 1937, and "Pneumoconiosis (Pulmonary Disease Due to Dust)," R. Teleky, Supplement to Occupation and Health, International Labour Office, Geneva, January 1938.

[2] Lanza, A. J., and Higgins, Edwin: Pulmonary disease among miners of the Joplin District, Missouri, and its relation to rock dust in the mines. Tech. Paper 105, Bureau of Mines, 1915, 47 pp.

Lanza, A. J., and Childs, Samuel B.: I. Miners' Consumption: A study of the Disease among zinc miners in southwestern Missouri. II. Roentgen-ray findings in miners' consumption. Public Health Bull. No. 85. Washington, Government Printing Office, 1917, 40 pp.

might be considered potentially hazardous to health. This preliminary report indicated that the major problems which called for more detailed investigation were exposure to siliceous dusts, lead and other metallic dusts, fumes, and gases. The chief industries in which these hazards might exist were the coal mines, nonferrous metal mines, and nonferrous metal smelters.

Consequently, legislation was passed in March 1939, authorizing and directing the State Board of Health, in collaboration with the United States Public Health Service, and the State Industrial Commission, to carry out a study of these three industries. A preliminary report was published in November, 1940, by the Utah State Board of Health (70).

The present bulletin represents one phase of this investigation, namely that dealing with the health and environment of nonferrous metal mine workers.

Field work was done in July and August 1939. Occupational and medical histories and physical and roentgenological examinations were made on 783 nonferrous metal mine workers. In addition, a complete oral examination was made by a dentist and the following laboratory examinations were performed: serological tests for syphilis, punctate basophilia and reticulocyte estimations, hemoglobin determinations, routine urinalyses, and spectroscopic examinations of 178 urine specimens.

Engineering studies were made in each mine establishment to determine the environmental factors which might have a bearing on the health of workers engaged in particular occupations. In this connection, examinations were made as to the nature and concentration of various types of dust, especially with regard to total silica, free silica, and lead, to which the workers were exposed. Studies of ventilation and humidity were carried out, and exposure to various gases, such as sulfur dioxide, carbon dioxide, carbon monoxide, hydrogen sulfide, methane, and others was determined. Also, methods and facilities for the control of health hazards, already in use in the metal mines in Utah, were investigated, with the view of recommending additional control measures where necessary.

SUMMARY

THE WORKING ENVIRONMENT

The present report is based on a study of three representative metal mines in the State of Utah. The ore and rock encountered by workers in these mines varied from limestone, containing no detectable free silica, to quartzite consisting of more than 99 percent free silica. Since most persons had worked in various locations, it was difficult to distinguish between those who had had high or low free silica exposures. Consequently, for statistical purposes, it was assumed that all underground workers had been exposed to atmospheric dusts having an average free silica content of 30 ± 10 percent. Particle size determinations of the dust suspended in the atmospheres of the various metal mines showed that the dust had a median diameter of 0.9 micron and that more than 96 percent of all the atmospheric dust particles were of a size which might readily reach the smallest air sacs in the lungs.

Of the 830 persons working in the metal mines when the engineering study was made, less than 1 percent were exposed to average dust concentrations higher than 30 million particles per cubic foot. Seven hundred and seventeen, or approximately 86 percent, of the workers were found to be exposed to dust concentrations between 6 and 30 million particles per cubic foot, and about 12 percent were exposed to less than 6 million particles. High dust exposures were usually associated with drilling, breaking, and handling of ore. Ventilation in some stopes with air already contaminated with dust also contributed to the high dust concentrations encountered in these stopes.

Examples of good mining practice with regard to the control of the principal sources of dust contamination showed that the dust can be reduced to concentrations below 6 million particles by proper use of present control measures, such as wet methods, adequate ventilation, air cleaners or settling chambers, and local exhaust ventilation.

Gas analyses of mine air showed that toxic gases, or atmospheres deficient in oxygen, are present at times, but that such conditions are of a temporary nature so long as adequate ventilation is maintained. Accidents from this cause can be prevented by constant supervision and investigation of all working places.

Extremely high and low temperatures, rapid temperature changes, dusts of toxic metals, illumination, and poor sanitary facilities in the mines and in the surrounding communities were found to be potentially harmful to health in some instances.

HEALTH OF THE WORKERS

The medical study of nonferrous metal mine workers included 783 persons, representing slightly less than one-fourth of the total number in this occupation in the State of Utah as reported by the United States Census of 1930. The age distribution of the group studied was similar to that shown in the Census for all Utah metal mine workers.

A detailed analysis was made of medical examination findings for the 727 workers whose entire experience in a dusty trade had been in metal mines. The remaining 56 workers had at some time in the past worked for more than 2 years in a dusty trade other than metal mines, hence their physical condition at the time of the examination cannot be attributed entirely to experience in one industry. This mixed exposure group showed an older age distribution and a higher incidence of silicosis (25.0 percent) than the group working only in metal mines.

Among the group of 727 metal mine workers there were 66 cases, or 9.1 percent, affected with silicosis, and 42 cases, or 5.8 percent, diagnosed as borderline silicosis. No cases of silicosis were found among metal mine workers exposed to an average dust concentration of less than 6 million particles, but this group of workers included only 2 face workers, each having worked only 1 year underground. Among those employed for a period under 10 years' duration, no case of silicosis was observed until the average dust concentration exceeded 18.0 million particles. The severity of pulmonary fibrosis among cases with silicosis increased greatly with increasing length of employment.

The silicosis problem among metal mine workers was found to be most acute for those persons engaged principally at the face, namely, muckers, miners, and drillers. The combination of a heavy dust concentration and a silica content of 20 to 40 percent resulted in a silicosis incidence of nearly a fourth of the face workers if those with less than 6 years' employment are excluded.

Eighteen metal mine workers had reinfection pulmonary tuberculosis, an incidence of 2.5 percent. Fourteen had minimal and 4 moderately advanced tuberculosis. The 4 who had moderately advanced tuberculosis were thought to be active; they also had silicosis. The other 14 were quiescent, apparently arrested or healed. Nearly 14 percent (9 cases) of the silicotic workers also had pulmonary tuberculosis, whereas only 1 percent of those not affected with silicosis had pulmonary tuberculosis.

Lead poisoning ranks next to silicosis as an occupational disease of workers in the three nonferrous metal mines in Utah investigated. The health problem as regards lead in these mine workers, like the dust problem, seems to be essentially one of face workers. About 20 cases of plumbism causing periods of disability ranging from a few weeks to two months had occurred in the 727 metal mine workers in the last five years, according to information recorded in their past medical histories. Seventy-five workers were diagnosed as having abnormal lead absorption (latent lead poisoning) at the time of examination.

No other form of metal intoxication was observed, possibly because of the low exposure to the more toxic metals and metalloids, and the relatively innocuous nature of other metallic compounds such as those of gold, silver, and copper.

Complaints of headaches were much more frequent among metal mine workers than among Utah coal mine and smelter workers. However, this excess of headaches was concentrated in the group of face workers and seemed to be due to inadequate ventilation at the face; other metal mine workers did not complain of headaches with appreciably greater frequency than workers in the other two industries.

A few cases of mild dermatitis were attributable to contact with sulfide ores.

The prevalence of the arteriosclerotic-hypertensive group of heart diseases was approximately the same as that observed in other comparison groups of employed industrial workers, but rheumatic heart disease was slightly more prevalent. No severe cases of cardiac decompensation were examined.

Only six cases of latent syphilis were observed, which represents an incidence rate (0.8 percent) less than half that observed in coal mine and smelter workers, and the State of Utah as a whole.

RECOMMENDATIONS

THE WORKING ENVIRONMENT

1. Adequate ventilation should be provided at all working places by means of mechanical ventilation.

2. Wet drilling methods, including wet collaring, should be employed in all mechanical drilling operations. Arrangements should be made for supplying wet drills with water at the rate of at least 1 gallon per minute and drills should be so maintained that the leakage of air into the water stream is minimized.

3. All ore and waste rock (muck piles) should be thoroughly wetted before and during loading.

4. Haulageways and faces should be sprinkled before blasting.

5. Water curtain should be used for preventing the promulgation of dust disseminated from blasting.

6. A sufficient period of time should be allowed after firing a charge so that dust and gas concentrations may be reduced to a safe limit before the next shift is allowed to enter the mine.

7. When wet drilling is not effective in reducing concentrations of dust to safe levels, it is recommended that such drilling be supplemented by adequate general ventilation, or by allowing the use of local exhaust hoods or traps. Local exhaust ventilation methods have been shown to reduce the atmospheric dust concentrations to less than 5 million particles per cubic foot; the present wet methods are seldom effective in obtaining concentrations as low as 5 million.

8. Dust, fume, and gas control equipment should be maintained at its highest efficiency by receiving continual attention.

9. Separate raises should be used for manways and for ore chutes.

10. Wet methods or local exhaust hoods should be employed in the bucking and crushing of ore.

11. Where it is necessary to use the same air for ventilating more than one workplace, this air should be passed through settling chambers or air cleaners.

12. Periodic studies of the condition of the working environment appear necessary to determine whether the control methods adopted are really adequate. The work of inspection and review should be performed by persons trained for such studies.

13. In the communities adjacent to metal mines, methods of sewage disposal approved by the State Health Department should be adopted.

14. In the mines proper, safe sanitary practices should be adopted instead of the present unsafe methods of fecal disposal.

15. Water supplies from contaminated sources should be properly treated.

16. The recommendations of the American Standards Association on general sanitation as given in code Z4.1 should be adopted insofar as applicable.

MEDICAL CONTROL OF OCCUPATIONAL DISEASES AND PROMOTION OF THE WORKER'S HEALTH

1. A technically good roentgenogram should be made of every applicant for employment as part of his preemployment physical examination.

2. Annual medical examinations, including an X-ray study of the chest, should be made of all employees in order to detect evidence of active pulmonary tuberculosis and early silicotic changes.

3. No worker should be rejected on preemployment examination or removed from work to which he is accustomed merely because of a diagnosis of simple silicosis, but rather the atmospheric dust in which he works should be brought within safe limits.

4. Every worker with active tuberculosis should be removed at once from a dusty occupation, put under treatment, and should not be permitted to return to his former job. If the worker has minimal, arrested or healed reinfection tuberculosis, he should be allowed to continue to work but should observe the same precautions as the man with simple silicosis.

5. Workers whose chest roentgenograms show healed primary tuberculosis should not be denied employment in a dusty trade on this account alone.

6. Close medical supervision is recommended of all workers in dusty trades in order to control and prevent common respiratory infections which are likely to have more serious after effects in silicotic than in nonsilicotic persons, and also in nonsilicotic persons exposed to siliceous dust than in those not so exposed.

7. It is recommended that all metal mine establishments provide conveniently located change rooms with hot and cold shower baths, drying rooms, and lockers.

8. Persons working in occupations with serious lead exposure should be examined often enough to prevent the occurrence of disabling lead poisoning. These examinations should include blood study with regard to reticulocyte counts and basophilic stippling and, in some instances, also, chemical determinations should be made of the blood and excreta.

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9. All workers should be passed upon by the medical department when reporting back to duty after absence on account of illness or injury. It is the responsibility of the physician to determine if the employee is able to work safely and efficiently.

10. Records of all absenteeism due to illness or injury should be kept by the mine medical department indicating the cause, nature, duration, and outcome of such disability. These records should be tabulated and included in a monthly report which should be studied and measures instituted to minimize such absenteeism.

11. Employees should be encouraged to report all minor non-disabling illnesses, particularly gastrointestinal, in order that the medical department may ascertain whether or not they are due to lead or other toxic agents.

12. The mine physician should be familiar with the various mine operations. He should report to the industrial hygiene or safety engineer the occurrence of lead poisoning or other toxic effects among workers in certain occupations.

13. Care should be required of the employee with respect to personal cleanliness and eating habits to avoid unnecessary ingestion and inhalation of lead and other toxic agents.

14. It is recommended that silicosis, lead poisoning, and other occupational diseases be reported to the State Board of Health.

THE WORKING ENVIRONMENT

GENERAL CONSIDERATIONS

NATURE AND SCOPE OF THE STUDY

An important procedure in the search for major factors in the causation of disease of suspected occupational etiology is a detailed investigation of the conditions under which the work is performed. In the present study, investigation of the working environment consisted of an analysis of the various operations and activities involved in the mining of metal ores, and the sampling and analysis of the atmospheric dusts, fumes, and gases. In addition, certain data were obtained on temperature, humidity, air movement, illumination, and sanitation facilities in this industry. A sanitary survey of the communities surrounding the workplaces was also made.

Knowledge of the potential hazards associated with the mining of metal ores and the number of persons employed in each occupation was obtained from a preliminary survey conducted in 1937 by the United States Public Health Service and the Utah State Board of Health (1). At this time the Utah State Industrial Commission had a record of 56 separate active nonferrous metal mining enterprises employing five or more persons. Under the heading of separate enterprises were included, as one mine, all interconnected mining operations owned by one company, even if portions of the mine were being operated under mining lease permits by independent operators. While no accurate data on the total number of workers in 1937 were available, it was assumed that the total employment in the State was approaching the 1929 level. The United States Census Bureau showed 49 copper, lead, and silver enterprises operating 55 mines and employing 8,182 persons in 1929 (1 zinc and 3 lode gold enterprises were also reported but no data on employment were given) (2).

Twenty-three of these mining enterprises (including 30 mines employing 5,390 persons) were visited during the preliminary survey. Two of these, employing approximately 1,900 persons, were not considered because they were open pit mines. On the basis of information obtained concerning the remaining 21 underground mining enterprises, three representative metal mines were selected for detailed study. Insofar as possible, the identity of individual mines has not been disclosed in this report, and data given relative to a specified mine field have been considered typical of all mines in that area.

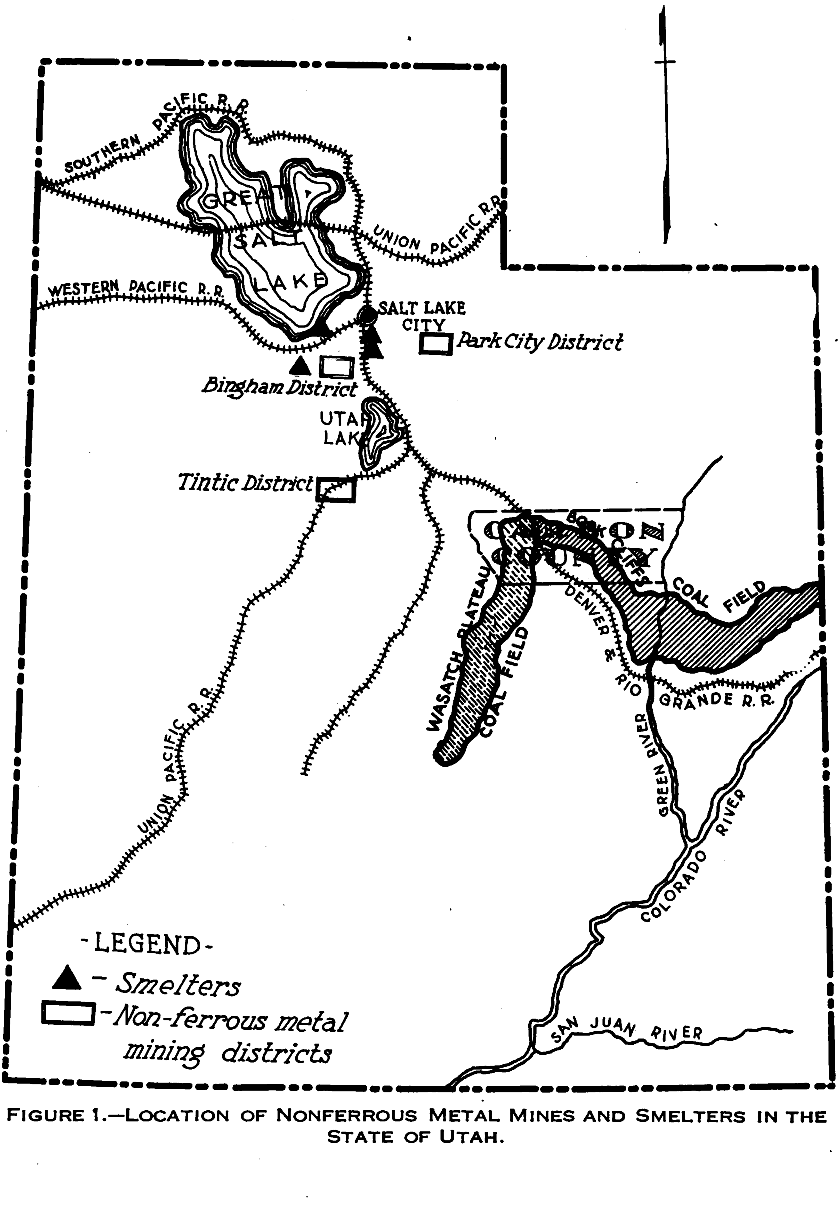

FIGURE 1.—LOCATION OF NONFERROUS METAL MINES AND SMELTERS IN THE STATE OF UTAH.

The location of the principal metal mining fields in Utah is shown in figure 1, which also shows the location of the principal smelters.

The metal mines studied were operated by three different companies, in three different mine fields. All were underground mines extracting lead-copper or lead-silver ores, in which gold and zinc occassionally occurred in sufficient amounts to be considered as supplementary ores. This study did not apply to the mining of iron, manganese, or mercury ores existing as independent deposits. Compounds of iron, manganese, arsenic, cadmium, selenium, and mercury occurred in the commercial ores being mined, and both arsenic and cadmium were being recovered in the smelting process, and were of hygienic significance there. However, neither the medical nor the engineering data showed that these elements were occurring in sufficient concentrations in the mines studied to constitute a health hazard in the mining, crushing or wet concentration of ore. Metal mining enterprises were so selected that they were representative of mining conditions which were cold and wet, hot and dry, and intermediate. Wide variations in ventilation practice were also encountered.

The preliminary survey had shown that the most frequent potential exposures to hazardous materials were to siliceous mineral dusts, metal dusts, noxious gases, and dermatitis-producing substances (skin irritants). The degree of exposure to these materials was determined by the following methods of sampling and analysis.

METHODS AND INSTRUMENTS USED IN THE STUDY

FIELD SAMPLING OF DUSTS AND GASES.

The hazards associated with each occupation, and the number of persons so exposed were obtained from occupational analyses made in each mine at the time of the first inspection of activities. At this time, certain typical places were selected for more detailed studies of the working environment.

Dusts.—To estimate an occupational dust exposure, the amount of dust suspended in the air breathed, the nature of the dust, and the duration of the exposure must be determined. In this study, the last-mentioned factor was obtained from the occupational history of each worker, which was recorded at the time of his physical examination. In measuring the quantity of dust to which each person was exposed, dust samples were obtained with the all-glass modification of the Greenburg-Smith impinger apparatus (3), or with the Bureau of Mines midget impinger apparatus (4), and were counted by the Public Health Service technique (5), except that the Page modification of the Whipple ocular micrometer (6), and either the Sedgwick-Rafter cell or the Dunn cell (7) were used. Supplementary check samples were collected with the Konimeter (5) in all working places where impinger samples were not collected. Data from Konimeter samples have not been given in the present report, since this instrument does not accurately measure high dust concentrations, and only a few selected samples were used in estimating the average exposure of workers in the less dusty occupations. The dusts from large volumes of air were collected for chemical analysis, where the atmospheric dusts were suspected of containing toxic metals. Samples for chemical analysis were collected with both the large impinger and the electro-static precipitator. Impinger samples of lead dust were collected in a 5-percent nitric acid solution.

To determine the mineral composition of the dusts, samples of settled dust and samples of ore and rock were collected at various locations and subjected to a chemical and a petrographic examination, as described later under laboratory procedures.

Since it was important to show that the industrially produced dust particles suspended in the atmosphere were of a size permitting access to the lung tissue (8), measurements were made of dust particles collected from the working atmosphere. This was done by taking portions of the dusts collected in the impinger tubes and measuring them by the technique described by Chamot and Mason (9).

The method employed in calculating the average dust exposure for an occupation and the weighted average of each worker's total exposure has been described in Public Health Bulletin No. 217 (5). In the present study, dust samples were obtained representing each activity in a number of dusty occupations, in order to determine the amount of dust which each activity contributed to the sum total of occupational exposure. In other cases, samples were taken over a sufficient time interval to include one or more complete cycles of the various activities in the duties of an occupational group. In this way, the average dust exposure for each numerically important occupational group could be estimated.

Gases.—Mine gases were collected in the standard Bureau of Mines vacuum flasks and analyzed through the courtesy of the United States Bureau of Mines at their laboratories (10). Field determinations were also made with an Orsat apparatus. Carbon monoxide concentrations were also determined with a carbon monoxide indicator (11).

Other determinations.—Temperature and humidity readings were made at the working places with the aid of the standard sling psychrometer; ventilation readings were made with a vane anemometer, a thermo-anemometer (12), or a Pitot tube; barometric readings with an aneroid barometer; and illumination readings with a photoelectric cell illuminometer.

LABORATORY METHODS OF ANALYSIS.

In addition to the above determinations two kinds of samples were collected for analysis; atmospheric samples and samples of materials. Atmospheric samples were analyzed for lead and qualitatively for cadmium, copper, arsenic, antimony, and other metals, while material samples such as settled dust, ores and rocks, were analyzed for lead, total silica, and quartz. The following methods were used.

Atmospheric lead.—Impinger and precipitator samples were evaporated on the hot water bath down to about 5 ml. in platinum dishes. Five milliliters of 1:1 sulfuric acid were added and the samples were carried to fumes of sulfuric acid on a hot air radiator. A few milliliters of hydrofluoric acid were added, followed by small amounts of nitric acid, at intervals, until all organic material had been destroyed. The sample was transferred to a 250 ml. Phillips beaker and diluted to 200 ml. It was next treated with hydrogen sulfide and allowed to stand overnight. The sulfide precipitate was filtered off and dissolved into a 125 ml. Phillips beaker with about 10 ml. of hot 1:1 nitric acid followed by hot water. The solution was boiled to eliminate any sulfur and then neutralized with sodium hydroxide solution. This was followed by acidifying with acetic acid. The solution was heated to boiling and lead was precipitated as the chromate by the addition of a potassium chromate solution. The precipitate was allowed to digest overnight on the steam table, and after being allowed to cool, was collected on a filter paper and washed thoroughly with water. It was next dissolved with cold 1:9 hydrochloric acid and washed through the paper into the beaker in which the chromate precipitation was made.

Potassium iodide, not in too great excess (usually not over one-half gram), was then added and the liberated iodine was titrated with 0.005 N solution thiosulfate using starch as an indicator (13).

In cases where the lead chromate was considerable, the following modified procedure was used: The lead chromate was filtered on to a Gooch crucible, washed, and then dried in the oven at 110° F. and weighed.

Total silica and quartz.—These chemical analyses were carried out according to the standard methods of rock analysis (13) (14). Lead was weighed as the chromate.

The free silica or quartz content of these samples was determined petrographically. A preliminary separation of the sample into fractions of approximately the same size was made by air elutriation. The Roller Particle Size Analyzer (15) was used for this purpose. The volume of sample necessary for such a fractionation is about 25 ml. and separations may be accomplished in about 7 hours. The samples were separated arbitrarily into fractions of 0–4, 5–9, 10–19, 20–39, 40–79, and 80+ microns based on the specific gravity of quartz. According to the theory on which such separations are based, the sample is fractionated into portions whose particles are all the same weight. This being the case, the percentage of quartz particles in a given fraction by count should be equal to the percentage of these particles by weight. Thus, the quartz particles were identified with the petrographic microscope and counted (usually 200 particles in a fraction were counted) and the percentage of quartz was determined. A summation of the quartz content of all the fractions of the sample was made and in this way the percentage of quartz in the samples was obtained (16).

GEOGRAPHY AND GEOLOGY OF UTAH ORE DEPOSITS

The principal ores mined in Utah are lead and copper ores mixed with ores of zinc and the precious metals. Ries and Watson (17) state that "the group of lead and zinc ores carrying more or less gold and silver as well as some copper and iron * * * is found chiefly in the Rocky Mountains, and is not only of complex character but differs in form and origin from the eastern deposits. Quartz is the common gangue material, while arsenic, antimony, and iron are common impurities." With regard to copper deposits, they say that copper ore exists as disseminated "bodies of sulfides deposited by magmatic waters, in igneous rocks or schists, either in connection with the preceding type (contact metamorphic deposits) or alone * * * The country rock is more or less fractured, and the low grade disseminated ore is sometimes present in large amounts. Its commercial value is due to secondary enrichment, and over it there is a leached capping of variable thickness * * *. Vein deposits of mixed character, in which the copper is associated with lead, zinc, gold, or silver, are worked at a number of points in the Rocky Mountains."

Metal mining is conducted in over half of the 29 counties of Utah. In many of the counties the mines are small, little more than prospects, with only a few employees doing prospecting or irregular development.

Approximately 97 percent of the metal mine production of the State comes from three mining sections known as the Bingham District, the Park City District, and the Tintic District. The location of these areas is shown in figure 1.

In 1929, approximately 72 percent of the metal ore produced in Utah came from the Bingham District, 14 percent from the Park City District, and 11 percent from the Tintic District (18). However, open pit mines from which most of the low grade copper ore is mined were not included in the present study. On the basis of the production of lead and silver metal, the approximate relative percentages of production were Tintic, 36 percent; Park City, 35 percent; Bingham, 26 percent, all other areas, 3 percent.

The relative proportion of the metals secured from the more important ores is shown in table 1. Obviously, the relative percentages of total production will have yearly variations, but the 1929 figures are a fair measure of capacity production at the present time. During the life of a mine, the percentage of carbonate and oxide ores will decrease and the percentage of sulfide ores will increase. This table has been presented to emphasize the wide variety of metal ores occurring in Utah metal mines, and to show that any analysis of Utah ores or rock can only be considered as representative of the immediate location sampled. Wide deviations from any estimated average ore analyses may be expected at different working faces.

TABLE 1.—*Utah metal production according to the percent derived from principal ore minerals, 1929*

Metal	Ore	Percent from specified ore mineral
Silver	Cerargyrite (silver chloride)	11
	Argentite (silver sulfide)	57
	Argentojarosite (basic sulfate of silver and iron)	1
	Native silver (dry siliceous ore)	30
	Freibergite (silver bearing tetrahedrite)	1
Gold	Native, in barite or quartz	96
	Sylvanite (gold-silver telluride)	4
Lead	Oxidized (oxides and carbonates)	22
	Sulfides	78
	Jamesonite (antimonial lead sulfide)	
	Galena (lead sulfide)	
	Plumbojarosite (basic lead ferric sulfate)	
	Wulfenite (lead molybdate)	
	Anglesite (lead sulfate)	
Copper	Bornite (copper iron sulfide)	61
	Chalcopyrite (copper iron sulfide)	2
	Enargite (copper arsenic sulfide)	
	Tetrahedrite (copper antimony sulfide)	7
	Malachite (basic copper carbonate)	11
	Covellite (copper sulfide)	
	Chalcocite (copper sulfide)	16
	Chalcanthite (hydrated copper sulfate)	
	Cuprite (copper oxide)	
	Azurite (copper carbonate)	3
	Native copper	

One of the primary purposes of the engineering study was to determine the exposure of the various workers to silica and toxic metal dusts. While no attempt will be made to describe the geology of the areas in detail, the following discussion illustrates the occurrence of widespread, but nonuniform sources of these materials.

Park City district.—Boutwell, in describing the ore deposits of the Park City district (19), reported that the sediments of this district are limestones, sandstones, quartzites and shales. The more important of these, from the point of view of ore deposits, are the Park City limestone, and the Thaynes formation, comprising limestones, sandstones, and shales. The strata have been arched forming part of the Park City anticline which has been broken by many faults. These sediments were intruded by diorite and diorite-porphyry magmas which metamorphosed them and caused the deposition of metallic sulfides. Subsequent fracturing occurred and permitted renewed deposition of sulfides. Further faulting presumably gave access of surface waters to the primary ore bodies, causing oxidation of the sulfides. This faulting also caused some displacement of the ore bodies.

Ores are both lode and bedded replacement type. Lode ores occur in both quartzite and limestone, while replacement ores are restricted to certain members of the two formations occurring at different horizons. The most valuable and productive deposits occurred in a limestone bed in the Park City formation about 100 feet from the Weber quartzite. Another very productive horizon was on the contact of the Weber quartzite and the Park City limestone. As the richer ore deposits are depleted it becomes necessary to go deeper into the quartzite to find commercial ore.

Average mill feed ores from this area contain about 15 percent lead sulfide and 60 percent nonmetallic gangue (45 percent quartz and 15 percent carbonate) (20).

Early returns from mining in this area were high from the time of its location in 1869 until 1884 when, after the bonanzas had been exploited, work began on the so-called "bedded" deposits. Yield from these deposits declined until 1900, when the effect of gradual depletion of high grade ore was partly offset by the development of relatively large bodies of lower grade ore at depth. By 1908 nearly all of the ore tonnage was from "bedded" rather than from fissure deposits and its bulk was made up of sulfides with little of the richer oxidized material. With improved milling, zinc became an appreciable factor in output by 1910 and the yield of this metal has increased, particularly since 1925. Few bodies of high grade ore have been discovered in the past two decades (21).

The decrease in the amount and proportion of oxidized ore produced, and the decrease in grade of lead ore should tend to diminish the amount and toxicity of lead dust produced per ton of ore mined. However, since the sulfide ores tend to occur more frequently in the quartzite or sandstone, while the carbonate and oxide ores occur more frequently in the limestone deposits, the general trend through the years has been to increase the silicosis hazard, which probably has only partly been counterbalanced by an increase in the efficiency of control measures during this time.

Bingham district.—Less information has been published concerning the geology of the Bingham district than about the other two districts, and most of this has dealt with the large deposits of low grade copper ore being worked by open cut methods. However, Fulton (22) and Lyon (23) show that the history and geology of the field is very similar to that at Park City except lead-copper ores are more common than the lead-zinc ores. Ore was discovered at approximately the same time. The lens-shaped deposits of oxidized ores in the limestone have been practically exhausted, and the ore now being mined is the deep sulfide ore which occurs either as beds between the limestone and quartzite or in fissures in the quartzite.

Tintic district.—Ore discoveries were made in the Tintic (Eureka) district in 1869 and developments were started in the western and southern parts of the district. Developments in the eastern part did not start until about 1900, after the discovery of commercial ore bodies having no surface outcrops, and under 500 feet of covering rock. Since 1918, the principal producing mines have been in this eastern part of the district. The geology of Tintic area has been described in detail (24). While its geological history differs from the other two districts, the present picture is nearly the same from the industrial hygiene viewpoint. High- and low-grade lead-silver ores exist as intrusions and large replacements in the limestones, adjacent to faulted faces of the shales and quartzites. Both ores are completely oxidized to 1,000 feet below the surface; for the next 500 feet the sulfide content of the ore increases until the ores are practically all sulfides. The sulfide ore frequently occurs between hanging walls of shales and limestones and footwalls of quartzite. Extensive postmineral faulting has brecciated a large part of this ore into fine sandy material intermixed with masses of heavy lead ore. The hanging wall shales have been altered by mineralizating solutions to a soft grey clayey material and the limestone areas over the ore bodies are altered by the introduction of silica and magnesium silicates.

The individual ore bodies, when adjacent to the quartzite fault faces, have steep dips ranging from 45 degrees to vertical; when distant from the quartzite fault faces, they are tabular replacements of flat lying limestone beds. The tabular commercial ore bodies range in height from 6 to 200 feet.

A typical geological section through the Tintic district is shown in figure 2.

Only a small proportion of the ore mined in the Tintic district can be classed as "gold and silver ore," which Henderson and Dunlop have defined as "dry and siliceous ores"[3] but both metals occur as valuable enrichments of base ores.

[3] Silica rich ores worked for the precious metals, with gold and silver usually free milling, and associated with relatively little metalliferous minerals, are called "dry and siliceous ores" by smeltermen.

"A 'dry' ore is one that carried so little lead or copper that by itself in quantity it would not satisfy the requirements for the smelter charge in lead smelting or copper smelting, respectively * * * Siliceous (silica in excess of iron) gold, gold-silver, and silver ores containing too little copper, lead or zinc to be classified as copper, lead, zinc, or mixed ores are called 'dry' ores regardless of the ratio of concentration * * *" (25).

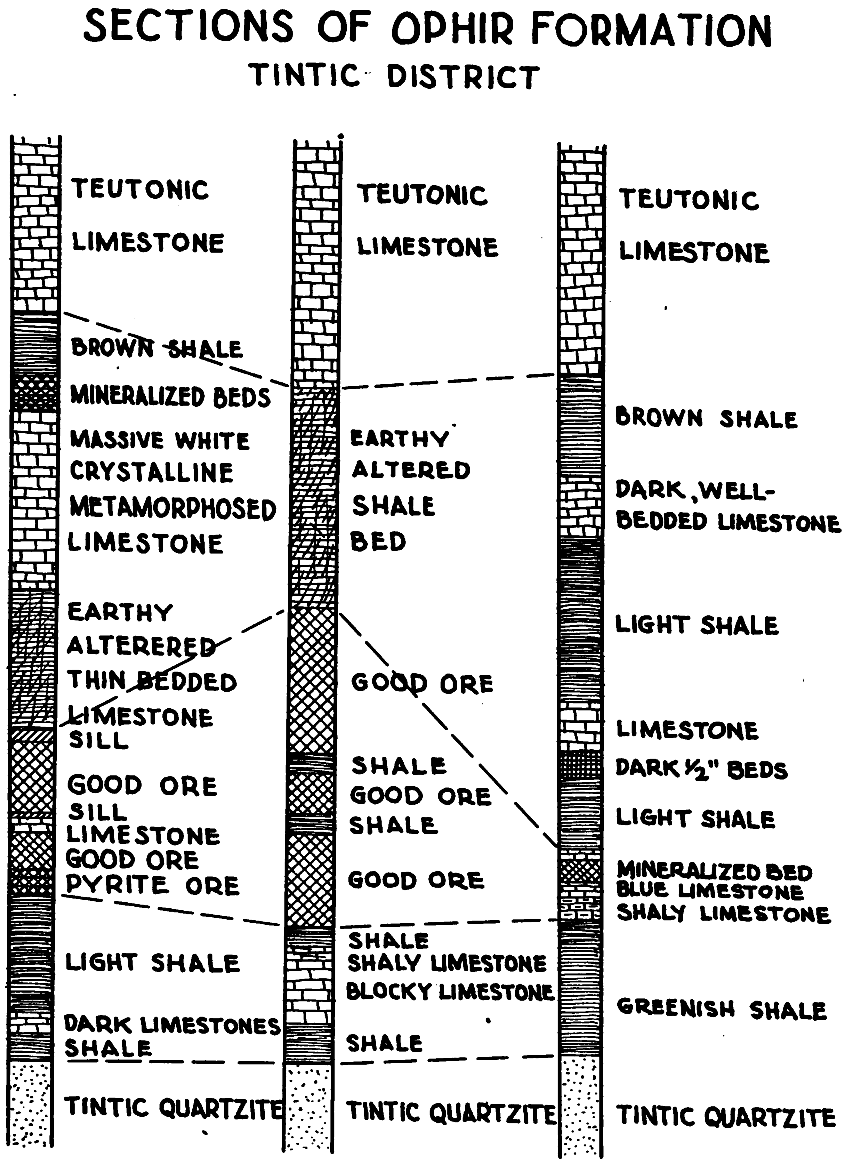

FIGURE 2.—TYPICAL SECTIONS THROUGH THE OPHIR FORMATION IN THE TINTIC MINING DISTRICT. (REPRINTED FROM BUREAU OF MINES INFORMATION CIRCULAR 6370.)

MINING METHODS[4]

There are many standard methods of mining metal ore, and several of these methods, or modifications of them, may be used in the same mining operation. The methods encountered have been described briefly in the following paragraphs, but no attempt has been made to give precise technical details. Underground mining operations may be roughly classified as follows: (*a*) Mine development and exploration, (*b*) stoping, and (*c*) transportation of ore and waste. Other underground operations, such as maintenance and construction, are essential but can be considered as supplemental to the actual mining of the ore.

MINE DEVELOPMENT AND EXPLORATION

Jackson and Hedges (26) have stated that: "The term 'mine development' is employed to designate the operations involved in preparing a mine for ore extraction. These operations include tunneling, (shaft) sinking, crosscutting, drifting, and raising."

In most mines, both exploration and development continue after ore extraction by stoping has begun, and often nearly to the end of the life of the mine. Although all of the mines studied had been operating over 20 years, and some of them for as long as 70 years, both exploration and development were being continued. The development system in one Utah metal mine is shown in figure 3.

Shafts and adits.—Both shafts and adits (haulage tunnels to the outside) are used for bringing ore to the surface. Since most Utah mines occur in areas of high relief where much of the deposit lies above surface drainage, it has been possible in many cases to use the same tunnel for drainage and haulage. However, in most instances the original development was by shaft, and later the adits were driven to a level station. Mines studied included mines with shaft collars at the surface, mines having both shafts and tunnels opening at the surface, and mines having underground shafts at the end of tunnel adits. Two of the mines studied were in the process of sinking new shafts, or deepening present shafts.

The usual shaft is vertical and of such dimensions, inside the timber, as to provide for two hoisting compartments and a ladder pipeway.

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[4] Metal Mining Practice by Jackson and Hedges has been used as a basis for this section (26).

Ore is hoisted, in balance, in cars on cages or in skips. Inclined shafts are used in some cases, especially for underground shafts used for lifting ore to main haulage levels from sublevels. In inclined shafts, or winzes, skip hoisting through a single hoist compartment is the most common procedure.

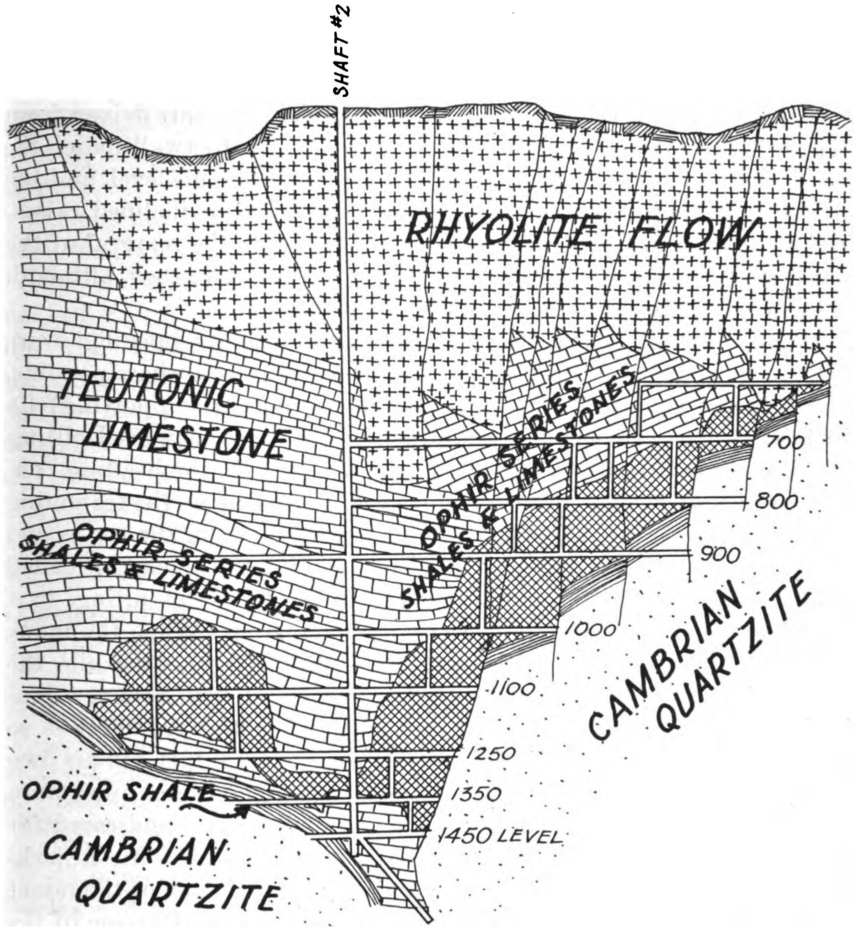

FIGURE 3.—DEVELOPMENT SYSTEM IN A UTAH METAL MINE. (REPRINTED FROM BUREAU OF MINES INFORMATION CIRCULAR 6360.)

A landing, or shaft station, is provided at each haulage level. These levels are seldom less than 100 feet or more than 200 feet apart after the shaft has penetrated the ore body. Except in those cases where the adit or drainage tunnel is on the lowest level, a sump is usually provided at the lowest shaft station, into which all water seeping into the mine is drained, and from which it is pumped.

Adits or haulage tunnels are similar to main haulage drifts. Their size is governed by the rate of production and the size of the mine car used. In general, they are high enough to permit suspension of the trolley wires well above the head of a man standing upright, and of sufficient width to allow for a manway on one side of the track and a drainage ditch on the other. Most of the mines studied had at least two openings to the surface serving as ventilation shafts or tunnels, although in several cases at least one of these openings was also used for haulage.

Drifts, crosscuts, and raises.—Drifts or haulageways are driven from the shaft stations through the ore, or through the footwall under the ore. These drifts are connected by crosscuts on the same level, and the drifts on different levels are connected by vertical or inclined raises. Drifts, crosscuts, and raises are driven to facilitate the removal of the ore from the mine and are usually driven in the native rock, although they may be driven in ore or along ore fissures.

In a typical system of tunnels, drifts, and crosscuts, openings were six feet wide and eight feet high. The roof was arched where possible, and in heavy ground (brecciated rock which is not self-supporting) 10-inch by 10-inch timber sets were used with six-foot spacing. Drilling and shoveling was done simultaneously, the crew in the heading consisting of a miner and one or two muckers, depending on the tramming distance. The miner stood on the muck pile to put in the top round of holes (cuts, relievers, and back holes). Shovelers (muckers) loaded broken rock into cars and trammed them to chutes for filling, to a switch station, or to the shaft station for hoisting. When the muck pile had been removed the miner drilled his lifter holes while the shovelers laid a platform of lagging to receive the next round. Timbering was done by a separate crew; but when the ground was so heavy that immediate timbering was necessary, the miner did his own timbering. The track and the compressed air and water pipe were advanced by a special crew, and a third crew advanced and cared for the ventilation pipe. Drawcut rounds were drilled with a jack-hammer, or if the ground was too hard for a jack-hammer, the miner used a drifting machine mounted on a horizontal bar. In some of the mines, drilling and mucking were performed on alternate shifts.

Raises, and the raising method, varied considerably in the different mines. In some sections raises required little timbering, while in others standard square sets completely lagged were necessary. In this case the raises were usually two sets wide, one set being used for a manway, a timberway, and for air, water, and ventilation piping, while the other side was used as an ore chute. A miner, using a stoper drill, and a mucker worked together in driving the raises, and kept the chute lined to within two sets of the top.

STOPING

The subject of stoping has been comprehensively discussed by Jackson and Gardner (27) and summarized by Jackson and Hedges (26). The following discussion is drawn from these references to which the reader is referred for detailed technical information.

The term "stoping" is applied in a broad sense to the operation of excavating ore by means of a series of horizontal, vertical, or inclined workings in veins, or large irregular bodies of ore; or by rooms in flat deposits. It covers the breaking of ore and its removal from underground workings, except those driven for exploration and development, and the timbering or filling of the stopes for the purpose of support.

Various methods of stoping have been devised for extracting ore safely and economically from deposits of different types. The stoping method, or methods, applied to a given ore body depend on the requirements for support of the stope—the maximum area of span of back and walls that will be self-supporting during the removal of the ore; the nature, size, and interval between supports required to maintain the backs and walls of the excavations; and the requirements for permanently supporting the overlying and surrounding country rocks and overburden to prevent their movement and subsidence.

A classification of stoping methods based upon method of support, adopted by the Mining Division of the United States Bureau of Mines in 1928 as shown in Bulletin 419 of that Bureau, follows:

A. Stopes naturally supported.
  1. Open stoping.
    a. Open stopes in small ore bodies.
    b. Sublevel stoping.
  2. Open stopes with pillar supports.
    a. Casual pillars.
    b. Room (or stope) and pillar (regular arrangement).
B. Stopes artificially supported.
  3. Shrinkage stoping.
    a. With pillars.
    b. Without pillars.
    c. With subsequent waste filling.
  4. Cut-and-fill stoping.
  5. Stulled stopes in narrow veins.
  6. Square-set stoping.
C. Caved stopes.
  7. Caving (ore broken by induced caving).
    a. Block caving; including caving to main levels and caving to chutes or branched raises.
    b. Sublevel caving.
  8. Top slicing (mining under a mat that, together with caved capping, follows the mining downward in successive stages).
D. Combinations of supported and caved stopes. (As shrinkage stoping with pillar caving, cut-and-fill stoping with top slicing of pillars, etc.)

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Practically all of these methods, and many modifications of them, were encountered during the present study. Modifications of the square-set stoping method were most frequently noted. In this

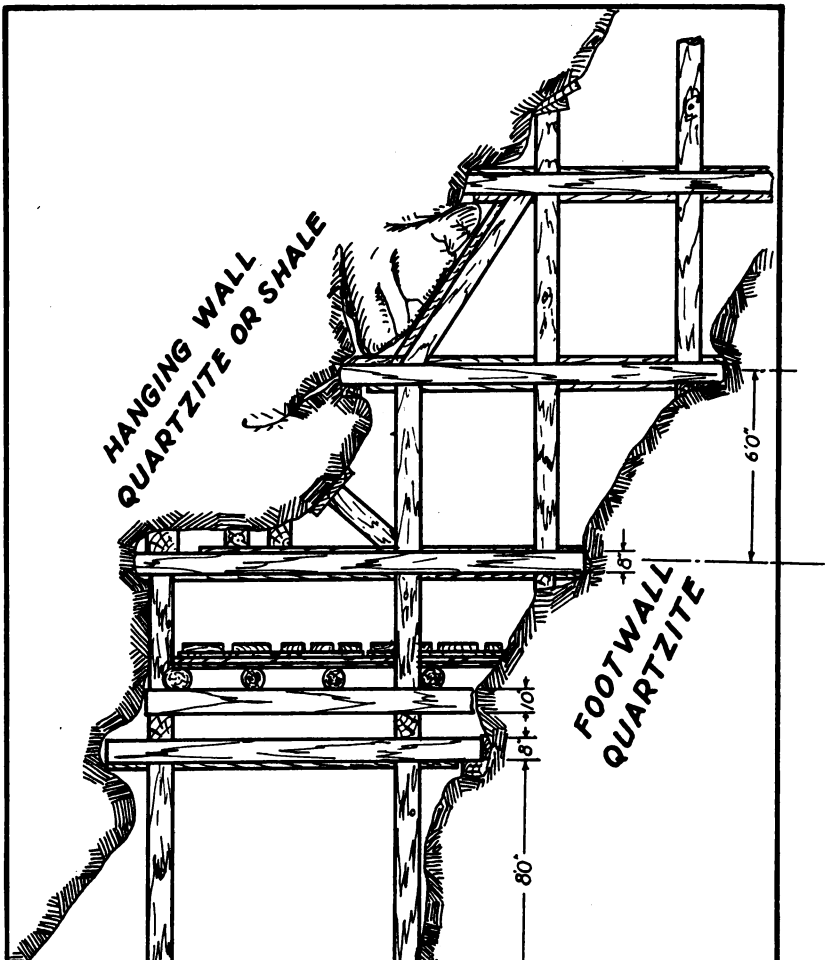

FIGURE 4.—STRINGER-SET STOPE TIMBERING. (REPRINTED FROM BUREAU OF MINES INFORMATION CIRCULAR 6851.)

method the ore is excavated in small rectangular blocks, one block at a time. After each block is removed its place is taken by a set of framed timber which serves as a temporary support to the surrounding ground. As best employed, square-set timbering is not used to permanently support the stope for it cannot hold great pressures. As soon as possible, waste filling is put in for permanent support. Stoping is commonly carried upward from a drift, or laterally from a raise, or both. In one mine where open stopes, a shrinkage stoping method, and a modified square-set method had been tried and found unsuitable, a regular square-set and back fill method had been adopted. This required the driving of a vertical square-set raise from the footwall at the level where the stope was to be started to the level above. This raise was the place where the stope was started and through which waste was dumped from the level above when filling was wanted. In this mine, ore was trammed in small ore cars from the active sets to ore chutes. These chutes lead to ore pockets in the main haulage drift or to crosscuts on the lower level. In another mine where combinations of horizontal square-set stoping and sublevel caving or top slicing were used, the ore was moved to the loading chutes with dragline scrapers (slushers). Stulled stopes, which might or might not subsequently be filled with waste, were developed in some mines. Many other modifications of standard stoping methods are also used in Utah metal mines. An example of stringer-set stope timbering is shown in figure 4.

TRANSPORTATION OF ORE AND WASTE

Transportation concerns the operations involved in the conveying of ore and waste from the face or stope where it is broken, to the surface; or the carrying of waste to a stope for gobbing (filling); but not the handling of the ore in the stopes, which has been discussed under "Stoping." It includes loading cars from chutes on the haulageways and intermediate levels, hand-tramming, animal and locomotive haulage, scraper transportation, operation of main transfer raises between levels, dumping into shaft pockets, the operation of skip loading devices, the caging of cars, and the hoisting of ore in cages or skips.

The transportation facilities which must be provided when underground work is begun may or may not be retained as mine development expands and ore production begins.

Hand tramming is frequently the only form of transportation used in small mines, and is used in larger mines as an adjunct to mechanical haulage systems. For tramming small tonnages of rock and ore short distances on the main levels, for short transfers on sublevels, and in some types of stopes, it may be the most practical method. It is particularly adapted to prospects and small-scale operations, such as those conducted by "leasers" (lessees). Small cars, of 12 to 20 cubic foot capacity, of either the end- or side-dumping type, are usually employed.

Mules and horses were extensively used for haulage in the past, but are being replaced by mechanical haulage methods.

Mechanical haulage in the metal mines studied was of two types: (*a*) Locomotive, and (*b*) scraper and slusher.

Locomotives for underground use were electric powered, and either of the trolley or storage-battery type. The trolley type was used for long hauls and heavy trains, while the storage-battery type was preferred for gathering service from a number of loading points to a main haulageway or shaft station. Small storage-battery locomotives of the "trammer" type that could be run on the mine cage, and transferred quickly from one level to another, were used in mines where the ore came from scattered areas and several horizons.

Scrapers powered by electric or compressed air motors, ordinarily were employed underground as mucking and loading machines; but they were also employed as conveying machines, and in some instances, were used to transport ore and rock several hundred feet from the face to chutes or mine cars.

The force of gravity usually is employed, wherever possible, to move broken ore from stopes to the haulage levels. Ore-passes from the stopes terminate at the bottom in chutes, by means of which the flow of ore into cars can be controlled. Loading chutes are constructed in various ways and consist essentially of a framework of timber, steel, or concrete with gates or other means provided for holding back the column of broken ore in the raise above. Chute gates are of many different types (28), but from the industrial health viewpoint, they are all apt to be sources of dust dissemination unless a satisfactory dust control method is employed.

Ore- and waste-passes are simply vertical or inclined openings for the transfer of broken ore to the haulage system, and of waste rock to the mined stopes. They may be cut in the ore or in the walls of the deposit, or be timbered openings through old or filled stopes. From a health viewpoint, the combination of an ore-pass and a manway in the same opening, even if they are separated by stulls and lagging, may cause serious dust exposures for men who must use the manways during or immediately after ore movement.

Hoisting in cages and skips.—Both cage hoisting and skip hoisting were employed in the mines studied. Arrangements for caging cars at the shaft stations varied. In some mines, stations were cut on both sides of the shaft. The loaded cars were pushed onto the cage from one side and the empty cars pushed off on the other. In other mines, the station was cut only on one side of the shaft so that the empty car had to be pulled back off the cage before the loaded car could be pushed on. Switches and crossovers were provided for pulling the empties off to one side to allow caging the loaded cars.

Skip hoisting was employed for moving ore from sublevels to main haulage levels at a higher elevation. Single compartment, skip-hoists with self-dumping skips were used in winzes or shafts. Muckers dumped the ore directly from small tram cars into the skip buckets. The skip buckets either dumped directly into large tram cars, or dumped into car loading pockets. Skip hoisting was also employed in some main shafts, in which case storage pockets and loading chutes were provided at the shaft stations. At two of the mines studied, ore was hoisted or lowered in the main shaft to a tunnel haulage level. At this level station, trains of ten to thirty cars were made up and hauled by trolley locomotives to the outside. Where skip hoisting was used, this required the loading of cars from ore pockets opening at this level station.

Hoisting in cages is considerably slower than hoisting with skips, due to the smaller net load that can be hoisted in a shaft of the same size, and to the time required for caging cars at the shaft stations and on the surface, and usually requires more labor. However, cage hoisting reduces the number of ore transfers, and every ore transfer is a potential source of dust dissemination.

A typical shaft "cage" consists of a double deck platform with boiler plate side shields and doors, and a steel canopy, the latter affording protection from debris and falling objects when men are raised and lowered in the shaft. The cages move along fixed guide rails and are provided with safety devices to prevent falling in case a hoisting cable breaks. The hoisting cables are strung over sheave wheels, mounted on the shaft head frame, and are connected to large driving drums located in a hoist house adjacent to the shaft.

OTHER UNDERGROUND OPERATIONS

Maintenance.—A large force of men is required to maintain the electrical, pumping, piping, and transportation services, and to maintain timbering in shafts and haulage drifts. The electrical services in a mine include lighting, telephone lines, signal systems, power wiring, motor installation and repair, and battery charging. Water pumps may be necessary to remove ground water, or water which seeps into the mine. There are also piping systems for compressed air and water. Transportation maintenance consists of track repair work, clearing drainage ditches, and the removal of rock and ore which accumulates along the main haulageways. In some dry mines, it is also necessary to sprinkle haulageways with water to reduce the dust concentrations.

Ventilation.—Only one of the mines studied had made any planned attempt to secure adequate mine ventilation by mechanical means. The other mines depended upon natural ventilation through shafts, adits, drifts, crosscuts and raises supplemented, in a few cases, by small fans or blowers supplying air to the stopes; and, in other cases, by the exhaust from compressed air drills, or from open valves in the compressed air lines. Where planned ventilation systems are used, air movement is produced by large surface fans working from the suction (or return air) side, and located at the collar of a ventilation shaft, or by underground fans located in a ventilation tunnel (fig. 5). Air enters the mines through other shafts, or adits, and flows through drifts and raises to the stopes; and then preferably, from the stopes to ventilation drifts which are brought together into a single airway leading to the exhaust shaft. The direction of air currents in the mine is controlled by brattice doors and partitions, and the velocity of the currents may be increased by supplementary booster fans (fig. 6). Small auxiliary fans and ventilation ducts are also required for ventilating blind stopes and dead ends.

Superintendence.—The mine foreman has general supervision of all underground activities. Since it is impossible for him to personally supervise so many different operations, he maintains contact with the miners through shift bosses and level foremen, who are responsible for the maintenance of scheduled output and all matters of safety in the sections of the mine under their jurisdiction. In some mines, they act as timekeepers, and also keep other records.

OUTSIDE ACTIVITIES

Surface transportation.—Ore coming to the surface through shafts in skip buckets is usually dumped directly into shipping pockets or ore docks. Ore reaching the surface in caged cars is hand trammed, and ore from the adits is hauled to the top of the docks and dumped. The railroad siding is usually beside the ore dock, and railroad cars can be loaded directly through chutes from the ore bins. In some mines, the topography prevents building a railroad line near the shaft location, in which case the ore is transported from the ore bins at the shaft head to the loading docks by means of an aerial tramway.

Other activities.—Surface maintenance crews repair portable mine equipment and may do emergency repair work in the mine. Essential operations include carpenter shops or saw mills in which timbers to be used in the mine can be cut and framed, electrical repair shops, and blacksmith shops for repairing ore cars and sharpening drill steel. The present tendency is to use detachable bits, and to sharpen bits or steel in automatic sharpening machines.

Most metal mines employ the services of an assayer who makes chemical and fire analyses of ore samples.

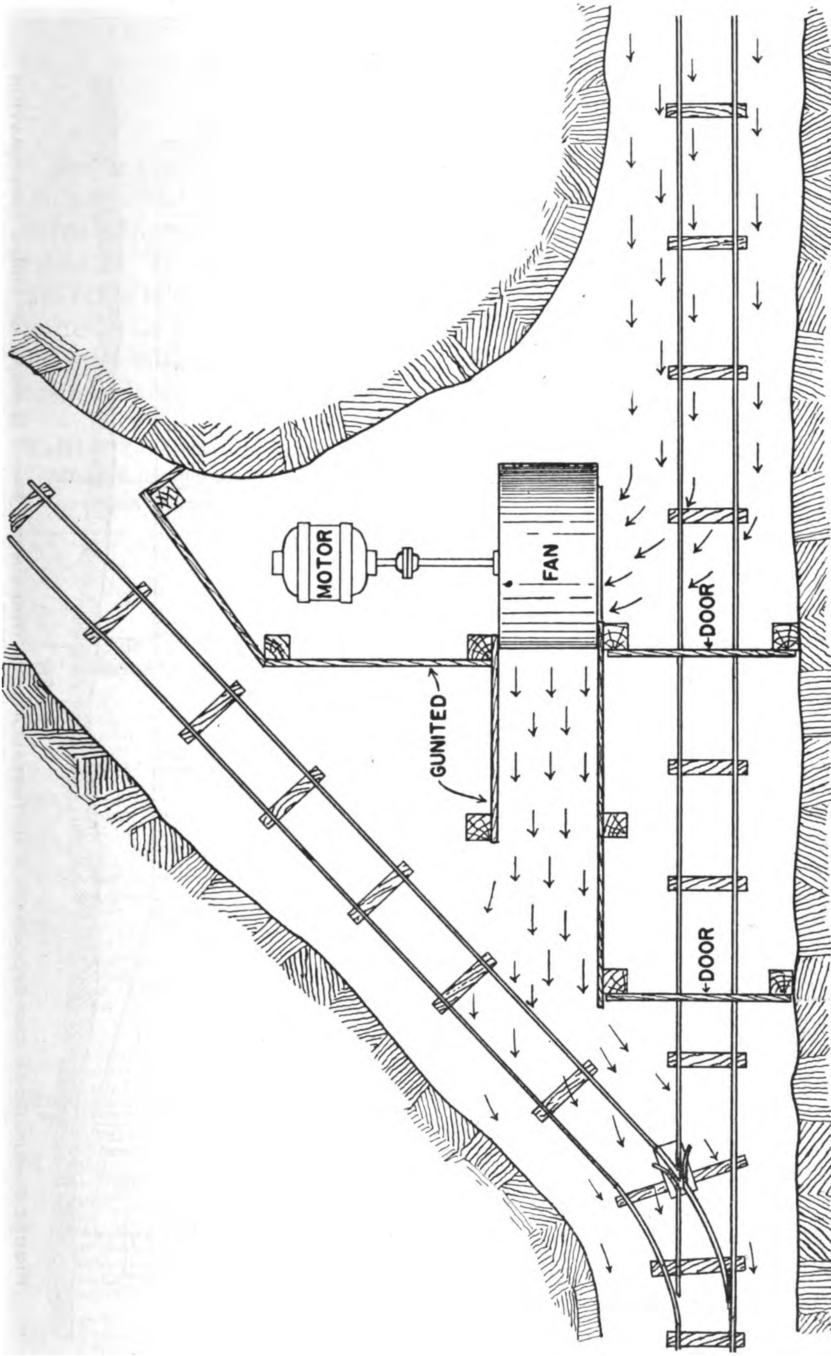

FIGURE 5.—TYPICAL UNDERGROUND PRIMARY EXHAUST FAN INSTALLATION. (REPRINTED FROM BUREAU OF MINES INFORMATION CIRCULAR 6360.)

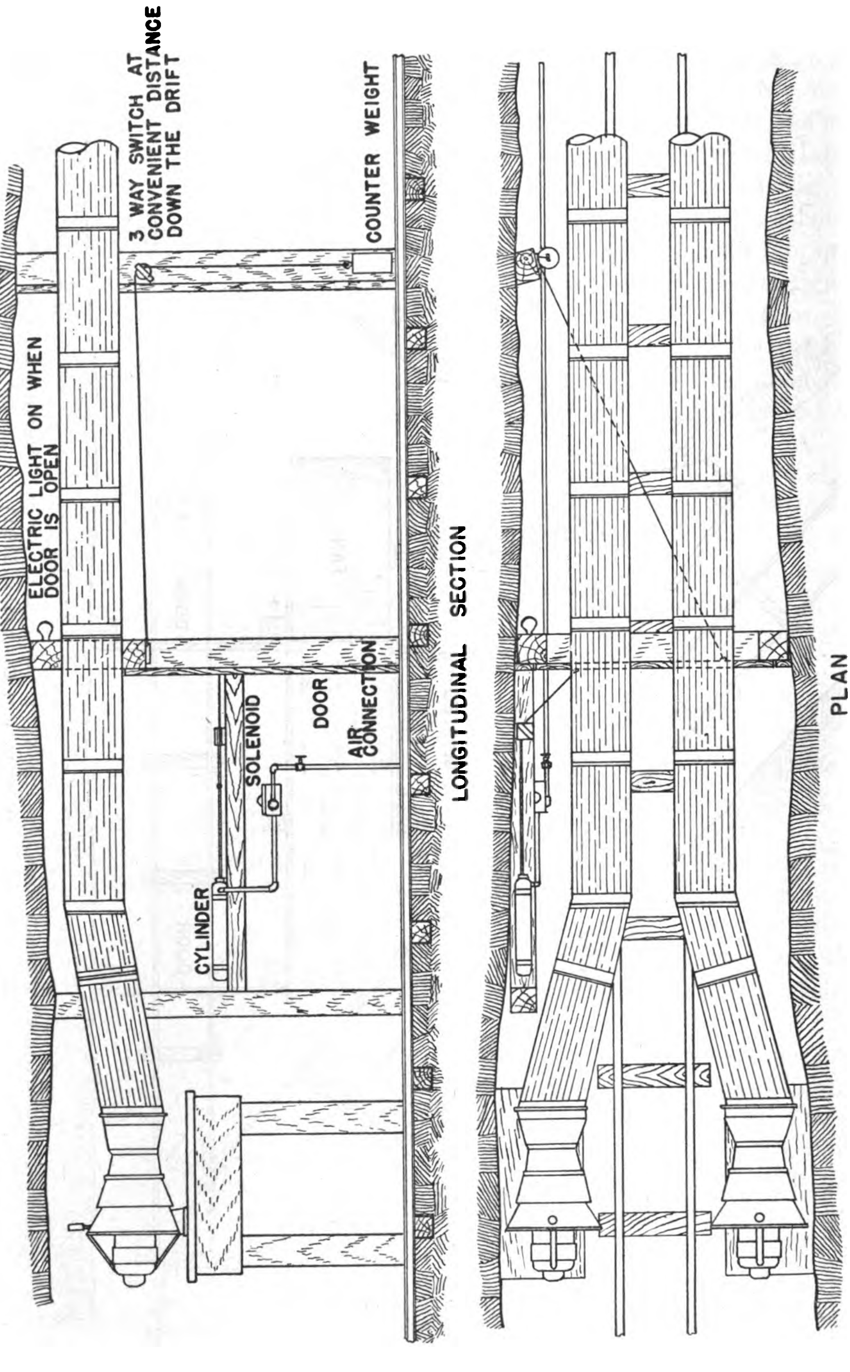

FIGURE 6.—AIR DOOR AND SECONDARY FAN INSTALLATION. (REPRINTED FROM BUREAU OF MINES INFORMATION CIRCULAR 6360.)

OCCUPATIONAL CLASSIFICATION

An occupational classification of the workers employed in 21 Utah underground metal mines in 1937, and of the workers employed in three mines at the time of the engineering study in 1939, is given in table 2. The number of men recorded for each occupation shown in the table is an average figure for the stated time. The metal mining industry is subject to abrupt fluctuations in employment caused by changes in the state of the market, and in the quantity and quality of ore available.

TABLE 2.—*An occupational classification of the employees of 3 metal mines studied in 1939 compared with an occupational classification of 21 metal mines surveyed in 1937*[1]

Section and occupation	Mines studied in 1939				Total for preliminary survey in 1937 of 21 mines[1]
	Total for 3 mines	Mine 1	Mine 2	Mine 3	
Total, all occupations	830	167	295	368	3,480
Office and general supervision	31	5	10	16	79
Superintendent, assistant superintendent, general foreman, manager	5	1	2	2	23
Engineer: mining, civil, safety, surveyor and geologist	14	1	6	7	20
Office worker, timekeeper, clerk, etc	12	3	2	7	36
Face operations, underground	399	68	154	177	1,977
Foreman, mine boss, shift boss, level boss	21	3	11	7	64
Miner, machine driller, machine man, driller	173	30	56	87	926
Mucker, hand miner, laborer, mucker and trammer	203	35	87	81	982
Sampler	2			2	5
Transportation, underground	111	29	45	37	401
Mule skinner, horse tender, trammer	12	12			84
Motorman, motorman's helper	34	5	11	18	129
Hoistman, winze hoistman, slusher man, tuggerman	37	6	31		92
Station tender, carman	6	4		2	20
Cager, cage rider	6			6	38
Nipper, tool nipper, supply man, material man	4	1	1	2	29
Powderman	10	1		9	9
Bin tender (car loader)	2		2		
Maintenance and construction, underground	131	29	55	47	490
Timberman, tunnel maintenance man }	106	20	48	38	366
Shaftman }					19
Pipeman	2	2			16
Trackman, track-and-pipeman	7	2	5		9
Ventilation man	4			4	8
Wireman, electrician					14
Mechanic, repairman, oiler	2	2			51
Sanitation man, inspector, general utility man	5			5	7
Compressor man, underground	2		2		
General labor, miscellaneous labor	3	3			

[1] Data from the files of the Unemployment Compensation Division of the Utah Industrial Commission showed that at the time of the preliminary survey there were approximately 56 active metal mines in the State. Of these, 23 were surveyed and found to employ 5,390 persons. Two were open-pit mines employing 1,910 persons which left 3,480 in underground mines.

TABLE 2.—*An occupational classification, etc.*—Continued

Section and occupation	Mines studied in 1939				Total for preliminary survey in 1937 of 21 mines
	Total for 3 mines	Mine 1	Mine 2	Mine 3	
Transportation, surface	48	20	2	26	208
Hoistman	7	4		3	66
Top carman, topman	15	3		12	43
Tram motorman, tramway operator	13	13			32
Waste dumpman, trackman					4
Bin man, ore loader, ore dumper, yard laborer	4		2	2	40
Truck driver, truck driver's helper	9			9	15
Tractor operator					5
Teamster					3
Maintenance and construction, surface	91	14	25	52	221
Compressorman [2]	6	3		3	13
Painter	3			3	4
Electrician [2]	5			5	16
Blacksmith, tool dresser, steel sharpener	17	7	5	5	61
Welder	1			1	3
Tinsmith, boilermaker	1			1	1
Cable maker					2
Machinist, mechanic [2]	11	2	5	4	44
Pumpman, pipeman, plumber [2]	4		3	1	4
Carpenter, timber framer, saw mill operator	14	2	3	9	43
Fireman, stationary engineer	3			3	14
General laborer	26		9	17	14
Battery man [2]					2
Milling operations					30
Concentration mill foreman					1
Concentration mill operator (dry crushing, wet flotation)					26
Concentration mill repairman					3
Assaying	11	2		9	24
Chemist, assayer	7	2		5	24 (Chemist, assayer and Bucker combined)
Bucker	4			4	
Miscellaneous	8		4	4	50
Watchman, guard, janitor	4		3	1	36
Warehouseman	4		1	3	5
Cook, waiter, store clerk					9

[2] Duties may necessitate underground work.

From table 2 it is apparent that there is a great diversity of occupations in the metal mining industry. A useful classification is on the basis of underground and surface workers, although many of the persons classified in the latter group spend part of their time in the mine. The occupations may also be divided into two other broad groups, namely, those associated with the actual extraction of the ore, and the indirect labor required in the mining operations. In mine 1, 39 percent of the total number of employees were miners and muckers; in mine 2, 48 percent, and in mine 3, 46 percent were thus employed. In the 21 mines previously surveyed, 55 percent of the 3,480 employees were classified as miners or muckers. Since the actual mining of the ore engages the direct attention of approximately half the total force, and since the drilling, blasting, and loading of the ore causes the generation of most of the dust in the mine, the chief interest is with those occupations which are directly related to or closely associated with the drilling and loading of ore. The sampling locations for atmospheric dust were so chosen that a representative picture of the various environmental conditions was obtained, samples being proportioned to the various occupations on the basis of the number of persons in each occupation, the estimated dustiness of the occupation, and the variation in exposure associated with the occupation.

Since the duties associated with each occupation tended to vary with the variations in the type of mining, it has been felt that a more detailed description of the occupational duties as contained in the preceding table should be given in this report. Such a detailed occupational analysis is shown in the appendix.

RESULTS OF ENGINEERING STUDY

VENTILATION, TEMPERATURE, AND HUMIDITY

Ventilation observations were made in some of the stopes, drifts, and shaft stations to determine the existing atmospheric conditions. In one mining field the air and rock temperatures were quite low, and the ore and rock were very wet; in another field, the air and rock temperatures were between 60° and 70° F. and part of the workings were comparatively dry; while, in the third area, air and rock temperatures were very high, and both the ore and rock were extremely dry. In the first two of the areas studied, the primary cause of air movement in the mines was natural ventilation, although this was occasionally supplemented by air from compressed air lines or from booster fans supplying stopes and blind-end drifts. In most of the mines in these areas, there was no evidence of any systematic attempt to control the flow of air through the drifts and crosscuts. In the third area, the high temperature and the presence of mine gases had made the use of systematic mechanical ventilation absolutely essential.

Natural ventilation depends upon the differential chimney effects of two shafts, or of a shaft and an adit having surface openings at different levels; upon the temperature difference between the mine air and the outside air; upon barometric pressure changes; and upon wind direction. The last three of these factors are subject to daily and seasonal variations, and, consequently, the ventilation determinations made at the time of the study are not necessarily representative of maximum, minimum or average conditions in the mines. Natural ventilation is never dependable, and always should be supplemented by mechanical methods of ventilation, if all working faces are to be continually active. This is especially true in Utah mines, which are subject to inflows of rock-strata gases. (See section on metal mine gases.) Some dead-end headings and blind stopes were ventilated by small fans driven by either direct-connected alternating-current motors or compressed air motors. Galvanized iron pipe and flexible canvas tubing were used as ducts to carry the air from the fan to the working face. In other "naturally ventilated" mines the air exhaust from the compressed air drills was the only available method for emergency ventilation of a working place. In such mines, it was common practice for the miners to open the valves on the compressed air lines before blasting at the end of the shift. By allowing the compressor to run for an hour after the shift had left the mine, and starting it again an hour before the next shift entered the mine, it was possible to disseminate and dilute the blasting fumes and other mine gases. It was also observed that many miners used air from the high pressure lines to supplement natural ventilation while mucking ore and timbering.

Mechanical ventilation practice varies, but usually the foul air is drawn from the mine at one or more points by large fans capping ventilation shafts, and pure air flows into the mine through intake shafts located elsewhere. After reaching the mine, the air is bled off at various shaft stations and distributed to many points through the various drifts, crosscuts, and raises. It then flows upward or downward through the stopes, and then out through other drifts to the exhaust shaft. Air flow is controlled by the use of ventilation doors, airbridges, brattice walls and booster fans. In some mines, air is blown into the air-entries, and in other mines, a combination positive and negative pressure fan system is used. It is not the custom in metal mines to provide separate air-ways and haulageways, as is done in coal mines. Consequently, most air-ways also serve as haulageways, and dust generated in the air-entries by hauling may be carried through the working stopes, while dust generated in the stopes may be carried to other stopes and to haulageways which are used as return air-ways.

Frequent complaints of "bad air" in metal mines were usually found to be due to physical conditions instead of the presence of noxious gases.

Proper distribution of air to where it was needed was uncommon in most mines, and many working faces did not have sufficient air movement to be detected even by close observation of the deflection of a match flame.

It has been shown (29) that low air velocities, high temperature, high humidity, and the vitiation of air by increase of carbon dioxide and decrease of oxygen have an influence on the comfort and presumably on the health of underground workers.

No specific optimum values for the air velocity, or volume of fresh air, required in a working place can be given, since both depend upon the type of stope, or heading, and the rate of contamination by dust or gases. Moreover, the determination of the actual volume of air supplied to a working place is extremely difficult because of the irregularities of the stopes and the difficulty in distinguishing between useful and turbulent air currents. Section 39 of the General Safety Orders Covering Underground Metal Mining Operations made effective August 1, 1931, by the Industrial Commission of Utah states:

The operator of every mine, whether operated by shaft, slope, tunnel, adit, level, or drift, shall provide and maintain for every such mine a good and sufficient amount of ventilation for such men and animals as may be employed therein, and shall cause an adequate quantity of pure air to circulate through and into all the shafts, winzes, levels, and all working places of such mine, and, except in case of an emergency, no man shall be allowed to work in an atmosphere injurious to health.

It will be noted that no specific recommendations are made as to either the volume or velocity of air required. McElroy (30) has reported:

If air conditions are normal and general blasting is confined to the end of each shift, 50 cubic feet per minute per man ordinarily would be satisfactory for operating concentrated working places two shifts with a long interval between shifts, but if the working places are scattered widely requirements would approach 100 cubic feet per minute * * * Extensive timbering, moderate production of gas, such as usually accompanies work in sulfide ores, or moderately high temperatures would individually increase requirements 50 to 100 cubic feet per minute per man. Except under extreme high-temperature conditions, the requirements will seldom exceed 500 cubic feet per minute per man, but under such conditions as much as 1,000 cubic feet per minute per man might be required for satisfactory results.

The volume of air entering a mine affords no information concerning the amount of air furnished at any particular working place. This is especially true in those workplaces at a great distance from the main air courses in mines depending upon natural ventilation. Two mines, in the same area, having mechanical ventilation, supplied 78,000 and 70,000 cubic feet per minute of air, respectively, to their workings, while a naturally ventilated mine in another area, employing approximately the same number of men per shift, had an inflow of approximately 20,000 cubic feet per minute. It is a well-established fact that mechanically ventilated mines usually supply more air per worker than those depending upon natural ventilation, and are not subject to such severe seasonal fluctuations in ventilation. Observations of psychrometric conditions in typical working places are summarized in table 3. This table shows that dry-bulb air temperatures ranged from 43° to 99° F. Considerable seasonal variation in mines having natural ventilation can be expected, but the records of a company operating a mechanically ventilated mine having an air temperature of 84° F. at the bottom of the main shaft at the time of the study, when the outside air temperature was 84° F., only dropped to 79° F. when the outside temperature dropped to 28° F. Relative humidities were constantly high, in this mine ranging from 40 to 96 percent and averaging 82 percent. Lower relative humidities can be expected in winter, especially in mines having mechanical ventilation.

TABLE 3.—*Psychrometric observations in 3 metal mines*

Mine	Dry bulb temperature (° F.)	Relative humidity (percent)	Air velocity (ft/min)	Effective temperature (° F.)
Mine 1:				
Maximum	46	97	190	46
Minimum	43	66	20	37
Mine 2:				
Maximum	71	99	105	71
Minimum	60	86	20	56
Mine 3:				
Maximum	99	96	750	94
Minimum	78	40	25	65

A wide range of air velocities was disclosed in studying the air movement at typical workplaces. These velocity studies indicated many readings in the order of 20 feet per minute (practically still air) and several as high as 750 feet per minute. This variation depends on such factors as the type of ventilation, location and type of stope, and the necessity of conducting mining operations in "dead end headings" while driving development tunnels, until airways have been created by connection with other passages. More than half of the air velocity observations were found to be less than 50 feet per minute, and the average in some mines was considerably lower than this. At the present time, there are no standards for the degree of air movement necessary in mine workplaces for the removal of noxious gases and dusts, nor is it possible to make specific recommendations in a general study of this type. As has been previously stated, the amount of ventilation necessary will vary under different conditions, and should be determined by a competent ventilation engineer for each working place in each mine.

Effective temperatures[5] both above and below the comfort range of men performing hard work were observed (31).

Low effective temperatures can be compensated for by the use of additional clothing. High effective temperatures can be decreased by reducing the relative humidity of the air or increasing its velocity. Usually the last procedure is the most practicable.

Usually where it was impossible to reduce the effective temperatures to comfort limits, it was noted that men were allowed frequent rest periods in cooler or better ventilated locations, and that salt tablets were used to prevent excessive reduction in the water-salt balance of the body with the resulting heat cramps.

Where wide differences exist between inside and outside temperatures, and men are moved quickly through shafts or adits, the rapid

[5] Effective temperature may be defined as that temperature of saturated air which, moving at a velocity of 15 to 25 feet per minute would produce the same sensation of warmth or cold as that produced by the combination of temperature, humidity, and air motion under observation.

temperature change may have a severe effect on the worker. When the shaft or haulageway is also used as a ventilation way, and the direction of travel is opposed to the normal direction of air motion, the worker may be severely chilled in transit, even though protected by heavy clothing. This practice offers another reason for the use of enclosed man cars, which from the safety viewpoint are always preferable.

At all mines studied, modern change houses with showers and clothing drying racks or "dryers" were provided.

ILLUMINATION

Adequate industrial illumination is advisable not only as a means of lessening eyestrain and saving sight, but also because it increases working efficiency and decreases the accident rates from such causes as falls, moving machinery, etc. The lighting of mines presents special problems. Permanent installations of incandescent lights at all shaft stations and in all hoisting rooms are required by Utah State law. The lighting at the working surfaces is by either carbide or electric lamps worn on the cap. The average intensity of illumination at shaft stations was approximately 10-foot candles, with a variation from 5- to 30-foot candles. The light from carbide lamps gave an illumination varying from less than 1 to a maximum of about 2.5-foot candles at a distance of 3 feet, while electric cap lamps gave an illumination of from 7- to 14-foot candles at the same distance. These variations were caused by differences in reflecting power of different ores, and by the condition of the lamps.

There are no standards for the illumination of working faces in mines, although every possible means should be used to keep above the minimum level of 3-foot candles recommended in the Code of Lighting of Factories, Mills, and Workplaces (32) drawn up by the Illuminating Engineering Society and approved by the American Standards Association.

In most instances better illumination and less eyestrain results from the use of electric cap lamps than from carbide lamps. It is also obvious that the use of electric lamps decreases the fire hazard in timbered mines. However, it has been necessary for the Utah State Mine Inspector to restrict their use to mines having a fan system of general ventilation, since atmospheres deficient in oxygen may occur in most Utah mines. If carbon monoxide is not present, a man may retain consciousness for several minutes in an atmosphere containing insufficient oxygen to support an acetylene flame. The failure of a flame cap lamp may serve as sufficient warning to enable the miner to return to a safe place, while a miner using an electric lamp might continue into bad air until he lost consciousness. However, this is not a condemnation of the electric cap lamp, but it is an indication that mechanical ventilation should be required in these mines. At best, the acetylene cap lamp is a poor index of oxygen deficiency since it requires only slightly more oxygen to remain ignited than a man needs to retain consciousness. Moreover, the acetylene cap lamp will not show the presence of carbon monoxide gas. In naturally ventilated mines, where oxygen deficiencies are known to exist, the combined use of electric cap lamps and mine safety lamps, as used in coal mines, should be considered.

ATMOSPHERIC DUST

As previously indicated, the principal factors to be considered in evaluating the hazard of dust inhalation are the nature and concentration of the dust in question, and the duration of exposure. The duration of exposure was determined from a comprehensive occupational history of each worker. It is now fairly well established that nearly all atmospheric industrial dust is of a size capable of gaining ready access to the lung tissue. However, a limited number of dust particles, collected from the air of metal mines, were measured to show that these dusts were present in the expected size ranges. The following section of the report on working environment presents the results of a study of the nature, size, and concentration of the dust associated with the various occupations involved in the mining of lead-zinc-copper-silver ores.

SILICEOUS CONTENT OF DUST

Sixteen samples of dust settled out at the breathing level in different working places, or collected in atmospheric dust collectors, were obtained for the purpose of determining the silica content of the dust to which metal mine workers are exposed. These samples were supplemented by eight samples collected in concentrating plants and sampling mills of smelters processing Utah ores. Table 4 presents a summary of the sources of the samples obtained and of the results of the analyses.

TABLE 4.—*Silica content of dusts in 3 metal mines*

Location	Number of samples	Percent total silica			Percent free silica		
		Maximum	Minimum	Average	Maximum	Minimum	Average
Ore milling processes [1]	12	62.1	9.5	31.8	43.0	1.0	18.7
Mine airways	4	58.7	23.9	43.6	37.0	8.6	22.6
Mine development	4	99.0	24.1	57.9	99.0	2.0	41.3
Stoping (ore breaking)	4	75.7	32.3	54.4	45.0	1.0	23.4

[1] Eight of these samples were collected in ore sampling mills, bucking rooms, and crushing mills operated in conjunction with concentration mills or smelters.

Total silica values were determined by chemical analysis while the percentage of free silica (quartz) in each sample was determined by petrographic analysis. The methods of analysis are discussed in the section on laboratory procedures.

It may be seen from table 4 that the free silica content of the dusts to which the workers are exposed may vary from less than 1 percent to 99 percent. This is to be expected when we remember that the ore deposits may lie in quartzite, in siliceous limestone, or in carbonate limestone, and may vary from narrow veins of ore to large bedded deposits. In general, the more massive the ore deposit, the lower the free silica content of the dust will be. Since the same crew of miners may drive a development drift in quartzite, a development raise through ore and limestone, and then work out a stope in the ore deposit between the quartzite and limestone, it is impossible to attribute a definite average free silica content to the dust to which any individual worker is exposed during his working life.

It must also be remembered that the average silica content of the atmospheric dusts will vary in different mines.

The settled dust samples collected in ore milling processes showed a lower average free silica content (18.7 percent) than those collected in stopes (23.4 percent), while the samples collected in drift and crosscut headings showed the highest average content (41.3 percent). Drifts and crosscuts are frequently driven through the native rock while stopes always contain a high portion of ore. The ore and waste rock are separated in the stope, whenever this is possible, and the rock is left underground for filling. Since the rock usually contains a higher percentage of quartz than does the ore, the quartz content of the dust generated tends to decrease as the ore concentration progresses.

On the basis of these data, which are substantiated by previously published analyses of ore and rock from these areas, it appears that the average underground worker is exposed to atmospheric dusts containing between 20 and 40 percent free silica, but it is also obvious that any specific worker may have been exposed to atmospheric dust containing either a higher or lower percentage of free silica.

SIZE OF DUST

Particle-size determinations were made on four impinger samples representing the dust actually suspended in the atmosphere at the breathing level of the workers. The method of making these measurements has been described previously (5). The results of the measurements are summarized in table 5.

From table 5 and figure 7, in which the percentage of particles is shown by size groups, it may be seen that half the dust suspended in the different working places in the mines was less than 1 micron [6] in average diameter and 96 percent were less than 4 microns.[7]

TABLE 5.—*Summary of the size-frequency distribution of dust suspended in the air of 3 metal mines*

Description of sample	Number of particles measured	Median size (microns)	Percentage frequency of each particle-size group (in microns)											
			0 to 0.49	0.50 to 0.99	1.00 to 1.49	1.50 to 1.99	2.00 to 2.49	2.50 to 2.99	3.00 to 3.49	3.50 to 3.99	4.00 to 4.49	4.50 to 4.99	5.00 or more	Total
Development work: heading drift through rock	200	0.97	8.5	44.5	25.0	8.5	3.5	2.5	1.5	1.0	0	1.0	4.0	100.0
Skip dumping pocket at shaft collar	200	1.10	12.0	31.5	29.5	10.0	7.5	4.5	3.5	.5	0	0	1.0	100.0
Mucking in stope	200	.96	10.5	43.0	22.5	6.0	4.0	1.5	2.0	3.0	3.0	1.0	3.5	100.0
Haulageway	200	.80	19.5	51.5	16.5	4.0	4.0	2.0	0	1.0	.5	0	1.0	100.0
Total	800	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Average	-----	.94	12.6	42.7	23.4	7.3	4.7	2.4	1.7	1.4	.9	.5	2.4	100.0

The median [8] particle size was 0.94 micron. It is apparent, therefore, that the dust particles are of a size capable of gaining access to the lungs.

OCCUPATIONAL DUST CONCENTRATIONS

A summary of the results of the determinations of the dust exposure in each occupation is given in table 6. It is evident from the data in this table that the underground occupations of chute tenders, miners, muckers, timbermen, slushermen, and the surface occupations of buckers and railroad carloaders are the most important from the viewpoint of dust exposure. Moreover, those underground maintenance and service occupations which require work in active stopes may also result in comparatively high exposures.

There are a number of reasons why so many dust samples were taken in studying the exposure of miners and muckers: First, this group comprised 45 percent of all workers in metal mines; second, they were exposed, with two minor exceptions, to the highest dust concentrations; and, third, there were especially wide variations in the amount and composition of the dust found in these occupations, because of different mining methods and the different ores encountered.

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[6] One micron = 0.001 millimeters = 0.00004 inches.

[7] The impinger sampling method, the light-field counting technique, and the method used for determining particle size, give accurate results for the atmospheric dust particles having an average diameter greater than 0.5 micron. Below this limit the sampling efficiency of the impinger decreases rapidly with decreasing particle size, and the microscopic system used renders visible only a small portion of the smaller particles actually collected.

[8] The median is the middle term in an array, and may be strictly defined as a point on the abscissal scale of a frequency distribution with 50 percent of the items on either side.

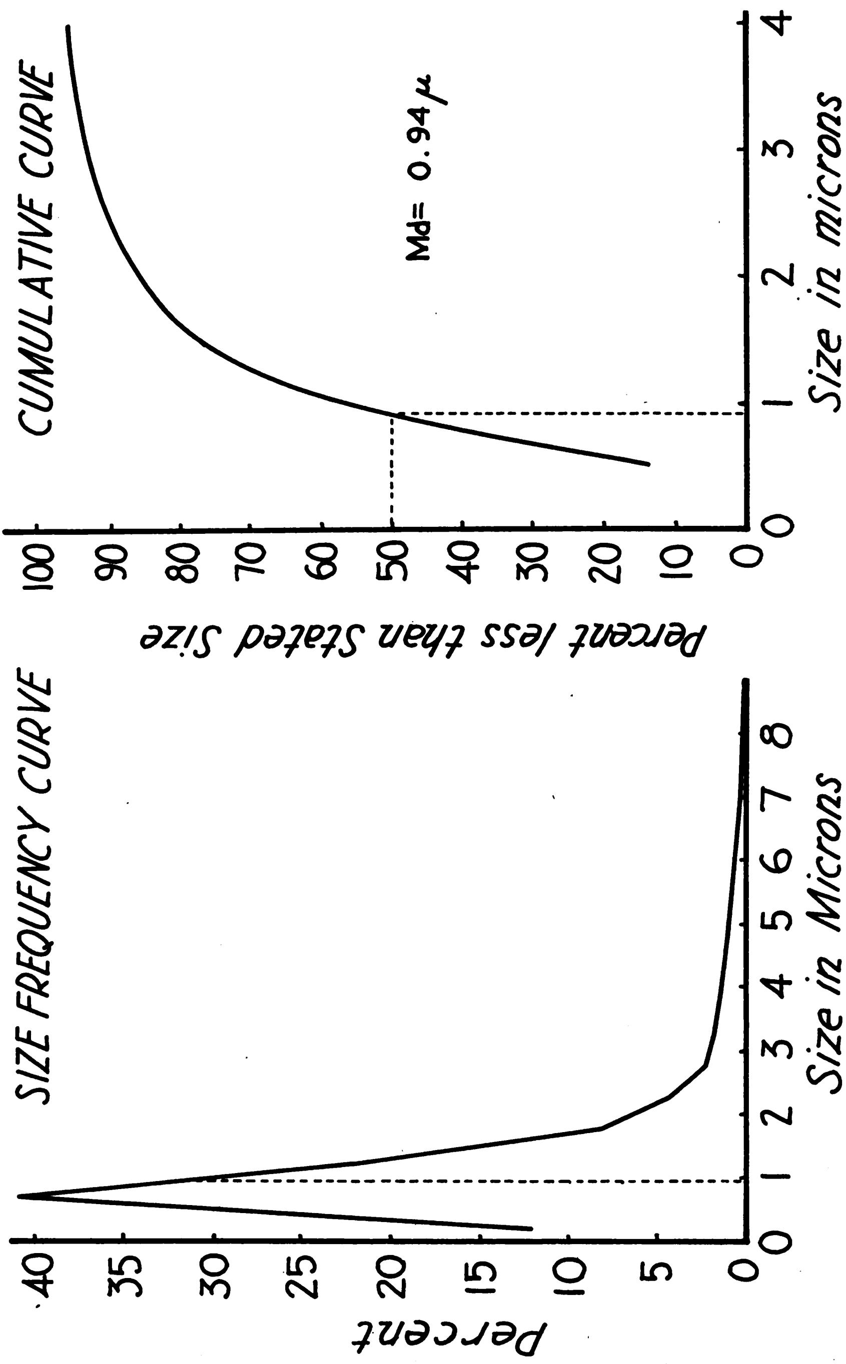

FIGURE 7.—PARTICLE SIZE DISTRIBUTION OF METAL MINE DUSTS.

TABLE 6.—*Summary of occupational dust exposure in 3 metal mines*

Section and occupation	Number of men employed	Number of samples taken	Number of millions of dust particles per cubic foot of air (weighted average)
Total, all occupations	830	(1)	----------
Office and general supervision:			
Superintendent, assistant superintendent, general foreman, manager, engineer, and geologist	19	[2] 20	4.0
Office worker	12	[2] 9	2.5
Face operations, underground:			
Foreman, mine boss, shift boss, level boss	21	17	10.5
Miner, driller, machine man	173	139 (combined)	23.1 (combined)
Mucker, hand miner, hand trammer	203		
Sampler	2	1	10.5
Transportation, underground:			
Mule skinner, horse tender, trammer	12	3	7.7
Motorman, motorman's helper	34	11	10.5
Hoistman, winze-hoistman	18	2	7.5
Hoistman, slusherman	19	7	18.2
Station tender, carman	6	[3] 6	3.8
Cager, cage rider	6	4	3.8
Nipper, tool nipper, material man and powderman	14	[4] 17	15.2
Bin tender, carloader, chute gate tender	2	4	37.5
Maintenance and construction underground:			
Timberman, tunnel maintenance man and shaftman	106	25	18.9
Sanitation man	5	7	7.7
Compressor man	2	1	7.5
All others	18	[4] 17	15.2
Transportation, surface:			
Hoistman	7	1	3.8
Top carman, topman	15	4	9.4
Tram motorman, tramway operator	13	3	6.0
Binman, ore handler, ore dumper	4	8	17.1
Truck driver, truck driver's helper, railroad car loader	9	[2] 9	2.5
Maintenance and construction, surface:			
Compressor man	6	1	3.8
Painter	3	[2] 9	2.5
Carpenter, timber framer, saw mill operator	14	1	5.5
Fireman, stationery engineer	3	[2] 9	2.5
All others	65	8	9.8
Milling operations:			
Concentrating mill foreman	----------	(5)	4.5
Dry crusher operator	----------	(5)	14.3
Flotation mill operator	----------	(5)	4.5
Concentrating mill repairman	----------	(5)	14.3
Assaying:			
Chemist, assayer	7	[6] 5	5.8
Bucker	4	4	57.9
Miscellaneous:			
Watchman, guard, janitor and warehouseman	8	[2] 9	2.5

[1] Samples were frequently representative of more than 1 activity, hence no total is given in this column.
[2] Includes 5 konimeter samples.
[3] Includes 2 konimeter samples.
[4] Includes 5 konimeter samples.
[5] All samples are from concentrating plants operated in conjunction with smelters.
[6] Includes 3 impinger samples from smelter assay office.

The occurrence of dust is expressed in terms of number of particles per cubic foot of air, which is the customary way of evaluating the hazard from a pneumoconiosis-producing dust. The metal content of these dusts is considered in later sections. However, it appears that if the dust concentrations in all working places are kept below the suggested minimum concentration which will produce silicosis, the hazard from dusts of toxic metals will also be eliminated; atmospheric gas contamination will be reduced, and the general quality of the mine air will be improved.

The sources of dust in metal mines are: (*a*) Sources of generation, such as drilling, blasting, ore breaking, mucking, dumping, or transferring, which are definable as to time and place of occurrence, and (*b*) the return of settled dust to the air by timbering, tramming, maintenance, and stray air currents. The sources contributing to the various occupational exposures were as follows:

Office and general supervision.—The exposures of workers in general supervisory and engineering capacities were received during the performance of their duties underground. An average exposure of 4.0 million particles per cubic foot was estimated for these occupations. Workers whose duties were mainly confined to office work had an average exposure of 2.5 million particles per cubic foot at the time of this study. This exposure is abnormally high—the average exposure of office workers usually being less than 1 million particles per cubic foot—but can be accounted for by the fact that this study was made during the dry summer season and the office air was contaminated by road and yard dust as well as dust from ore bins.

Face operations, underground.—Miners and muckers comprised the largest portion of this group, and were found to have an average exposure of 23.1 million particles per cubic foot. Most of the exposures of underground bosses and samplers were received during the time they were in active stopes and headings, but since a large portion of their time was spent in travel between different workings, their average exposure was only 10.5 million particles per cubic foot.

Wide variations were found between the amounts of dust created by different miners and muckers in performing their duties. These variations were due to several factors, including (*a*) differences in the ore and rock being worked, (*b*) differences in drilling and mucking practice, (*c*) the number of simultaneous operations being performed in a stope or heading, (*d*) the amount of fresh air being supplied to the working place, and (*e*) the quality of this air. These factors will be discussed in the section on control of the dust hazards.

Transportation, underground.—Bin or chute gate tenders had the highest average exposure in this section, 37.5 million particles per cubic foot, but this was a numerically unimportant occupational group. Any point where ore is dumped or transferred is a dust source which should be controlled.

The exposures of motormen and helpers were highest during loading under chutes or scraper loading stations. Another source contributing to their exposure was the frequent occurrence of drifts used both for tramming and returning vitiated air to upcast shafts. The exposure of mule skinners and horse trammers was slightly lower than that for motormen (7.7 and 10.5 million particles per cubic foot, respectively). Nippers and powdermen had an average exposure of

15.2 million particles per cubic foot, partly received in the stopes and partly while riding in empty mine cars.

Slushermen, or scraper loader operators, might be classed as face operators. Their high average exposure (18.2 million particles per cubic foot) was due to their locations above ore dumps or bins at the foot of inclined stopes where dry ore was handled.

The exposure in the other occupations in this group were not significantly high.

Maintenance and construction, underground.—Timbermen were found to have an average exposure of approximately 19 million particles per cubic foot. Timbermen are exposed to the dust generated during drilling and mucking, and also to previously settled dust thrown into the air while erecting and wedging timber.

Most of the other occupations in this section were grouped together and given an average exposure based on the mean of all samples representing these maintenance operations.

Transportation, surface.—The only occupations in this section having significantly high exposures were topmen and binmen. The workers in both these occupations were engaged in handling ore, either dumping it from ore cars to bins or operating chutes from bins to railroad cars, or both.

Maintenance and construction, surface.—While several of the occupations in this group had an average exposure of nearly 10 million particles per cubic foot, these were primarily shop exposures to dusts having a very low free silica content. The application of the average exposure for this group to individual cases must be made with extreme caution.

Milling operations.—The average exposures assigned to occupations in this group are based on the study of concentration mills operated in conjunction with smelters, since no concentration mills were being operated at the mines studied.

Assaying.—Workers in these occupations are subject to the exposures typical of a chemical laboratory, and also to considerable dust where ore samples are pulverized in dry grinders. Dust respirators were used in the bucking rooms studied, and both rooms were equipped with local exhaust systems. However, due to the high dust concentrations associated with these operations, it was obvious that the control systems were not efficient, so design data on these systems have not been included in this report.

METHODS OF MINIMIZING THE SILICA DUST HAZARD

The analysis of dust counts according to occupation suggests the lines along which attempts to minimize the dust hazard could be most effectively directed. These suggestions will be presented in the same order as was followed in the discussion of dust counts according to occupation, but will be given only for those occupations having significant dust exposures, or which are primary causes of air dustiness.

Face operations.—Previous studies by the United States Public Health Service (33) and the United States Bureau of Mines (34) have shown that drilling, mucking, and blasting are the most important primary sources of atmospheric dust contamination in mines. Utah metal mines are required to use hollow drill steel and wet methods in all drilling operations, and this practice has been in common use for at least 15 years. That this method of dust control has borne results is attested by the estimated average dust exposure of 23 million articles per cubic foot for miners and muckers. In a recent study of the health of pegmatite workers (35) it was shown that dry drilling caused an average dust concentration of 76 to 760 million particles per cubic foot, while wet drilling caused an average concentration of only 15.5 million particles per cubic foot. Blasting in Utah metal mines was not a primary source of dust exposure when all blasting was done at the end of the shift, and from 2 to 16 hours elapsed before the next shift entered the workings. However, where stopes or headings were poorly ventilated, the fine dust generated or dispersed by blasting settled close to the face and was redispersed by mucking or timbering operations, unless it was thoroughly wetted down. One mine made a policy of washing down the walls and roof upon entering a heading, and thoroughly soaking the muck pile with water before starting mucking and whenever, thereafter, that the muck appeared dry. Another mine had been sprinkling their muck piles for about 6 months. While wet drilling and sprinkling will not eliminate the dust problem, they will definitely decrease it, and the proper use of wet methods supplemented by adequate ventilation should reduce dust concentrations to safe limits. However, even with proper control measures, occasions will occur when high dust concentrations will be unavoidable for short periods. In these cases, a filter respirator of a type approved by the United States Bureau of Mines for use against silica and lead dust should be furnished the worker, and used by him. Respirators were furnished for this purpose by some operators, but it is doubtful if these respirators were of much value since the worker seldom had one with him when it was needed.

Recommendations for improving the ventilation in stopes and headings, if followed, should reduce the dustiness by dilution or by flushing the workings with air. Improved ventilation should be supplemented by better control of the dust at its source. The Bureau of Mines has shown that increasing the water flow through the drill steel of drills in common use in the United States to at least 1 gallon per minute, will reduce dust concentrations during drilling (36). They explain this as follows:

> In most pneumatic rock drills air passes through the drill steel with the water. Ordinarily some of the high-pressure air supplied to the drill for its operation escapes into the back end of the drill steel, even when the operating throttle is not in the blowing position, and travels up to the face of the hole being drilled. The amount of air escaping is affected by the water flow through the drill steel; as the water flow through the drill steel increases the air flow decreases. Mining officials in South Africa concluded that such air leakage, although probably facilitating removal by the water of the cuttings from the hole, was responsible for entrapping fine dust and blowing it into the air during drilling (37). Consequently they have devoted much attention to designing drills that permit the minimum practical air leakage through the drill steel and have established regulations on the use of such drills. Canada is also doing much work along this line, and recent reports state that such drills are practical and produce about one-fourth the dust concentration of corresponding drills without the "dustless-head" features (38).

While it makes very little difference to the practical operators whether reduction in dust concentration is caused by increased water flow or by decreased air leakage, they will be interested in knowing that they can reduce dust cencentrations, resulting from drilling, by increasing the water flow through the drill steel, either by increasing water pressure or by the use of water tubes of larger inside diameter.

Where water is scarce, and insufficient water is available for adequate dust control, the use of dust traps and local exhaust hoods should be permitted (39).

Transportation underground.—The high exposures of slusher operators and chute tenders were due to the handling of dry ore. These exposures can be controlled by thorough sprinkling of the ore, by location of chute tender's or slusher operator's stations on the fresh air side of the ore transfers, by the use of personal respiratory protective devices, or by a combination of these three methods. The exposures of motormen and mule skinners at transfer points can also be reduced by such measures. Their exposures should be further reduced by sprinkling both loaded and empty ore cars before transit, and by eliminating the dual use of drifts for haulage and return airways, as is done in coal mines.

Maintenance and construction, underground.—It is probable that proper ventilation, and a more general application of wet control methods to processes other than drilling, will decrease the dust exposures in these occupations, but respirators should be used on dusty jobs until such exposures are reduced.

Surface operations.—Bucking rooms should be provided with both local exhaust ventilation and general ventilation. Chemical analyses producing toxic dusts and gases should be performed under hoods.

Top trammers, bin tenders, and railroad carloaders should be provided with respirators unless their dust exposure can be decreased by use of water sprays or by mechanization of dumping and loading processes.

Ore concentrating plants.—The methods of controlling dust in ore concentrating plants are similar to those used in any occupation requiring the grinding, crushing, and screening of ore. Wet methods and local exhaust ventilation are the main means of securing such control, while personal respiratory protective devices should be used in the absence of the other control methods. A detailed discussion on the control of dust hazards in ore concentrating plants in the State of Utah will be found in a proposed publication dealing with the health of workers in the smelting industry.

A comparison of the dust control practices.—Table 7 summarizes the results obtained under poorly and well controlled working conditions in Utah metal mines. These are actual results of samples taken at various locations during the evaluation of occupational exposures. They are not comparable with the weighted average dust exposures shown in table 6, but are examples of maximum and minimum conditions in the occupations described. The control conditions were found in certain places in the mines studied and were by no means universal.

It is apparent that the dust hazard may be greatly lessened and in some instances adequately controlled by the extension of the control methods already employed in these mines.

TABLE 7.—*The effect of good and poor practice on the dust concentrations to which metal mine workers are exposed*

Operation	Dust concentration (million particles per cubic foot of air)		Remarks
	Good practice	Poor practice	
Hand mucking:			
Wet stope	2	10	Lower concentration due to thorough wetting of muck pile and good ventilation.
Dry stope	5	105	Lower concentration due to thorough wetting of muck pile and adequate supply of fresh, clean air.
Mechanical mucking	3	142	High concentration due to dry mucking and supply of air from active stope.
Drilling	6	43	Amount of water, state of repair of drill, and ventilation affect dust concentration.
Bucking		33–80	Local exhaust ventilation system as operated was insufficient. Respirator necessary.
General air supply	.7	6–10	Effect of spray collectors and settling chambers in decreasing dust concentration.

EVALUATION OF THE LEAD HAZARD

Attention has been called by previous investigators to the occurrence of cases of occupational lead poisoning in the metal mines of

Utah (40). Since all of the mines studied were producers of lead ore, and most of the ore extracted contained some lead compounds, the need for a study of atmospheric lead concentrations was apparent. However, since both the time and funds available for the study were limited, and since an extensive engineering investigation was not justified by evidence of existing cases of lead poisoning, the study of lead exposures was limited to analyses of drinking water samples collected from the mine water supplies, and the collection and analysis of 30 impinger samples and 4 precipitator samples of atmospheric dust at representative locations in the different metal mines. All but one of these samples were collected underground. One sample was collected at an obviously hazardous location in a machine shop. Other potentially hazardous surface occupations were considered comparable to similar occupations in concentrating mills, bucking rooms and ore docks operated in conjunction with Utah smelters, and the data from the study of environmental conditions in smelters were applied to them.

The atmospheric lead concentrations, shown by analysis of these samples, are presented in table 8.

TABLE 8.—*Atmospheric lead concentrations to which workers are exposed in 3 metal mines*

Operation	Number of samples	Lead exposure, in milligrams of lead per 10 cubic meters of air		
		Maximum	Minimum	Average
Face operations and skip loading	24	13.5	<0.1	3.7
Other underground operations	[1] 8	1.0	<.1	.2
Special surface operations [2]	1			6.5

[1] Includes 4 samples collected in main haulageways and air returns with electrostatic precipitator.
[2] Sample collected beside lathe operator using white lead cutting compound while machining threads.

The threshold value of atmospheric lead (lowest concentration causing lead poisoning), is approximately 1.5 milligrams of lead per 10 cubic meters of air (41). This threshold value is based primarily on studies of workers exposed to lead-oxide dusts. The toxicity of lead-sulfide dust is probably slightly lower than that of the more soluble oxides and carbonates (42).

Table 8 shows that the exposures of face workers and workers at skip loading averaged 3.7 milligrams of lead per 10 cubic meters of air, while the exposures of other underground workers were below the threshold value. No appreciable lead exposure was attributed to surface occupations similar to occupations in which it has been shown that the average lead exposure is less than 0.3 milligrams of lead per 10 cubic meters of air (43). Determinations of the nature of the lead compounds present in the atmospheric dusts were not made, but analyses of these concentration data on the basis of the principal type of lead ore being mined, presented in table 9, show that the average lead concentration was higher in carbonate and oxide stopes than in sulfide stopes.

TABLE 9.—*Variations in atmospheric lead concentration with respect to type of ore being mined and type of operation*

Type of ore and operation	Number of samples	Lead concentrations in milligrams per 10 cubic meters of air		
		Maximum	Minimum	Average
Sulfide ore:				
Face operations	16	9.3	<0.1	2.7
Skip loading	3	5.2	4.5	4.8
Oxide or carbonate ore: Face operations	6	13.5	<.1	6.1
General haulageways and shaft stations: Air entries	2	<.1	<.1	<.1
Air returns to surface	6	1.0	<.1	.3
Bucking rooms [1]		76.4	3.0	34.4
Ore crushing [1]		7.4	3.7	5.5

[1] Results are based on samples collected in bucking rooms and crushing mills operated in conjunction with concentration mills or smelters.

Wide variations in the percentage of lead in the ore are experienced, even within short distances in the same vein. In general, the grade of ore is lower than that mined in past years, and the ratio of oxide to sulfide ore being mined is steadily decreasing; both are factors which tend to diminish the potential lead hazard, but not to eliminate it.

Occupational lead poisoning will always be a potential hazard in lead mining, but in the Utah mines studied, this hazard should be slight if the siliceous dust problem is controlled. Wet drilling, adequate general and local ventilation, and strict personal hygiene, will keep the lead problem under control.

The water supplies of the mines studied all showed lead concentrations lower than the Public Health Service maximum tolerance of 0.1 part per million (44). There is some possibility of the ingestion of lead dust which has settled on lunches, common drinking cups, and water bags; but the use of metal lunch buckets and individual water bags with protective caps has minimized this hazard in some mines.

OTHER POTENTIALLY HAZARDOUS EXPOSURES

OTHER TOXIC METALS.

Spectrographic analyses of settled dust samples showed the presence of copper, silver, manganese, mercury, arsenic, antimony, and selenium in some, or all, samples, but analyses of atmospheric dust samples did not show that any of these metals were present in toxic quantities. In the absence of definite clinical signs of present or past intoxication from these metals, it seems probable that no poisoning will occur if the atmospheric contamination is kept at the low level which will result from adequate control of the silica and lead dust hazards. This statement applies only to the type of metal mines studied and would probably be untrue for mines producing commercial manganese or mercury ore where other factors would have to be considered.

NOXIOUS GASES.

Several detailed studies have been made of the noxious gases occurring in Utah metal mines. These studies have shown that the presence of toxic concentrations of these gases are indications of abnormal conditions, and that injury resulting from exposure to these concentrations is usually acute and accidental. However, the possibility of chronic effects from continued exposures to low concentrations of these gases must be considered.

Harrington and Denny (45) report that methane has been found in a number of metal mines and explosions have been caused by this gas. Some metal mine atmospheres contain appreciable amounts of highly explosive hydrogen. Carbon dioxide flows into the mines in some regions, while in other regions high temperature gases containing a mixture of gases of sulfur (SO_2, H_2S, SO_3), carbon dioxide and nitrogen have been found at the working faces. The hydrogen sulfide concentration may be in lethal proportions at blasting time in some high sulfide metal mines. Carbon monoxide constitutes a decidedly dangerous hazard in connection with metal mine blasting, because of heavy charges of dynamite employed, and the use of a fuse which, in burning, gives off this gas. All of the above gases, as well as volatile compounds of some toxic metals, may be produced in mine fires, by the slow oxidation of the ores, or by other chemical reactions.

The results of gas analyses are shown in table 10. These samples were supplemented by tests for carbon monoxide made with the carbon monoxide indicator (11), and for hydrogen sulfide with the lead acetate tube indicator (46). Significant concentrations of these gases were not found in the workings investigated, although the odor of hydrogen sulfide was noticed on several occasions, and the presence of dangerous concentrations in some worked out sections and drainage tunnels was known.

The normal or average percentage composition of the air is shown in the International Critical Tables to be 0.03 percent CO_2, 20.75 percent O_2, 77.08 percent N_2, 0.01 percent H_2, 0.93 percent Argon, and 1.2 percent water vapor, the last factor being extremely variable and causing proportional changes in the other constituents. The corresponding partial pressures, and percentages of dry volume at sea level, are shown in table 10. It will be noted that the percentage composition of the gas samples collected did not vary appreciably from these normal values, but that, since all mine workings were between 5,000 and 9,000 feet above sea level, the partial pressures were considerably less. In the absence of appreciable amounts of toxic gases, the most serious hazard is oxygen deficiency, especially in the presence of excess carbon dioxide. It is known that acclimitization to the lowered partial pressure of oxygen encountered at high altitude is accompanied by a decrease in alveolar carbon dioxide tension, but even in persons who have become so adapted, a sudden decrease in atmospheric oxygen pressure, an increase in carbon diox-

TABLE 10.—*Summary of analyses of mine air samples for gaseous composition in 3 metal mines*

Location	Number of samples	Barometric pressure (mg. Hg)	Results of gas analyses [1]						
			Partial pressures of component gases				Percent total dry volume		
			Carbon dioxide (mm. Hg)	Oxygen (mm. Hg)	Nitrogen (mm. Hg)[2]	Water vapor (mm. Hg)	Carbon dioxide (percent)	Oxygen (percent)	Nitrogen (percent)[2]
Normal air at sea level[3]		760	0.2	156.7	594.0	9.1	0.03	20.93	79.04
A. Results tabulated on an operational basis irrespective of mining area									
Development work:									
Average	7	617	1.7	122.7	477.5	15.1	.28	20.36	79.36
Maximum		648	5.7	128.8	500.0	28.0	.92	20.83	80.12
Minimum		555	.3	114.7	433.8	4.9	.05	18.96	79.02
Stoping:									
Average	8	611	3.3	119.3	475.5	12.9	.57	19.94	79.49
Maximum		652	12.3	133.5	510.8	29.3	2.12	20.75	80.01
Minimum		576	.4	103.2	452.7	7.4	.06	19.38	79.15
Haulageways:									
Average	5	632	1.2	127.1	488.6	15.2	.20	20.62	79.18
Maximum		649	3.4	132.0	504.0	21.8	.59	20.80	79.31
Minimum		578	.5	116.1	458.4	7.4	.11	20.10	79.12
Abandoned dead-end raise near junction with drift	1	633	4.2	105.9	506.0	16.5	.68	17.17	82.15
B. Results tabulated on basis of mining area irrespective of operation									
Mine 1:									
Average	8	585	3.3	115.9	459.3	6.9	.58	20.05	79.37
Maximum		652	12.3	113.5	510.8	7.4	2.12	20.83	80.01
Minimum		555	.4	103.2	433.8	4.9	.06	17.87	79.02
Mine 2:									
Average	4	627	4.1	116.0	492.3	15.0	.67	18.92	80.41
Maximum		633	5.7	120.8	506.0	16.5	.92	19.86	82.15
Minimum		621	3.1	105.9	483.3	12.4	.51	17.17	79.58
Mine 3:									
Average	9	645	.6	129.2	494.8	20.7	.10	20.76	79.21
Maximum		649	.9	132.0	504.0	29.3	.15	20.84	79.38
Minimum		637	.3	127.2	489.9	11.9	.05	20.57	79.11

[1] Methane, carbon monoxide, and hydrogen reported absent in all samples.
[2] Nitrogen content obtained by difference, value includes other inert gases.
[3] International Critical Tables.

ide pressure, or the presence of small amounts of carbon monoxide will cause a severe, or even fatal anoxemia.

Haldane (47) has shown that a man may advance for some distances into an atmosphere deficient in oxygen before he begins to be seriously affected; for the temporary increase in the breathing may at first prevent an appreciable fall in the alveolar oxygen pressure. When the breathing begins to quiet down again the effects of the atmosphere will develop fully and it may then be too late to turn.

Rosenau (48) states that the limit at which life may be sustained is about 26,000 feet (barometric pressure of the air is 251 millimeters and partial pressure of oxygen 52 millimeters, equivalent to 6.8 percent of the oxygen at sea level), but that dyspnea is common above 12,000 feet, and as the altitude increases, headache, muscular weakness, apathy, and psychic disorders occur. Twelve thousand feet altitude is equivalent to a normal barometric pressure of approximately 485 millimeters, and a partial oxygen pressure of 102 millimeters. It is the partial pressure which exerts physiological effects, and it will be noted that the pressure of oxygen in several of these samples had been reduced to nearly dangerous levels.

The United States Bureau of Mines (49) has reported the presence of rock-strata gases in the East Tintic mining district and has stated that fatalities from such rock gases have occurred in the Park City district and elsewhere (45). The present study confirmed the presence of these gases and showed that they were present in all mines studied, although seldom in serious amounts. Such gases were presumably formed by the absorption of oxygen by sulfide ores, or its conversion to carbon dioxide by oxidizing ore or decomposing timber. In the Tintic district the absence of rock-strata gases in large quantities, at the time of this study, was partly due to the use of mechanical ventilation, and partly due to the fact that this study was made in July, August, and September, when sudden barometric changes are unusual.

McElroy states (49):

> A study of individual inflows in the mines affected shows that the time and amount of gas inflow is determined by variations of barometric pressure * * * and that the inflows are caused by rapid and extreme decreases in pressure. Since such decreases are quite prevalent from November to April, and quite rare from May to September, gas inflows are also quite frequent during the winter months and happen rarely or not at all during the summer months.

Gases have been reported that contained more than 60 percent carbon dioxide, whereas other gases were almost pure nitrogen and so hot that they accumulated in raises. It is expected that air containing a high percentage of carbon dioxide will flow to the lowest level of a mine. It is the accepted theory that these heavy gases settle down through the porous and shattered quartzite and rest, presumably, on water at an unknown depth. A decrease in the barometric pressure causes an increase in volume of this large body of gas contained in the quartzite and as the body is confined on the sides and bottom, the increase in volume tends to raise the level of the gas.

Since field observations have shown heavy inflows only from shattered and fissured zones, it is concluded that the rate of penetration of gas into the porous quartzite is so much slower than the rate of increase in volume that the excess is pushed up through shattered zones and may rise to working levels where an inflow to mine openings results. As barometric pressure rises the increase in pressure causes a contraction of the gas body and the level of the gas in the shattered zones recedes.

A minor example of this type of inflow was given by two samples collected in a raise heading at 9:20 and 11:40 a. m., respectively. During this period the barometer fell from 652 to 576 millimeters, the carbon dioxide content of the air increased from 0.06 to 0.75 percent, the nitrogen content from 79.2 to 79.9 percent, and the oxygen content decreased from 20.8 percent to 19.4 percent. In another case air in a worked out area, as sampled through a bulkhead, showed 8 percent carbon dioxide and only 12 percent oxygen content.

The presence of blasting gases in metal mines must always be considered. The oxides of nitrogen and carbon monoxide are extremely hazardous. The occurrence and control of these gases have been investigated by Gardner (50). Control of this hazard embodies proper choice of an explosive, correct blasting technic, adequate ventilation, and use of water in spraying muck piles. Occurrence of "powder headaches" is prima facie evidence of insufficient control of blasting fumes.

SANITARY SURVEY

A sanitary survey made in the metal mines studied, and in the adjacent towns, showed the existence of conditions which may be detrimental to health.

The drinking water supply for the workmen in one of the mines, and for the residents of the camp adjacent to this mine, originates in an abandoned mine tunnel and in a diamond drill hole. This supply appears to be protected satisfactorily against contamination at the source, but slant-jet bubblers should be provided for mine workmen at drinking water stations, instead of hose bibs or open pipes which are now used. At another mine, all of the mine's water supply and some of the municipal supply comes from a bulkheaded mine drift. The remainder of the municipal supply comes from two mine tunnels and a spring. Consequently, while the mine's supply will require only protection against contamination at the inlet pipe, the municipal water supply will not be satisfactory until sterilization equipment has been installed. In this mine the workmen fill their individual canteens or jugs from a tap or from the bulkhead overflow.

At the third mine, shaft seepage is used for drinking water. One shaft is subject to contamination by dust-laden return air. Water is made available to the workmen at chilled water taps, where they also fill water bags with artificial ice and chilled water. These bags are carried into the workings where they become dirty with continued use. Each worker should have his own container and keep it clean. The source of contamination of the water supply should be discovered and eliminated. The water supply of the adjacent town should also be studied since occasional contamination has been reported.

Waste disposal in some mines and mining towns is unsatisfactory. The use of open flumes in mine tunnels for the deposition of human wastes permits the exposure of workmen and the pollution of streams. The use of chemical cans or boxes, with proper precautions for preventing odors and keeping all wastes covered, is more satisfactory. Full boxes are hoisted to the surface and dumped. Frequent emptying of such boxes, and the proper disposal of their contents are essential.

Municipal sewage disposal in metal mine camps consisted of either the use of septic tanks or the dumping of raw sewage into nearby streams. Improved methods of municipal waste disposal should be adopted.

Cases of dysentary and typhoid fever occurred recently in some of these camps.

Housing facilities seem overcrowded.

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SKIN IRRITANTS AND SOURCES OF INFECTION

Many of the materials handled in metal mining may be irritating to the skin. In most cases, the use of protective clothing and proper personal hygiene will eliminate the trouble from this source. The common policy of wearing work clothes continually until they are "worn out" is unhygienic. The provision of laundry facilities at the mines should be considered. Engineering data on skin irritants are necessarily limited and the reader is, therefore, referred to the medical section of this report, where it will be noted that the incidence of dermatoses in metal mine workers is low (p. 96).

The high humidities and absence of sunlight in underground workings make them theoretically ideal environments for the transmission of air-borne bacteria. Unfortunately, data on the transmission of bacteria in mines are not available, and fortunately, no crowding in working places occurs. However, due to these factors, and to the known susceptibility of silicotics to pulmonary infections, workers should not enter mines when suffering from an acute respiratory infection.

Infections transmitted by contact are a constant nuisance in mining camps. Athlete's foot, trench mouth or Vincent's angina, and other infections may be eliminated by proper hygienic methods.

HEALTH OF THE WORKERS

GENERAL PROCEDURE OF MEDICAL STUDY

OBJECTIVES

The purpose of the medical observations was (1) to ascertain the incidence of silicosis, lead poisoning, and other occupational diseases in metal mine workers in Utah; (2) to correlate the clinical findings with the environmental findings as determined by industrial hygiene engineers; (3) to appraise nonindustrial diseases or conditions of public health importance; and (4) to make recommendations for protecting and improving the health of these workers.

PROCEDURE OF MEDICAL EXAMINATIONS

Workers were examined from a metal mine of each of the three principal metal mining districts in Utah. An effort was made to examine every employed worker without selection. Those not included were either laid off temporarily, on vacation, ill, or were unwilling to be examined for various reasons. Their cooperation generally was excellent. In many cases the workers gave up their free time for the period of the examination.

Temporary medical examination facilities for observation of the metal mine workers were established in the local Union headquarters, in a local grade school, and in a mine company's dispensary. The operators supplied the necessary furniture, utilities, and heavy wiring installation for the X-ray equipment. Local officials of the International Union of Mine, Mill, and Smelter Workers delegated a committee to schedule examinations and urge the men to report for examination. The management assisted materially in some locations by permitting workers to be examined on company time.

About half of the metal mine workers presented themselves during off hours of the day or night shift, and the other half were examined during working hours. Three or more physicians and a dentist were present at all times, together with the laboratory staff.

As they came in for their medical examination, the men were assigned to the physician for physical examination, to the laboratory technicians for blood sampling, urinalysis, and X-ray, and to the dentist for dental examination, as expediency required. The complete examination usually required about one hour for each worker. As the worker entered the examining booth he was requested to strip to the waist, thus giving the physician ample opportunity while recording the history to observe abnormalities or defects and to form a tentative opinion of the general physical condition of the man who was later to be examined more thoroughly. A detailed chronological record was made of each man's employment from the time he began working to the present. This occupational history included, for each specific occupation and industry, the number of years worked, the number of days per week, exposure to occupational hazards, and the type of dust control measures, if any, employed. Care was taken to record the exact geographic location where each job had been performed, since this might be of value in determining the nature of past exposures. A typical history of occupations, past illnesses, and present illnesses or complaints is shown in figure 8. Names were not entered on these records in order to insure complete anonymity for all medical findings. It will be observed that the past medical history contains information concerning the exposure to and contraction of a number of common diseases and any sequelae resulting therefrom. Chronic complaints relating to the various systems such as respiratory and digestive, were also recorded together with injuries and operations. Symptoms and complaints present at the time of examination were noted under a history of present illness.

Following this, a physical examination was performed according to established practice. Beginning with the close inspection of the head and continuing with the neck, thorax, abdomen, and extremities, special attention was given to the examination of the respiratory and cardiovascular systems. Blood pressure was determined by the auscultory method with a mercury sphygmomanometer. Examination of the abdomen, genitalia, and anal region was omitted unless indicated by the history. A simple neurologic examination was done and a rough estimation of the psyche was recorded.

The laboratory procedure included taking a single X-ray film of the chest at 48 inches by a 30 milliampere mobile X-ray unit, and a fluoroscopic examination of the chest by one of the physicians. Most of the X-ray films were processed in the laboratories of the Division of Industrial Hygiene, National Institute of Health, at Bethesda, Maryland. The films were classified objectively by a group of physicians, and then final diagnoses were made, taking into consideration the X-ray and physical findings, case histories, and laboratory findings.

Among those in whom tuberculous lesions were suspected from the history and physical examination, sputum was collected and sent to the State Health Department for examination. Blood was drawn for examination for reticulocytes, hemoglobin (Newcomer), stippled cells, and a serodiagnostic test. The Kahn test for syphilis was performed routinely by the State Health Department and was checked

U. S. PUBLIC HEALTH SERVICE AND UTAH STATE METAL MINE STUDY

NO. 9999 PLANT A B C Company DATE August 6, 1939

~~NAME~~

AGE 54 AGE BEGAN WORK 15 YEARS WORKED 39

OCCUPATIONAL HISTORY

SPECIFIC OCCUPATION	INDUSTRY	No. yrs. in Metal mine	No. yrs. in Other dusty	No. yrs. in Non-dusty	WORK DAYS PER WEEK	CONTROL MEASURES (mask, wet drilling, local exhaust, kind of rock, etc.)
Pres. Timberman	Park City	7			5	Mining processes wet, no respirator
Prev. Miner	Eureka Stand	2			6	Wet, no respirator
"	Chief Consol.	5			7	" "
"	Eureka Bingham	6			7	" "
"	Eureka-U.S.	2			7	" "
Policeman				2		
Nipper	Silver King	2				Dry- no respirator
Shaftman		2				" "
Prospector	Cu, Au, + Ag mines	11				Wet and Dry: Nevada + Arizona
Total		37		2		

PAST MEDICAL: (Insert date, severity, and sequelae)

TUBERCULOSIS CONTACT

TUBERCULOSIS

PNEUMONIA

INFLUENZA

PLEURISY (dry - wet) Periodically 1910-1920: mild, longest duration 1 week 1919: No sequelae

BRONCHITIS

DISABLING COLDS Severe 1938-1 week duration - no sequelae

LOSS OF WEIGHT PAST YEAR 6 lbs. in past year

HEART DISORDERS

DIGESTIVE DISTURBANCES Epigastric distress, 1924 to 1939: 3 hours after meals-relieved by food or medication

LEAD POISONING Moderately severe, 1930. Duration 2 mo.: No sequelae

V. D.

OTHER 1904: Skull fracture - no sequelae

PRESENT ILLNESS OR COMPLAINTS: (Indicate severity and duration)

FREQUENT COUGH PRODUCTIVE (amt.) ʒ ss: 10 years

HEMOPTYSIS NIGHT SWEATS

DYSPNEA Slight, 2 years ASTHMA

CHEST PAIN WEAKNESS

NAUSEA VOMITING

CONSTIPATION COLIC

METALLIC TASTE HEADACHE

NEURITIS CHILLS

ARTHRITIS SKIN

OTHER Hay fever, past 7 years (Russian thistle + Rag weed)

FIGURE 8. TYPICAL HISTORY OF OCCUPATIONS, PAST ILLNESSES, AND PRESENT COMPLAINTS.

by other standard procedures when positive or doubtful results were obtained. Urine was collected and examined by the sulfosalicylic acid method for albumin, and the Benedict qualitative test for sugar. If albumin was present, specimens were centrifuged and examined microscopically for casts, and for red and white blood cells. In addition, 250-cc. specimens were obtained for spectrographic analysis.

After determining the average dust concentrations for each occupation in these industries, the engineers were able to assign a single average weighted dust exposure value to each worker, based upon his occupational history, (5) for the purpose of correlating the results of the engineering study of the environment with the medical study of the possibly harmful effects of the environment on the worker's health.

The physiological effects of the various dusts to which workers were exposed were studied upon experimental animals by the intraperitoneal injection method of Miller and Sayers, as described on page 98.

CHARACTERISTICS OF THE METAL MINING POPULATION

COMPARISON WITH CENSUS DATA.

In the medical study, 783 male metal mine workers were examined. They represented about 90 percent of all the persons then employed in three metal mines located in the State of Utah.

Data from the 1930 census by age are available, for operatives only, in copper, gold, silver, lead and zinc mines. Persons with duties of a clerical, technical or managerial nature are not included in the totals for these mines, which consequently do not agree with figures given elsewhere in this report.

As shown in table 11 the known age distribution of metal mine operatives in the State of Utah compares rather closely with the age distribution of all workers in this study. For example, under 35 years of age there are 53.4 percent in the present study and 52.4 percent in the entire state; 35 to 44 years there are 24.1 and 24.8 percent, respectively; and 45 years and over there are 22.5 and 22.8 percent. At the extremes of the age distribution there is a slightly larger proportion in the State of Utah group. When metal mine operatives in the United States are compared with the present study there is a smaller percentage under 35 years of age, about the same percentage in the middle age group, and a greater percentage in the older age group.

TABLE 11.—*Number and percent of metal mine workers according to age for the United States, the State of Utah, and this study*

Age in years	Number			Percent		
	United States [1]	Utah [2]	This study [3]	United States	Utah	This study
All known ages	65,197	3,379	783	100.0	100.0	100.0
Under 25	11,554	768	83	17.7	22.7	10.6
25 to 34	16,770	1,005	335	25.7	29.7	42.8
35 to 44	15,951	837	189	24.5	24.8	24.1
45 to 54	11,920	513	122	18.3	15.2	15.6
55 and over	9,002	256	54	13.8	7.6	6.9

[1] 15th Census of the United States (1930), Population vol. V, pp. 118-119.
[2] 15th Census of the United States (1930), Population vol. IV, p. 1626.
[3] Includes 56 workers with mixed dust exposure.

NOTE.—U. S. Census figures include copper mine operatives, gold and silver mine operatives, lead and zinc mine operatives.

Information concerning the racial distribution of workers in the mines studied is not available, but it is the opinion of the examining physicians that the proportion of persons other than native or foreign-born white is low.

WORKERS WITH EXPERIENCE IN OTHER DUSTY TRADES.

A group of 56 persons who were working in metal mines at the time of the study had previously worked more than 2 years in some other dusty trade. These are therefore excluded from all the following tabulations because of the possibility that their physical condition might be affected by their nonmetal mine experience. Work in some other nondusty occupation, no matter for how many years, was not a cause for exclusion. Among these 56 metal mine workers 23 had also worked in coal mines, 24 had worked in smelters, 4 had worked in both industries, and 5 had worked at other dusty jobs such as stone cutting, pottery manufacture, and quartz mining. These persons were older than the average for industrial workers, only 28.6 percent being under 35 years of age. Because of their older age and varied experience with respect to dust, it is not surprising that the percent with silicosis is high. Among this whole group 25.0 percent had silicosis, while for those 45 years of age and over the percentage was 40.7. All but 1 of these 14 persons with silicosis were 43 years of age or over. Only 2 had less than 9 years' experience in metal mines, and 6 had 20 or more years' experience.

The 6 persons with mixed dust exposure who had second stage silicosis had the following experience: A 43-year-old man with possibly active, moderately advanced tuberculosis had worked 2 years as a metal miner and 3 years as a laborer in the construction of Boulder Dam; a 43-year-old man had worked 24 years as a metal miner, 3 years as a coal miner, and 1 year as a quartz miner; a 47-year-old man with active, moderately advanced reinfection tuberculosis had worked 19 years as a metal miner and 5 years in a coal mine; a 47-year-old man had worked 29 years as a metal miner and 3 years in a smelter; a 54-year-old man with quiescent, moderately advanced reinfection tuberculosis had worked 28 years as a metal miner and 13 years as a coal miner, part of the time in France; and a 56-year-old man with quiescent, moderately advanced reinfection tuberculosis had worked 30 years as a metal miner, and 6 years as a coal miner in England. In most of the above cases the metal mine experience would appear to have been the predominating influence in bringing about silicosis.

AGE DISTRIBUTION.

An age distribution of the remaining 727 metal mine workers by 5-year intervals is presented in table 12. The proportion of workers under 35 years of age is nearly the same for this study as for the study of pottery workers made by the United States Public Health Service (51). The former showed 55.9 percent, whereas the latter showed 55.3 percent. However, the pottery study showed more persons 50 years and older; 14.7 percent, as compared with 12.0 percent for metal mine workers. Of the studies made in recent years by the United States Public Health Service, workers in the following industries showed an average age greater than for metal mines: anthracite coal mines (33), pottery (51), iron and steel, granite cutting, fur cutting, post office, and foundry (52). Workers in the following industries showed a lower average age: glass, gas, cigar, cement, rubber, and asbestos textile (52).

TABLE 12.—*Number and percent of metal mine workers, according to age*

Age in years	Workers		Age in years	Workers	
	Number	*Percent*		*Number*	*Percent*
All ages	727	100.0	45 to 49	61	8.4
15 to 19	3	0.4	50 to 54	43	5.9
20 to 24	80	11.0	55 to 59	27	3.7
25 to 29	169	23.3	60 to 64	17	2.3
30 to 34	154	21.2	65 and over	1	.1
35 to 39	98	13.5			
40 to 44	74	10.2	Average age	36.0	

LENGTH OF EMPLOYMENT.

The average number of years employed in the Utah metal mines was 11.1, whereas in a study of Utah coal mines (53) it was 14.1. Since the average age in these two industries was nearly the same, the shorter length of employment for metal mine workers indicates that these workers did not enter their present industry at as early an age as did the coal mine workers. From an examination of the work histories it would appear that a considerable group of metal mine workers spent a portion of their adult working life in agriculture before engaging in industrial employment. The percentage of workers with 10 years or more of employment was 45.8 for metal mine workers, which is nearly the same as for the 10,000 industrial workers (54) who had 45.3 percent in this group. A larger proportion of the workers with 10 years or more of employment was found among pottery workers (51), 50.1 percent, Utah coal mine workers (53), 58.7 percent, and anthracite coal miners (33), 72.4 percent.

DIAGNOSIS AND SYMPTOMATOLOGY OF SILICOSIS

Earlier investigations, both in this country and abroad, have shown that the outstanding occupational disease occurring among workers in dusty trades is silicosis (55) (56). Inhalation of silicious dust almost invariably results in silicosis if a certain combination of circumstances has prevailed during the working experience of a miner or workers in other dusty occupations. Among these circumstances are that the dust be of respirable size, that it be present in the atmosphere at the breathing level in concentrations exceeding five million particles per cubic foot on the average, that it be inhaled for a number of years, and that it contain silica in a free state, such as quartz. If respirable dust of very high quartz content is inhaled in high concentrations, the disease develops and causes disability in a shorter period of time than if the quartz content and atmospheric dust concentrations are low.

As silicosis was the principal occupational disease found in the examination of 783 metal mine workers, the following general discussion will be of interest. These cases resemble in many respects those found by the Public Health Service in previous studies of anthracite miners (33), pottery workers (51), and pegmatite miners (35). The relationship between X-ray and other clinical findings is shown later.

Silicosis has been defined by the Committee on Pneumoconiosis of the American Public Health Association (57) as "a disease due to breathing air containing silica (SiO_2), characterized anatomically by generalized fibrotic changes and the development of miliary nodulation in both lungs, and clinically by shortness of breath, decreased chest expansion, lessened capacity for work, absence of fever, increased susceptibility to tuberculosis (some or all of which symptoms may be present), and by characteristic X-ray findings."

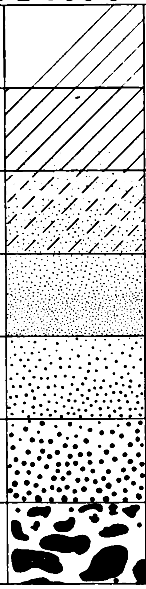
A diagnosis of silicosis was based upon three factors:

1. Characteristic lung-field markings as shown by a satisfactory X-ray film of the chest.
2. Symptoms and physical findings which support the X-ray findings and exclude other diseases as being the cause of these X-ray changes.
3. An occupational history which reveals prolonged exposures to dust containing silica.

X-RAY EXAMINATIONS (LUNG-FIELD MARKINGS)

The foundation for a diagnosis of silicosis is a characteristic appearance in the lung-field markings of an X-ray film. A system developed in other recent investigations of the Public Health Service (33) (35) (51) is shown in figure 9, which describes diagrammatically the sequence of bilateral changes in the appearance of the lung-fields from a healthy chest to advanced silicosis, indicating increasing degrees of pulmonary fibrosis. The **linear phases** are characterized by the dominance of the peribronchial or linear pulmonic

SCHEME REPRESENTING THE SEQUENCE OF LUNG-FIELD MARKINGS IN A TYPICAL CASE OF UNCOMPLICATED SILICOSIS



LINEAR	NORMAL LUNG MARKINGS & 1ST DEGREE EXAGGERATION OF LINEAR PULMONIC MARKINGS.	This is the range of markings usually seen on X-ray examination of persons who have never worked in a dusty trade.
	2ND DEGREE EXAGGERATION OF LINEAR PULMONIC MARKINGS, WITH OR WITHOUT BEADING.	
GRANULAR	1ST DEGREE DIFFUSE GROUND GLASS OR GRAINY APPEARANCE, NOT OBLITERATING LINEAR MARKINGS.	These are the earliest markings in the sequence of dust-induced changes which can be clearly differentiated from the changes that usually accompany advancing age, bronchitis, cardiac stasis, etc. Fine discrete nodules stereoscopically and pathologically.
	2ND DEGREE DIFFUSE GROUND GLASS OR GRAINY APPEARANCE, OBLITERATING LINEAR MARKINGS.	
NODULAR	1ST DEGREE DISSEMINATED NODULES UP TO SIZE OF MILIARY TUBERCLES.	Films showing granular or nodular markings are consistent with stage I or stage II silicosis depending on history, signs, and symptoms.
	2ND DEGREE DISSEMINATED NODULES EXCEEDING 1 MM IN SIZE, EMPHYSEMA PRESENT, USUALLY.	
COALESCENT NODULES AND CONGLOMERATE SHADOWS (EMPHYSEMA ALWAYS PRESENT)		Consistent with stage II or stage III silicosis depending on history, signs, symptoms, and disability.

FIGURE 9.—SCHEME SHOWING THE SEQUENCE OF X-RAY MARKINGS IN THE COURSE OF AN UNCOMPLICATED CASE OF SILICOSIS.

markings. Little or no exaggeration of these markings is normally found in healthy young adults, but they may become exaggerated normally in older persons due to such factors as arteriosclerosis, repeated bronchial infection, excessive smoking, exposure to irritating gases, and pulmonary congestion often associated with heart diseases. Beading is often associated with these **second-degree** exaggerated linear markings. Such increased markings are also part of the sequence of dust-induced changes as shown in figure 9, but may not be altogether attributable to such exposure. The second-degree linear change is comparable to the classification more fibrosis than usual or commencing generalized fibrosis used by earlier investigators (58).

With increasing dust exposure, the lung fields assume a diffuse **granular** or stippled appearance, often called **ground glass,** which indicates the formation of the minute nodules characteristic of silicosis in the parenchyma of the lungs. Although diffusely disseminated, this granular appearance is more easily recognized in the middle thirds and infraclavicular regions, being rather indistinct in the bases and above the clavicles. The transition to the granular phase from the linear phase is gradual; when the film is distinctly granular but the linear markings still predominate, the film is classified as **first-degree granular.** This phase, if well established, is usually, but not always, consistent with a diagnosis of early silicosis. Many cases showing only this degree of change may be regarded as borderline silicosis. In other words, the changes designated as linear are within normal variations when not accompanied by recognized organic disease (59).

As the minute nodules increase in size the linear markings are gradually obscured, especially in the middle thirds. This disappearance of the linear markings due to the increasing stippled or granular shadows has been likened by Irvine (58) to the growth of leaves on a tree which gradually obscures the branches. Eventually the majority of the linear markings are obscured, but often heavy peribronchial markings are seen to persist, extending into the bases and sometimes the apices. This **second-degree granular** phase is characteristic of early silicosis.

As the nodules continue to increase in size they may be observed as discrete, separate nodules on the flat film. The change from the granular to the nodular phase is gradual but when many definite, discrete nodules can be identified the film is classed as **nodular.** These shadows, like the granular, are most easily observed in the middle thirds and infraclavicular regions. If the average size of the nodules tends to be 1 millimeter or less in size, the film is classified as **first-degree nodular;** if the nodules are predominantly larger than this, the film is classified as **second-degree nodular.** With increasing size of the nodules, radiolucency indicating emphysema is often observed in the bases. These distinctly nodular films present the classical picture of silicosis, provided it is shown that they are not attributable to pulmonary infection. There may be a tendency for the nodules to cluster in the outer zones of the infraclavicular regions and middle thirds of the lung fields.

During the nodular phase, nodules may appear to coalesce to form **conglomerate** shadows, which are usually bilateral, and appear frequently in the middle thirds and infraclavicular region, and less often in the bases. They may range in size from 6 millimeters to an area occupying the entirety of one or more lobes. These conglomerate areas often increase in size and density. Films classified in this phase are usually consistent with a diagnosis of well-advanced silicosis. Compensatory emphysema is generally present in the bases in this phase, and areas of vicarious emphysema may be observed throughout the lung fields, and frequently in the apices. Pneumothorax, a severe complication in silicosis, is rarely seen in employed workers.

Infection, tuberculous or otherwise, may complicate the findings in any phase of this sequence of changes as reported by a committee on the roentgenological appearances in silicosis and underlying pathological lesions (59). It is generally characterized by asymmetrical distribution of shadows, localized discrete densities or string-like shadows, a mottling lacking uniform density and distribution with ill-defined borders, and massive shadows of homogeneous density not of pleural origin.

Considerable care is necessary in the interpretation of massive shadows in advanced silicosis when tuberculosis or other infection is suspected. As stated in the report of this Committee (59):

> The differentiation between these **massive shadows** of infectious origin and the conglomerate shadows of far-advanced simple silicosis is difficult and not always possible. Repeated reexamination of the patient for evidence of change in the roentgenographic appearance of the lesion, penetration of the massive areas by overexposure to analyze its internal structure, the clinical behavior of the patient, and repeated bacteriological examination of the sputum may all be necessary to determine whether an active infection is present.

SYMPTOMS AND PHYSICAL FINDINGS

The symptoms and physical signs of cases of silicosis observed in this study are discussed in sections dealing with representative case histories and with relation to degrees of change of pulmonary fibrosis as shown by the lung-field markings on the X-ray film. These symptoms and signs are the same as found previously by the Public Health Service in studies of pottery workers (51), anthracite miners (33), pegmatite workers (35), granite cutters (55), and others. In this connection, it should be remembered that the workers are all employed and presumably in fairly good health.

According to the Report on Medical Control of the National Silicosis Conference (60), shortness of breath, cough, chest pain, hemoptysis, and such general complaints as weakness, loss of weight, digestive disturbances, night sweats, insomnia, dizziness, and edema of the extremities are common symptoms of complicated silicosis. Decreased chest expansion, prolonged expiration, and rales are frequently noted on physical examination. Fluoroscopic examination affords an opportunity for studying diaphragmatic movement. The presence of fibrosis is also usually noted by fluoroscopy but is, of course, shown in better detail by roentgenogram examination.

Infection may complicate the picture of silicosis at any time, usually being manifested by pleural pain, fever, night sweats, weight loss, anorexia, weakness, and a cough producing large amounts of sputum or blood-tinged sputum. All of these factors must be evaluated in estimating the degree of disability, if any, in connection with the diagnosis of silicosis.

DIAGNOSIS

In making a diagnosis of silicosis, or silicosis with superimposed infection, it is important from the administrative and medico-legal viewpoint to classify silicotic workers into groups indicating the degree of physical impairment or disability, based upon all available evidence, including symptoms, physical findings, X-ray changes, and laboratory tests. The group of physicians who classified these films later took all these factors into consideration in reaching a final diagnosis. For this purpose the cases observed were classified conveniently into three stages:

1. *First stage silicosis*.—Slight but definitely characteristic X-ray changes with little or no evidence of physical disability. This does not imply, however, that there is not a potential disability in the individual's lessened resistance to pulmonary infection and further harmful dust exposures, or possibly his ability to do unusually strenuous work.

2. *Second stage silicosis*.—Moderate to well-advanced X-ray changes with moderate disability.

3. *Third stage silicosis*.—Well-advanced X-ray changes and well established or total disability. In some instances these individuals are capable of doing light work although incapable of heavy manual labor.

In addition to the three stages of silicosis as defined above, many workers showed early dust-induced changes on their X-ray films, but not sufficiently so to justify a diagnosis of silicosis. These were classified as **borderline** cases. Their lung-field markings were usually in an early phase of the granular type, and the workers with those markings showed no symptoms or present evidence of disability. The diagnosis also included a statement as to whether there was evidence of tuberculous infection, either active or latent, or infections of other nature.

The differentiation of silicosis from miliary tuberculosis, chronic fibroid phthisis, cancer, and other conditions has been more fully discussed in the pottery bulletin (51) where references to the literature relative to this problem may be found.

SYMPTOMS AND SIGNS IN RELATION TO LUNG-FIELD MARKINGS AND SILICOSIS

PRESENT COMPLAINTS

With respect to silicosis, the symptoms of dyspnea, frequent cough, productive cough, chest pain, and weakness were complained of in the order listed. This is in general agreement with the symptomatology reported in investigations of a similar nature by the Public Health Service (33) (35), as well as those reported by other investigators (61) (62) (63).

It should be remembered that seldom have all of these symptoms occurred at a single time in any individual worker, but they have often appeared in two's and three's, and in combination with other less frequent complaints. As is to be expected, the occurrence of symptoms is highest in those workers having the most severe degree of lung involvement. The prevalence of the various symptoms in those with conglomerate lung-field markings is three to four times that of workers with no appreciable pulmonary fibrosis (linear 1 and 2).

Table 13 shows the occurrence of these five symptoms among persons with border-line silicosis, silicosis, and silicosis plus reinfection tuberculosis compared with persons not affected with silicosis. It will be observed that the percent of workers complaining of dyspnea and of frequent cough in the borderline group is more than double that of the nonaffected group. There is only a slightly greater percent of the silicotic group compared with the borderline group who made these complaints. On the other hand, complaints of productive cough and of weakness did not show a sharply increased occurrence until the worker was classified as a silicotic, and complaints of chest pain increased greatly only when reinfection tuberculosis was superimposed on silicosis.

There were other infrequently reported complaints which showed an excess among persons with silicosis and borderline silicosis. These included night sweats, asthma, and vomiting. Such complaints as nausea, constipation, colic, and skin diseases, however, showed no important difference between the groups affected with silicosis and those not affected.

The quartz or free silica content of dust in these metal mines is commonly between 20 and 40 percent (p. 40), which is about the same range as found for certain workers in other dusty trades (51)

(55) (35). It is therefore to be expected in these studies that the symptomatology and other medical findings will be comparable for workers with similar average dust exposures.

TABLE 13.—*Number and percent of metal mine workers classified on basis of diagnosis of silicosis and reinfection pulmonary tuberculosis, who complained of certain symptoms*

Symptoms	Total	Essentially negative		Borderline silicosis		Silicosis		Silicosis with reinfection tuberculosis	
Number of workers	727	619		42		57		9	
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Dyspnea	138	93	15.0	16	38.0	25	43.9	4	44.4
Frequent cough	142	100	16.2	15	35.7	22	38.6	5	55.6
Productive cough	114	82	13.2	8	19.0	21	36.8	3	33.3
Chest pain	56	43	6.9	4	9.5	7	12.3	2	22.2
Weakness	30	19	3.1	2	4.8	8	14.0	1	11.1

PAST MEDICAL HISTORY

Pleurisy, pneumonia, and bronchitis were reported almost twice as frequently by workers with advanced pulmonary fibrosis as shown by X-ray findings than by those showing first- and second-degree linear, or normal markings. Among the former group, pleurisy was reported by 32 percent, pneumonia by 29 percent, and bronchitis by 18 percent, while for the latter group the percentages were 22, 17, and 11, respectively. Respiratory conditions of this type have shown a similar percentage increase in recent investigations of other dusty trades, which suggests the possibility that such conditions may be interchangeably related with both cause and effect of fibrotic changes in the lung tissues.

Nearly one-half of all the workers questioned admitted a serious attack of influenza some time in the past. The percent was only slightly greater for the silicotic than for the nonaffected group. Disabling colds, digestive disturbances, and loss of weight (6 pounds or more) during the past year were reported more frequently by persons with silicosis. One hundred and two gave a past history of acute episodes of lead intoxication, as discussed on page 85.

PHYSICAL FINDINGS

As regards general appearance, these 727 metal miners were, for the most part, normal healthy men, but in thirty instances the examiners were impressed by their unhealthy or cachexic appearance. Nine of the 30 were affected with silicosis or borderline silicosis, of whom all but one had silicosis complicated by pulmonary infection. The remaining 21 showing cachexia were scattered among those not affected with silicosis, but affected with such conditions as cardiovascular disease, latent lead poisoning, hand infections, syphilis, and nontuberculous lung infections. As would be expected, most of the 30 were underweight.

Weight deviation.—The percent deviation of each worker's weight from the average for men of comparable height and age was calculated from data compiled by the Association of Life Insurance Medical Directors and the Actuarial Society of America (64). Arbitrarily, plus or minus (±) 5 percent deviation from this insurance average has been considered normal. As seen in table 14, those figures marked minus (−) represent the percent weight deviation below this "normal," whereas those marked plus (+) designate the percent of weight deviation above "normal." For comparison, similar data on 877 truck drivers (65) recently examined by the Public Health Service are shown in the right-hand column. It was observed that 43.9 percent of the men having first or second stage silicosis were underweight for age-height compared with 32.4 percent of the nonaffected group and 30.6 percent of 877 truck drivers.

TABLE 14.—*Distribution of percent weight deviations for metal mine workers, classified by diagnosis of silicosis, and for truck drivers*

Percent weight deviation	Percent of workers				
	All metal mine workers	Diagnosis of silicosis			Truck drivers
		First and second stage	Borderline	Nonaffected	
Number of workers	727	66	42	619	877
−25 to 34	0.6	4.5		0.2	0.3
−15 to 24	5.5	7.6		5.6	6.2
−5 to 14	27.1	31.8	26.2	26.6	24.1
±5	36.4	25.8	42.9	37.2	29.2
+5 to 14	20.8	21.2	19.0	20.8	22.1
+15 to 24	7.4	9.1	9.5	7.1	10.3
+25 to 34	1.4		2.4	1.5	4.4
+35 to 49	.4			.5	2.5
50 and over	.4			.5	.9
Average [1]	+.4	−1.8	+2.1	+.6	+4.6
Standard deviation	11.8	12.7	10.2	11.8	14.5

[1] Averages represent the percent the workers fell below or above the average for life insurance applicants of comparable age and height.

As a group, the silicotics fell 1.8 percent below, and the nonaffected 0.6 percent above, the average weight of life insurance applicants of comparable age and height. The group of borderline cases was heavier on the average than the first and second stage cases. However, when the borderline cases are compared with the nonaffected group, no important differences can be seen from inspection. When all metal mine workers are considered, they are found to have weights almost identical to those of life insurance applicants.

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Physical findings in relation to X-ray findings.—In table 15 are summarized the more important physical findings in relation to degree of pulmonary fibrosis as shown by X-ray findings. Abnormally shaped chests were rarely observed. In the 25 workers with barrel-shaped chests, the abnormality was nearly four times as frequent among workers with advanced pulmonary fibrosis as in the group with first- and second-degree linear markings. Abnormal breath sounds were observed in approximately one-fifth of the workers with relatively clear chests, and in slightly more than half of those showing positive changes in the chest on X-ray examination. Impaired or restricted diaphragmatic action, as observed on fluoroscopy, was noted in 23.8 percent of the normal workers, in 42.2 percent of workers with ground-glass markings, and in 65.8 percent with nodular and conglomerate markings. Change from normal percussion note, impaired chest mobility, dyspnea, curved or clubbed finger nails, and decreased chest expansion were other findings of importance for a diagnosis of silicosis. Nonpersistent rales, chest lag, pleural rubs, and retracted supra- and infra-clavicular fossae, while of assistance in the diagnosis of individual cases, did not show a high degree of correlation with the degree of lung involvement and are not shown in the table. The occurrence of a combination of these findings in individual workers is presented in selected case records (figs. 14, 15, and 16).

TABLE 15.—***Number and percent of metal mine workers classified according to degree of pulmonary fibrosis as shown by X-ray findings, who were found to have certain abnormalities on physical examination***

Physical finding	Percent of workers			Number of workers		
	First- and second-degree linear	Ground glass	Nodular and conglomerate	First- and second-degree linear	Ground-glass	Nodular and conglomerate
Number of workers examined				617	64	38
Average age				34.4	43.5	48.8
Abnormal breath sounds	19.8	42.2	71.1	122	27	27
Restricted movement diaphragm	23.8	42.2	65.8	147	27	25
Change from normal percussion note	8.8	26.6	44.7	54	17	17
Impaired chest mobility	3.2	17.2	10.5	20	11	4
Barrel-shaped chest	2.4	7.8	13.2	15	5	5
Dyspnea	5.2	14.1	21.1	32	9	8
Curved or clubbed fingernails	7.8	14.1	28.9	48	9	11
Chest expansion below 6 centimeters	18.5	31.2	26.3	114	20	10

It is apparent from these data that not only a smaller proportion of workers are affected with silicosis, but also less severely than has been found in certain other studies of metal mine workers, for example, in the tri-State district of Oklahoma, Kansas, and Missouri (63) and South Africa (66) investigations. Some of the factors relating to this are discussed in the following section.

INCIDENCE OF SILICOSIS

RELATION OF SILICOSIS TO DUST CONCENTRATION AND DURATION OF EMPLOYMENT

The incidence of silicosis among workers in the metal mines is related both to the length of their employment in that industry and to the average dust concentration to which they have presumably been exposed during all their working years in metal mines. The procedures employed in determining weighted average dust concentrations have been described in Public Health Bulletin No. 217 (5).

Table 16 and figure 10 show the result of grouping the 727 metal mine workers according to weighted average dust concentration in arbitrary intervals of 6 million particles per cubic foot of air. Each of these five groups is subdivided into three durations of employment in metal mines, namely, less than 10 years, 10 to 19 years, and 20 years and over. A total of 66 cases of silicosis was found on examination of these men. Forty-two were first stage and 24 second stage silicosis. No third stage cases were observed. Forty-two others were diagnosed as borderline silicosis.

TABLE 16.—*Number and percent of metal mine workers with silicosis according to years employed in metal mines and dust concentration*

Dust concentration, million particles per cubic foot		Total	Years employed in metal mines		
			Less than 10	10 to 19	20 and over
0–5.9	Number exposed	39	17	11	11
	Number with silicosis	0	0	0	0
	Percent with silicosis				
6.0–11.9	Number exposed	98	44	36	18
	Number with silicosis	3	0	1	2
	Percent with silicosis	3.1		2.8	11.1
12.0–17.9	Number exposed	115	51	43	21
	Number with silicosis	7	0	3	4
	Percent with silicosis	6.1		7.0	19.0
18.0–23.9	Number exposed	272	189	56	27
	Number with silicosis	22	1	11	10
	Percent with silicosis	8.1	0.5	19.6	37.0
24.0 and over	Number exposed	187	89	76	22
	Number with silicosis	32	3	14	15
	Percent with silicosis	17.1	3.4	18.4	68.2
All dust concentrations [1]	Number exposed	727	394	228	105
	Number with silicosis	66	4	30	32
	Percent with silicosis	9.1	1.0	13.2	30.5

[1] Includes 2 cases of silicosis among 16 workers with unknown dust concentration.

From the table it is observed that in concentrations of less than 6 million particles of dust there was no case of silicosis even for those working the longest period.[9] In dust concentrations of 6.0 to 11.9 million particles, three cases of silicosis were observed among persons who had worked 17, 20, and 24 years in metal mines. From an examination of the working experience of these persons it would appear likely that for certain periods during past years each had been exposed to very much higher concentrations of dust than indicated by an average representing his entire working history.

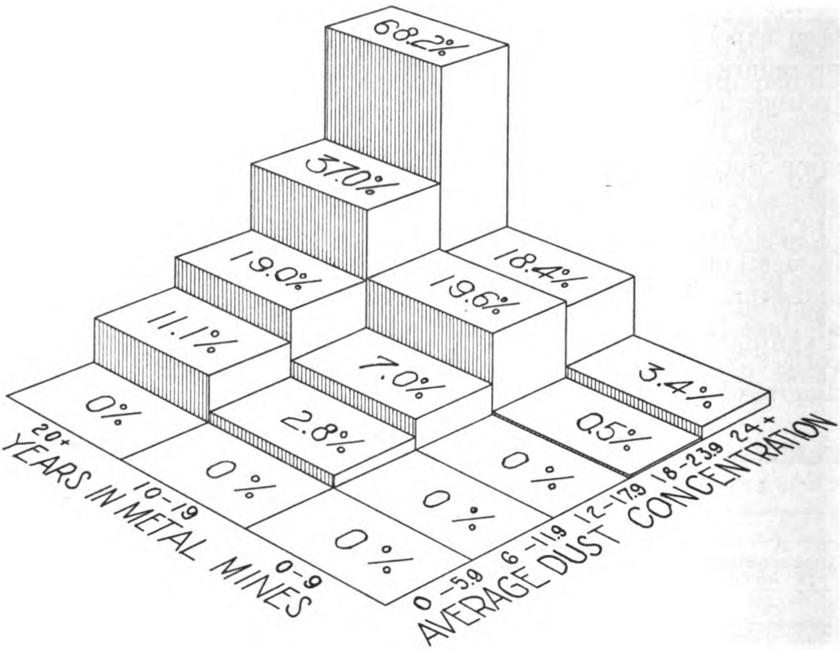


FIGURE 10.—RELATION OF AVERAGE DUST CONCENTRATION AND DURATION OF EMPLOYMENT IN THE METAL MINES TO THE PERCENTAGE OF WORKERS FOUND TO HAVE SILICOSIS (FIRST AND SECOND STAGE).

Among those employed for less than 10 years there was no case of silicosis in the first 3 dust concentration groups; there was one case in the 18.0 to 23.9 dust group; and there were 3 cases, or 3.4 percent, in the 24.0 million particles and over dust concentration group. In the 10- to 19-year employment group the percent affected rose from 2.8 in the 6.0 to 11.9 dust concentration group to 19.6 percent in the 18.0 to 23.9 dust group. Those with the longest employment, 20 years and over, showed a much larger proportion

[9] There were only 7 underground workers in this group, 2 of whom were face workers with one year's experience each.

affected in each dust group, reaching 68.2 percent among those having a weighted average dust exposure of 24.0 million particles and over. This tendency for silicosis incidence to increase, both with increasing length of employment and with increasing dust concentration, has been observed in other studies made by the U. S. Public Health Service in such dusty trades as anthracite coal mining (33), asbestos textile manufacture (52), pottery manufacture (51), and mica and pegmatite mining (35).

X-ray findings of silicosis cases.—The increasing severity of lung-field markings of silicotics with increasing years of employment in metal mines is shown in table 17. Ground-glass lung-field markings represent the maximum degree of involvement found in cases with less than 10 years of employment. Half of the cases with 10 to 14 years of employment show nodular markings, whereas conglomerate markings are not found until the 15- to 19-year duration group. Among persons with over 14 years of employment it will be noted that there is a steady decrease in the percentage of silicosis cases showing ground-glass markings and a corresponding increase in both the percentage showing nodular and the percentage showing conglomerate markings. The latter increases more rapidly with lengthening duration of employment, as has been shown in other studies of silicosis. In addition to the expected increase with duration of employment, another factor that probably played a part among the older workers was the practice of dry drilling until about 1924. Nevertheless, 14 cases of silicosis, 5 of them with nodular markings, were found among workers with less than 15 years' exposure. This fact, as well as the results of the engineering study, indicates that the control methods in present use are not sufficient to prevent silicosis, but if the dust concentration is kept below 10 million particles per cubic foot of air, it would appear that the silicosis hazard in these mines would be eliminated.

TABLE 17.—*Number and percent of first and second stage silicosis cases among metal mine workers with specified X-ray findings according to years employed in metal mines*

Years employed in metal mines	Number of workers				Percent of workers			
	Total	Ground-glass	Nodular	Conglomerate	Total	Ground-glass	Nodular	Conglomerate
Total	66	28	24	14	100	42.4	36.4	21.2
Under 5	0	0	0	0	----------	----------	----------	----------
5 to 9	4	4	0	0	100	100.0	----------	----------
10 to 14	10	5	5	0	100	50.0	50.0	----------
15 to 19	20	9	7	4	100	45.0	35.0	20.0
20 to 24	11	4	4	3	100	36.4	36.4	27.2
25 and over	21	6	8	7	100	28.6	38.1	33.3

Employment outside of Utah.—In the group of silicosis cases just described, there were 13 men who had worked in metal mines outside of Utah for more than 2 years at some time in the past. A portion of their dust exposure was obtained from this experience, although the exact amount cannot be ascertained. They also had considerable experience in Utah alone, only 1 for less than 10 years, and 8 for more than 20 years. On the other hand, only 2 had outside experience for more than 10 years. When the incidence of silicosis is computed for those working outside of Utah, the percent affected is found to be 31.7. Some of this excess in rate may be accounted for by the older age distribution of men who have worked both in Utah and outside. The percent of persons over 40 years of age in this group is 70.8 compared with 28.3 percent for those who had worked in Utah only. However, the percent affected in the 40–59-year age group was 37.9 percent and 20.5 percent, respectively, so there apparently still remains an excess of silicosis among those working outside. This may be due to less effective dust control methods, a greater proportion of free silica, or other factors.

SILICOSIS BY PRINCIPAL OCCUPATION

Any account of silicosis incidence in the metal mines is incomplete unless attention is directed to occupational differences. As shown in table 18, silicosis cases and borderline silicosis cases are concentrated in a few occupations while in many occupations no one is affected. It will be observed that there were only one silicosis case and five borderline cases found among the entire group of persons whose work experience has been principally above ground, milling operations excepted. This person with first stage silicosis had worked as a blacksmith for 23 years and during that time possibly had been exposed to free silica while sharpening miners' tools. Cases of silicosis are found in six different underground occupations, namely, face workers, mule skinners, powdermen, pipemen, shift bosses, and timbermen.

Table 19 shows the incidence of silicosis and borderline silicosis by years in metal mines for three broad occupational groups. The persons affected with silicosis represent 11.2 percent of the face workers (i. e., drillers, miners, and muckers), 7.0 percent of the other underground workers, and 0.9 percent of the surface workers. Only for face workers were there cases of silicosis among persons with less than 10 years in metal mines. For face workers and for other underground workers, the percent affected with silicosis was 22.1 and 10.3, respectively, among those who had worked 10 to 19 years; 55.0 percent and 23.1 percent among those in the 20- to 29-year group; and 62.5

percent and 25.0 percent in the 30 years and over group. When borderline silicosis is included, the percent affected rises to 33.6 for face workers and 15.4 for other underground workers in the group who had worked 10 to 19 years, and 75.0 percent and 38.5 percent in the group who had worked 20 to 29 years.

TABLE 18.—*Metal mine workers by principal occupation according to years employed in metal mines, and diagnosis of silicosis*

Principal occupation	Number employed				Number affected	
	Years employed in metal mines				Diagnosis of silicosis	
	Total	Under 10	10 to 19	20 and over	First and second stage	Borderline
Total	727	394	228	105	66	42
Underground workers	513	321	143	49	52	27
Face workers	385	253	104	28	43	21
Transportation workers:						
Motormen	20	18	2	0	0	0
Hoistmen	19	11	4	4	0	1
Mule skinners	11	4	4	3	1	0
Cagers	6	0	5	1	0	1
Other transportation workers	8	2	2	4	1	1
Maintenance workers:						
Timbermen	37	26	8	3	4	0
Pipemen and trackmen	6	2	4	0	1	1
Sanitation and ventilation men	5	1	3	1	0	1
Other maintenance workers	8	4	2	2	0	0
Supervisors and shift bosses	8	0	5	3	2	1
Surface workers	115	41	48	26	1	5
Superintendents and engineers	17	12	2	3	0	0
Blacksmiths	13	3	7	3	1	0
Clerks	11	2	7	2	0	0
Electricians	10	4	3	3	0	1
Carpenters	10	3	5	2	0	0
Laborers	8	3	5	0	0	0
Machinists and mechanics	8	0	4	4	0	0
Top car men	6	2	3	1	0	1
Hoistmen	5	0	1	4	0	1
Chemists	5	2	3	0	0	0
Truck drivers	5	4	1	0	0	0
Other surface workers	17	6	7	4	0	2
Milling operations	13	2	4	7	1	1
No principal occupation	86	30	33	23	12	9

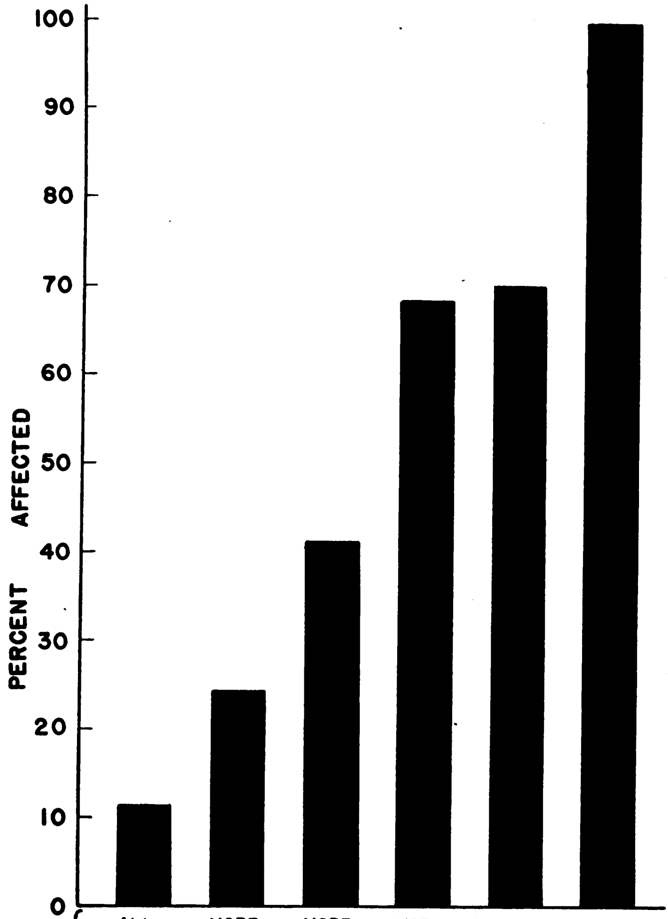
Since face workers, both proportionately and numerically, have the greatest problem of silicosis, this occupation will be examined in more detail. Of the 385 workers in this group, 88.2 percent were exposed to an average dust concentration of 20 million particles and over, compared with 24.8 percent for other underground workers and 4.3 percent for surface workers. Samples of dust collected at the face showed a free silica content of approximately 20 to 40 percent (p. 40). This should be remembered along with the fact that the average dust concentration for face workers was 23.6 million particles. As shown in figure 11, this combination of a heavy dust concentration and a high silica content resulted in a silicosis incidence which affected nearly a fourth of those who had worked in metal mines for over 6 years, and all 4 workers who had been employed for 34 years and more. The increase in the percent affected is especially great when those with over 13 years' employment are compared with those having over 6 years. Since the population exposed to risk is rather small for those working more than 20 years, not too much dependence should be placed on the percent affected for these particular groups, but the trend toward an increasingly serious problem is unmistakable. Whereas conglomerate lung-field markings were not present in any of those affected, when the duration of employment was less than 15 years, these markings indicating marked pulmonary fibrosis, were observed among 55 percent of those with experience of 20 to 29 years.

TABLE 19.—*Number and percent of metal mine workers with silicosis according to broad occupational group and years of employment*

Principal occupation and years in metal mines	Number exposed	Number affected — Silicosis: Total	Number affected — Silicosis: First and second stage	Number affected — Silicosis: Borderline	Percent affected — Silicosis: Total	Percent affected — Silicosis: First and second stage	Percent affected — Silicosis: Borderline
Total:							
Face workers	385	64	43	21	16.6	11.2	5.4
Other underground workers	128	15	9	6	11.7	7.0	4.7
Surface workers	115	6	1	5	5.2	.9	4.3
Under 10 years:							
Face workers	253	8	4	4	3.2	1.6	1.6
Other underground workers	68	1	0	1	1.5	0	1.5
Surface workers	41	0	0	0	0	0	0
10 to 19 years:							
Face workers	104	35	23	12	33.6	22.1	11.5
Other underground workers	39	6	4	2	15.4	10.3	5.1
Surface workers	48	5	0	5	10.4	0	10.4
20 to 29 years:							
Face workers	20	15	11	4	75.0	55.0	20.0
Other underground workers	13	5	3	2	38.5	23.1	15.4
Surface workers	18	0	0	0	0	0	0
30 years and over:							
Face workers	8	6	5	1	75.0	62.5	12.5
Other underground workers	8	3	2	1	37.5	25.0	12.5
Surface workers	8	1	1	0	12.5	12.5	0

Figure 12, in which the width of the bar is proportionate to the number exposed, emphasizes the importance of the group of face workers who have been employed 10 to 19 years in metal mines and shows an incidence of silicosis of 22.1 percent, and of silicosis and border-line silicosis combined of 33.6 percent. These account for 23 cases of silicosis compared with 16 cases for all longer durations.

The above data should be considered a minimum estimate of the actual incidence of silicosis produced by work at the face of the metal mines. Of the 23 cases with silicosis who were classified as

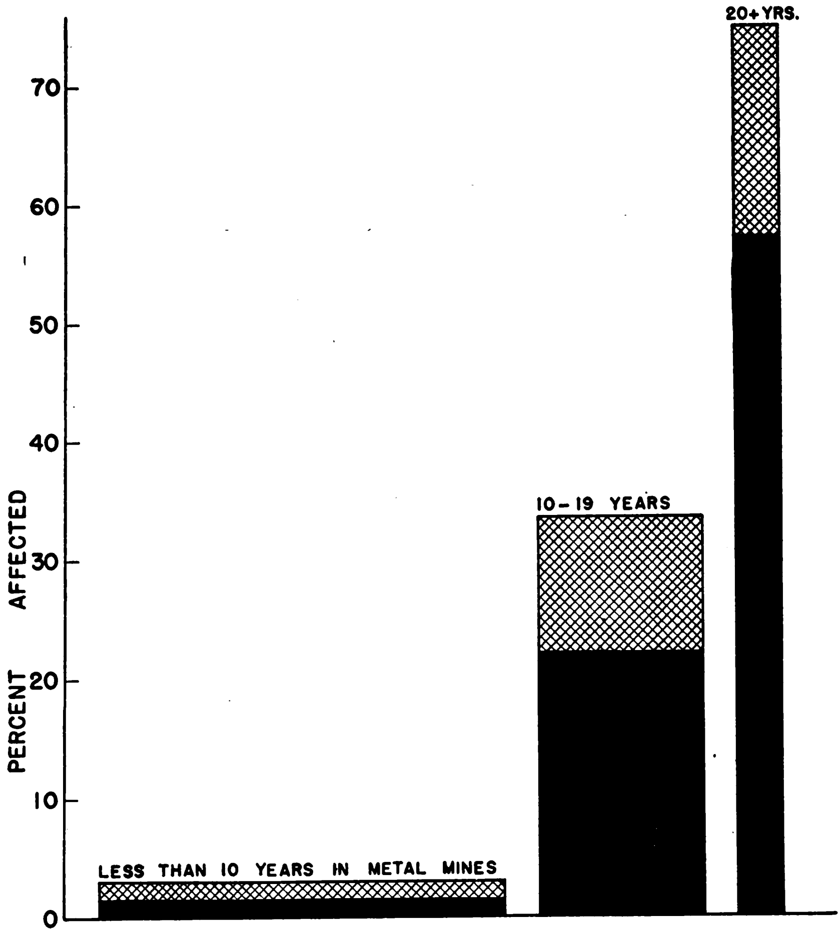


YEARS IN METAL MINES	ALL DURATIONS	MORE THAN 6 YEARS	MORE THAN 13 YEARS	MORE THAN 20 YEARS	MORE THAN 27 YEARS	MORE THAN 34 YEARS
NUMBER OF WORKERS	385	176	73	22	10	4
NUMBER WITH SILICOSIS	43	43	30	15	7	4
PERCENT AFFECTED	**11.2**	**24.4**	**41.1**	**68.2**	**70.0**	**100.0**

FIGURE 11.—PERCENTAGE OF FACE WORKERS FOUND TO HAVE FIRST AND SECOND STAGE SILICOSIS, CLASSIFIED BY DURATION OF EMPLOYMENT IN METAL MINES. (NUMBERS OF WORKERS ARE CUMULATED DOWNWARD.)

other than face workers, 78 percent had worked at the face at some time in the past, 5 for less than 5 years, 7 for 5 to 9 years, and 6 for 10 years and over. It is evident that many of these had a serious dust exposure while working at the face, although they might have spent many years at other and less dusty occupations.

There appears to be a tendency for persons affected with silicosis to be placed in jobs requiring less strenuous work. For example.



NUMBER OF WORKERS	253	104	28
NUMBER WITH SILICOSIS	4	23	16
PERCENT WITH SILICOSIS	1.6	22.1	57.1
NUMBER WITH BORDERLINE SILICOSIS	4	12	5
PERCENT WITH BORDERLINE SILICOSIS	1.6	11.5	17.9

SILICOSIS   BORDERLINE SILICOSIS

FIGURE 12.—PERCENTAGE OF FACE WORKERS FOUND TO HAVE SILICOSIS, CLASSIFIED BY DURATION OF EMPLOYMENT IN METAL MINES. (WIDTH OF BAR IS PROPORTIONATE TO THE TOTAL NUMBER OF WORKERS FOR THE GIVEN PERIODS.)

a tabulation of silicosis cases by present occupations shows a markedly different picture than for principal occupation. Instead of 43 cases classed as face workers, there are now 29, and instead of 1 surface worker there are now 11, showing that many former face workers have been transferred to the surface.

REPRESENTATIVE CASE HISTORIES

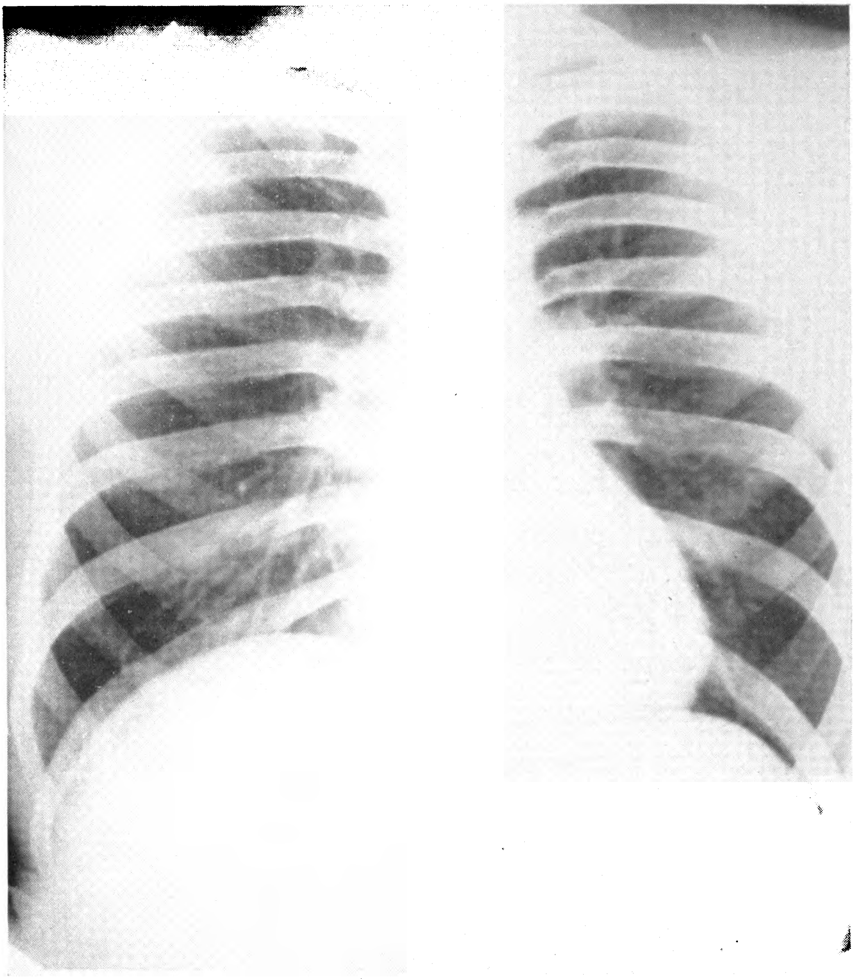


FIGURE 13.—NORMAL CHEST. WHITE MALE, AGE 29.

Occupational history.—Mine office clerk, 5 years; farming, 6 years.

Estimated dust exposure.—Three million particles per cubic foot (weighted average).

Past medical history.—Influenza, 1923; appendectomy, 1938.

Present complaints.—None.

Physical examination.—Robust appearance; height, 66 inches; weight, 142 pounds; chest expansion, 7 centimeters.

Fluoroscopy.—Apices clear, diaphragm regular, and no restriction in motion; hilar shadows of usual size and density.

Film.—Normal linear markings present in both lungs. Heart, negative.

Diagnosis.—Essentially negative.

Comment.—This roentgenogram has been reproduced for comparative purposes. It shows the type of lung-field markings observed in the chest of a normal young adult. With increasing age the linear pulmonic markings usually become accentuated, but do not show granular, nodular, or nodulo-conglomerate markings characteristic of silicosis.

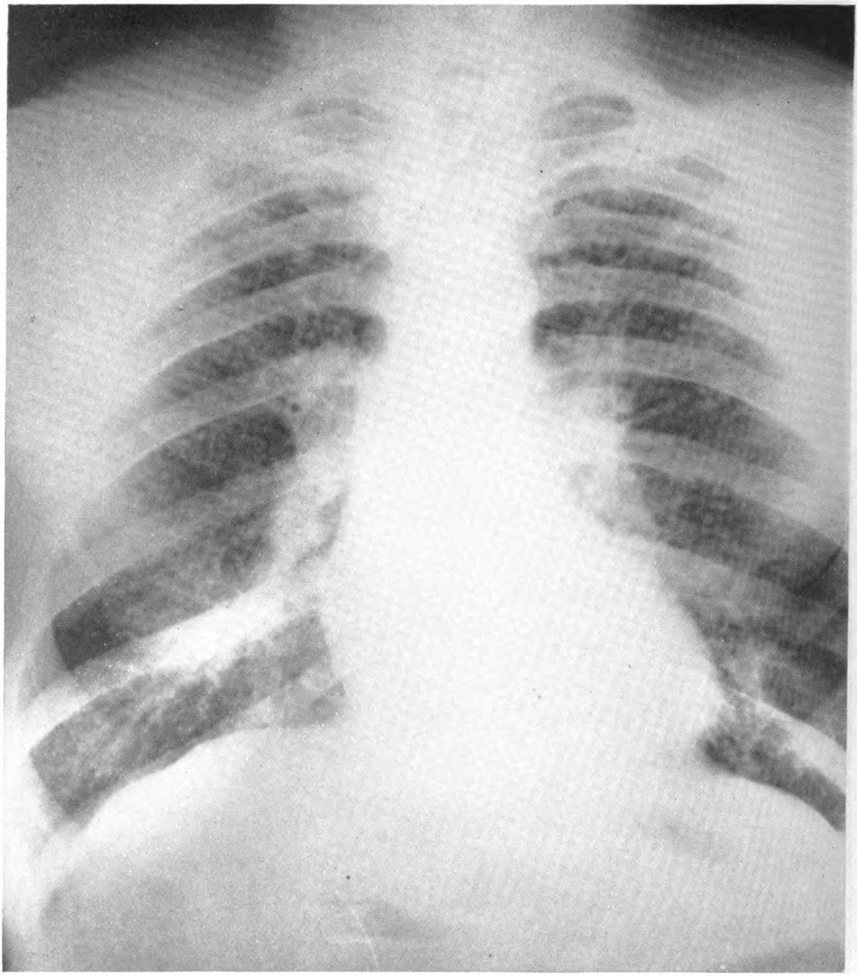


FIGURE 14.—FIRST-STAGE SILICOSIS. WHITE MALE, AGE 32.

Occupational history.—Top car man, 5 years; contract miner, ½ year; station tender, 1 year; and mucker, 6 years.

Estimated dust exposure.—Sixteen million particles per cubic foot (weighted average).

Past medical history.—Pneumonia in childhood; frequent colds in past few years. Weight loss in past 6 months, 6 pounds. Otitis media with drainage, 1916; occasional sinusitis; tonsillectomy, 1925.

Present complaints.—Frequent colds with sinusitis for past 4 years.

Physical examination.—Average appearance; height, 68½ inches; weight, 160 pounds; chest expansion, 10 centimeters; chest findings, negative.

Fluoroscopy.—Soft granular appearance with almost complete obliteration of linear markings throughout both lungs. Movement of diaphragm not restricted.

Film.—Diffuse granular appearance, linear markings obliterated. Slight emphysema in the bases; right cardiophrenic angle slightly obliterated; both costophrenic angles shallow.

Diagnosis.—First-stage silicosis.

Comment.—This film demonstrates a well-defined first stage of simple silicosis. The past history and present complaints are fairly typical. The physical findings in the chest are negative. The film, however, has a fairly heavy and uniform infiltration of granular markings which are becoming nodular in the periphery of the upper halves of both lungs.

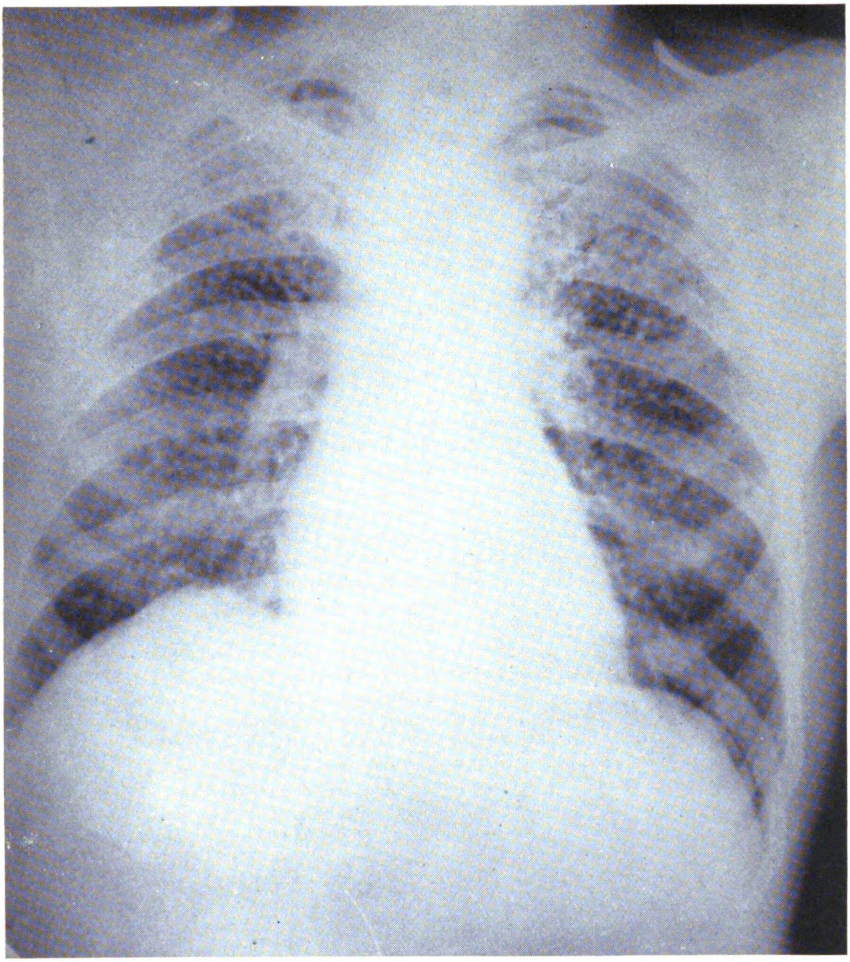


FIGURE 15.—SECOND-STAGE SILICOSIS. WHITE MALE, AGE 63.

Occupational history.—General mining, 16 years; sheep herding, 30 years; farming, 4 years.

Estimated dust exposure.—Thirty-one million particles per cubic foot (weighted average).

Past medical history.—Appendectomy, 1919; influenza in 1934, 1936, and 1937; occasional abdominal cramps, 1938.

Present complaints.—Mild shortness of breath on exertion for the past year.

Physical examination.—Average appearance; height, 64 inches; weight, 134 pounds; chest expansion, 6 centimeters; breath sounds, rough; wet, coarse, nonpersistent rales in the right middle lobe anterior.

Fluoroscopy.—Early nodulo-conglomerate markings throughout both lungs. Movement of diaphragm moderately restricted.

Film.—Shows diffuse nodular shadows throughout both lungs and beginning coalescence of nodular markings in both the upper thirds. Linear markings are obliterated. Slight emphysema in bases.

Diagnosis.—Second-stage silicosis.

Comments.—The past history and dyspnea are suggestive of a more chronic condition. Rales are often found in this stage of involvement because of the associated bronchitic or bronchiolitic changes. The above findings, together with the heavy mottled appearance in the roentgenogram and fairly long exposure, give a good description of this stage of involvement.

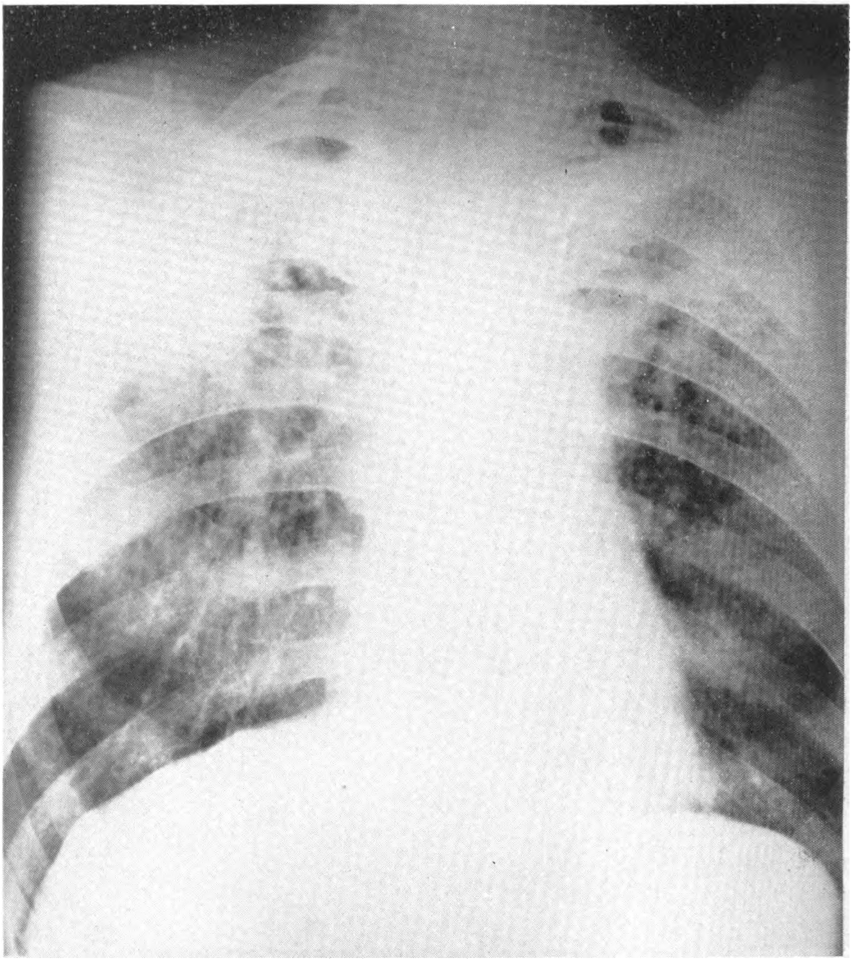


FIGURE 16.—SECOND-STAGE SILICOSIS WITH INFECTION. WHITE MALE, AGE 47.

Occupational history.—Timberman, 12½ years; mucker, 14½ years.

Estimated dust exposure.—Twenty-nine million particles per cubic foot (weighted average).

Past medical history.—Pneumonia of the right base, 1925; severe cold, 1936.

Present complaints.—None.

Physical examination.—Cachectic appearance; height, 69 inches; weight, 160 pounds; chest expansion, 8 centimeters; retracted fossa on inspection; interscapular dullness; breath sounds, rough in interscapular region.

Fluoroscopy.—Coalescing nodular shadows throughout both lungs. Movement of the diaphragm moderately restricted.

Film.—Nodular appearance throughout both lungs with coalescence of nodular markings in the left upper third. Large irregular dense infiltration in the right infraclavicular region. Moderate emphysema present at both bases, especially the right. There is mediastinal distortion with heavy bands pulling on both diaphragms.

Diagnosis.—Second-stage silicosis plus infection.

Comment.—This case is similar to that of other metal miners who have worked over 20 years at timbering and mucking. The irregular fibroid areas, soft nodulation, and long shadows in the right base, the mediastinal distortion, and asymmetry of markings, together with the history and physical examination, all suggest an infective condition with well-advanced silicosis.

Two broad classifications of pulmonary tuberculous disease are generally recognized: the healed (or healing) primary or childhood type of tuberculosis, and the reinfection or adult type of tuberculous lesion (67).

A healed primary lesion, as seen in the X-ray film, is usually characterized by the appearance of small, often dense, opacities in the lymph nodes of the hilus, or at the site of the original infection in the lung parenchyma (68). This infection occurs chiefly during early life, but might appear later in those persons not exposed to the disease until after adolescence. Usually no symptoms are noted in the development of this pulmonary lesion and the patient is neither disabled nor likely to transfer the disease to others in the community, provided that the infection is arrested at this point and becomes encapsulated.

The reinfection or adult type of tuberculosis may or may not be preceded by a demonstrable primary lesion. In the beginning it is most readily recognized by its anatomic distribution and peculiarities of its appearance on the X-ray film. It is possible for an infection of this kind to precipitate no recognizable symptoms and to become arrested or quiescent while the worker is performing his usual activities. Frequently, however, the disease progresses, the patient is disabled, and he becomes a source of tuberculous infection to his family, fellow workers, and others in his community.

In the analysis of the examination records made in this study, the diagnosis of pulmonary tuberculosis was reached only after careful consideration and review by several physicians. All cases with insufficient clinical evidence to permit a decision were regarded as essentially negative.

The classification of the cases studied according to the activity of the disease is more or less arbitrary since only one film was available for each man examined. The lesions in cases classified as active appeared as soft, infiltrating shadows in the lung parenchyma, accompanied by symptoms of tuberculosis elicited in the history or signs revealed by the physical examination. The lesions in quiescent, apparently healed, or arrested cases were more sharply defined, usually with some evidence of scarring, and were not accompanied by any symptoms or signs referable to tuberculous infection.

Table 20 gives a classification of both types of tuberculosis according to degree of activity. It will be observed that there were only 4 cases which were thought to show activity on the basis of physical and X-ray findings and, in addition, 2 of these had evidence of healed primary lesions. Three were classed as second stage silicosis cases and 1 was considered a borderline silicosis case. The other 14 workers with reinfection or adult type pulmonary tuberculosis had lesions which were minimal and apparently healed. Half of the workers with reinfection tuberculosis also showed healed primary lesions. A total of 116 metal mine workers showed healed primary lesions but had no indication of reinfection tuberculosis.

TABLE 20.—*Classification of 134 primary or reinfection tuberculous lesions occurring in 719 metal mine workers according to degree of activity*

Degree of activity	Type of tuberculosis			
	All types	Reinfection only	Reinfection and primary	Primary only
Total	134	9	9	116
Active	4	2	2	0
Apparently healed	14	7	7	0
Healed	116	0	0	116

Primary tuberculosis.—It is often stated that calcified pulmonary nodules are of no clinical significance at any age. Calcified tracheobronchial lymph nodes in young adults indicate severe exposure to tuberculosis in childhood, but there is no incontrovertible evidence that such persons are particularly liable to tuberculosis in later life. Fellows (69) found no significant difference in the development rate of pulmonary tuberculosis in a serial chest roentgenological study of 3,179 office employees from 1926 to 1938, whose first roentgenogram of the chest was classified as average, healthy, or negative chest, when compared to a smilar group whose first roentgenogram showed a healed primary complex.

Table 21 shows the number and percent of metal mine workers with healed primary tuberculosis, grouped according to age. It is seen that 16.1 percent of the metal mine workers have evidence of a primary lesion as shown by X-ray. Among 801 male office workers examined by Fellows, 87, or 10.9 percent, were found with healed primary tuberculosis. The incidence of primary lesions has a tendency to increase with age, which is especially evident among metal mine workers when the 35 to 44 year group is compared with the 45 to 54 year group. Previous dust investigations made by the Public Health Service (51) (35) also show this age trend. The findings in the present investigation, as well as earlier Public Health Service studies, indicate that a healed primary complex does not appear to be a contraindication for employment in a dusty trade.

TABLE 21.—*Number and percent of cases of primary and reinfection tuberculosis found on examination of metal mine workers, classified by age*

Age	Number of workers in age group	Primary tuberculosis		Reinfection tuberculosis[1]	
		Number of workers	Percent of workers	Number of workers	Percent of workers
All ages	719	116	16.1	18	2.5
15 to 24	82	11	13.4	0	0
25 to 34	319	40	12.5	2	0.6
35 to 44	171	24	14.0	2	1.2
45 to 54	102	30	29.4	9	8.8
55 and over	45	11	24.4	5	11.1

[1] Reinfection or adult type including those with primary lesions.

Reinfection tuberculosis.—Table 21 shows the distribution of reinfection tuberculous lesions in 719 metal mine workers, according to age. It is noted that 18 of these workers are affected, representing 2.5 percent of all those of whom chest X-rays were made. This prevalence of reinfection tuberculosis is nearly the same as that observed in 489 Utah coal mine workers (2.7 percent), but less than half that found in 1,384 Utah smelter workers (5.4 percent) (70). Studies of adult male populations in other parts of the country show results which do not differ greatly from those for Utah metal mine workers. In Framingham, Massachusetts (71), a study revealed that about 1 percent suffered from the active form of tuberculosis and in another 1 percent the disease was arrested. The Life Extension Institute (72) examined 100,924 adult white males and a prevalence rate of tuberculosis of 1.5 percent was indicated when suspected cases were included. In the tri-State district (63), the prevalence of tuberculosis was 3.8 percent in 1929.

The effect of age is much more marked for reinfection tuberculosis than for primary tuberculosis. It will be noted that although 80 percent of the workers examined were under 45 years of age, only 22 percent of the cases of reinfection tuberculosis were found within this age group. Similar results were reported from an X-ray examination of 1,682 male applicants for employment (73). This study showed the following prevalence of affected persons: Age 17 to 24, 1.1 percent; age 25 to 34, 2.4 percent; age 35 to 44, 4.0 percent; and age 45 and over, 10.1 percent. These persons who were seeking work showed a slightly greater prevalence of tuberculosis than persons actively engaged in metal mining.

From the standpoint of diagnosis of silicosis, it is apparent from table 22 that the percent affected with reinfection tuberculosis is directly proportional to the degree of lung involvement due to dust. In the group of 611 metal mine workers who showed no evidence of silicosis, the proportion affected (1 percent) is as low or lower than in the general population. The borderline group has a percentage 7 times as high, and the group classified as having first or second stage silicosis is nearly 14 times as high as the group free from silicosis.

Of the 18 persons diagnosed as having reinfection tuberculosis, 3 had borderline silicosis, 4 had first stage, and 5 had second stage silicosis. Two persons had lung-field markings classed as linear 1 on X-ray examination, and 5 persons had markings classed as linear 2; the remainder had markings indicating the more severe degrees of pulmonary fibrosis. The weighted average atmospheric dust concentration per cubic foot was less than 18.0 for 4 persons, 18.0 to 23.9 for 6 persons, and 24.0 and over for 8 persons. Only 3 of these 18 workers were as much as 5 percent overweight and 11 were more than 5 percent underweight.

TABLE 22.—*Incidence of reinfection tuberculosis among metal mine workers, classified by diagnosis of silicosis*

Diagnosis of silicosis	Number of workers	Workers with reinfection tuberculosis[1]	
		Number	Percent
Total	719	18	2.5
Nonaffected	611	6	1.0
Borderline	42	3	7.1
First stage	42	4	9.5
Second stage	24	5	20.8

[1] Reinfection or adult type including those with primary lesions.

According to principal occupation, eight of the metal mine workers with reinfection tuberculosis had worked at the face as machine men, miners, or muckers; three had been supervisors or shift bosses; one had been a tool sharpener; another an electrician; another a pumpman; and another had worked in the crushing plant. Three did not have any principal occupation.

In general, it would appear that neither primary nor reinfection tuberculosis is found in a significantly greater percent of these metal mine workers than would be expected in any group of employed workers of like age. However, there does exist a problem of reinfection tuberculosis among those persons affected with silicosis. Russell's (74) recent contribution shows that silicosis cases complicated by reinfection tuberculosis have an unfavorable clinical course when they continue to be exposed to relatively high concentrations of granite dust.

LEAD POISONING AMONG METAL MINE WORKERS

PAST HISTORY OF LEAD POISONING

Lead poisoning has been known to be an industrial disease of the metal mine workers in Utah for a number of years. Murray's studies (75) demonstrated the frequency of the disease and showed that the incidence of disabling plumbism was related to the type of ore mined. The incidence in lead mines is lowest in those workings where lead sulfide ore is being extracted and highest in lead carbonate ores. This finding is in conformity with general opinion (76).

On the basis of the information in the past medical histories of all metal mine workers examined in the summer of 1939, it is apparent that disabling lead poisoning is still an industrial health problem among the personnel employed in this group of mines. The number of cases giving a history of lead poisoning according to the time of occurrence of disabling acute episode and the present age of the individual is shown in table 23. Of the 727 metal mine employees [10] examined, 102 (table 23) gave a history of acute episodes of lead intoxication. Nineteen mine workers reported that they had had acute episodes within the past four and one-half years (1935-39). In a few of these cases the period of disability was recent, antedating the study by only a few months. The majority of the acute episodes, as the table shows, occurred when workers were under 30 years of age. This high prevalence in the younger age groups is comparable to experience elsewhere (77).

TABLE 23.—*Number of cases giving a history of lead poisoning according to present age and date of disability*

Present age	Total	Time of occurrence of acute lead episode					
		Prior to 1915	1915–19	1920–24	1925–29	1930–34	1935–39
Total	102	5	4	11	24	39	19
20 to 29	19	0	0	0	3	6	10
30 to 39	34	0	0	3	11	15	5
40 to 49	29	2	3	4	5	11	4
50 to 59	16	3	1	2	5	5	0
60 to 69	4	0	0	2	0	2	0

[10] Of the 56 miners with a mixed occupational exposure (p. 62), 8 gave a history of acute episodes of lead poisoning. One of these was convalescing at the time of examination.

The duration of the disability in recent years seldom exceeded two months and in most instances lasted only 2 or 3 weeks. The disabling symptoms were predominantly of a gastrointestinal nature. According to Belknap (78) this is the most common type of industrial lead poisoning. It is manifested by typical lead constipation and violent abdominal pain which is called lead colic. Associated with these gastrointestinal symptoms there is a corresponding rise in stippled cell count and related erythrocytic changes. No instances of lead palsy or encephalopathy were reported in these past medical histories.

As Kehoe, et al. (79) have shown, there are safe levels of lead intake. With the recently introduced and more refined methods of lead analysis (41) (80) of biological specimens, it has become increasingly apparent that even the so-called normal nonexposed individual may have measurable amounts of lead in his blood and excreta. The lead intake of nonexposed individuals has been shown to be somewhat less than 0.5 milligram per day and probably is about 0.2 to 0.3 milligram per day (79) (81). The so-called threshold limit of intake before clinical plumbism ordinarily develops in industrial workers is 1.5 milligram of lead per 10 cubic meters of air (41). This threshold is approximately the same as that determined by Legge and Goadby in Great Britain (82). Table 24 shows that nearly one-half of the workers were exposed at the time of the study to lead concentrations exceeding the above threshold. This table also shows that the great proportion of mine employees having this exposure also had a high weighted average dust exposure, and suggests that the lead problem, like the dust problem, is essentially one of face workers.

TABLE 24.—*Relation of weighted silica dust concentration to present lead exposure*

Dust concentration, million particles per cubic foot	Total		Lead exposure, milligrams of lead per 10 cubic meters of air					
			Less than 0.3		0.3 to 1.4		1.5 [1] and over	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	[2] 725	100.0	104	100.0	266	100.0	355	100.0
0 to 5.9	38	5.2	21	20.2	13	4.9	4	1.1
6.0 to 11.9	97	13.4	44	42.3	44	16.6	9	2.5
12.0 to 17.9	115	15.9	25	24.1	65	24.4	25	7.1
18.0 to 23.9	272	37.5	7	6.7	94	35.3	171	48.2
24.0 and over	187	25.8	5	4.8	42	15.8	140	39.4
Unknown	16	2.2	2	1.9	8	3.0	6	1.7

[1] Average exposure for group centers about 3.7.
[2] Excludes 2 workers with known dust concentration but with unknown lead exposure.

ESTIMATE OF PRESENT INCIDENCE OF ABNORMAL LEAD ABSORPTION

The case records of 141 actively employed metal mine workers were selected for intensive study because of some sign or symptom indicative of abnormal lead absorption. In only 75 of these did a diagnosis of latent plumbism (abnormal lead absorption) seem justified. Although the sense of well-being in these men was unaffected, each had a combination of 2 or 3 of the signs or symptoms associated with abnormal lead absorption. A diagnosis of lead intoxication was not warranted for any man. Two-thirds of these 75 cases were employed at the face and about one-third were timbermen and transportation and maintenance personnel. Isolated cases occurred in mechanics, carpenters, blacksmiths, and bosses.

The frequency of occurrence of certain signs and symptoms among the 75 metal mine workers with abnormal lead absorption is compared with the essentially negative group of 652 workers in table 25. It will be noted that the former group shows a larger proportion with each of the listed findings than the latter group. For example, gastrointestinal disturbances which included complaints of colic, constipation, vomiting, and abdominal pain, present or chronic at the time of the physical examination, were reported twice as frequently by the affected as by the nonaffected group. Neurological disturbances represented by some form of tremor, or increased or decreased knee jerk, occurred more frequently in the affected group. Loss of weight of 10 pounds or more within the past year, or a weight deviation of 10 percent or more from an average based on height and age,[11] was found in 40 percent of the group with abnormal lead absorption. Complaints of headache were made twice as frequently by the affected group, and pallor was observed 3 times as often in this group. The proportion of workers who showed some degree of pyorrhea upon dental examination was large in both groups, being 58.7 and 37.1 percent in the affected and the nonaffected groups, respectively (83).

With respect to hematologic findings, reticulocyte counts of 1.0 percent and more were found more frequently in the affected than in the nonaffected group. Basophilic stippling of the red blood cells, an important criterion in selecting workers with possible abnormal lead absorption, was observed in 77.3 percent of the affected workers as compared with 7.1 percent in the negative group. However, only 10 of these workers had values of 100 or more stippled cells per 100,000 red blood cells. Unless accompanied by other signs or symptoms suggestive of lead absorption, workers with the single finding of basophilic stippling were excluded from further consideration.

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[11] See p. 71.

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TABLE 25.—*The frequency of occurrence of certain findings among 75 metal mine workers with abnormal lead absorption compared with 652 nonaffected workers*

Finding	Percent of workers		Number of workers	
	Affected	Nonaffected	Affected	Nonaffected
Gastrointestinal disturbances	28.0	12.9	21	84
Neurological disturbances	26.7	13.5	20	88
Loss of weight or underweight	40.0	22.7	30	148
Headache	29.3	14.4	22	94
Pallor	16.0	4.8	12	31
Metallic taste	9.3	3.5	7	23
Pyorrhea	[1] 58.7	[1] 37.1	37	224
Arthritis or neuritis	20.0	14.0	15	91
Reticulocytes, 1.0 percent and more	41.3	24.5	31	160
Hemoglobin less than 12 grams per 100 cubic centimeter blood	[2] 16.2	[2] 8.8	11	57
Basophilic stippling	77.3	7.1	58	46
Present lead exposure of 1.5 milligrams or more per 10 cubic meters of air	66.7	46.8	50	305

[1] Pyorrhea rates are based on 63 affected and 603 nonaffected workers. Edentulous individuals are excluded.
[2] Hemoglobin rates are based on known values for 68 affected and 649 nonaffected workers.

No significant differences between the affected and nonaffected groups were found for complaints of metallic taste, arthritis or neuritis, and for hemoglobin (Newcomer) content of less than 12 milligrams per 100 cubic centimeters of blood.

The proportion of workers with present lead exposure of 1.5 milligrams per 10 cubic meters of air was greater for the affected group, showing that some correlation exists between the magnitude of lead exposure and diagnosis of lead absorption. It has previously been shown in table 24 that those workers who are exposed to high concentrations of silica dust are also likely to be exposed to the higher concentrations of lead. It is noted that a diagnosis of silicosis or borderline silicosis was made for 13 of the 75 affected workers. However, the difference between the proportion so diagnosed was too small to be statistically significant.

Several other subjective and objective findings which form a part of the clinical picture of lead absorption were given weight in the diagnosis of individual cases, but, because of small numbers or incomplete data, were not included in table 25. One of these criteria, the presence of a metallic line, usually regarded as a cardinal sign of plumbism, was not consistently recorded for the workers in all three mines, but in one mine where the dental examination included this finding, 22 out of 30 workers classified as having abnormal lead absorption showed some evidence of a metallic line on the gums. Quantitative determinations for urinary lead, which were made on only 20 of the 75 workers, showed that half of these men had values below 0.05 milligram of lead per liter; the 3 highest values recorded were 0.36, 0.36, and 0.38 milligram of lead per liter. A few workers complained of weakness, but no instance of wrist drop or other form of lead palsy was observed.

Although the data which have been presented indicate a tendency for association of findings indicative of lead absorption in this group of 75 workers, the following facts must be considered before any conclusions are drawn.

First, these 75 workers were chosen because they had a combination of two or three signs and symptoms that form a part of the clinical picture of lead poisoning. On this basis, it is to be expected that the proportion with these findings in the affected group would be greater than in the nonaffected group.

Second, these signs and symptoms are not necessarily specific for plumbism. They may occur in many common diseases found among persons with no lead exposure. Furthermore, the degree of severity of the subjective findings could not be evaluated, but it was evidently slight since all workers were actively engaged in their various occupations at the time of the examination. Hematologic findings indicated that in most instances the values found were within the range of normal experience for any large group of male workers.

And, third, when the signs and symptoms observed in the 75 affected men are arranged in the form of association tables,[12] it appears that the tendency for association of findings is less pronounced than was indicated by table 25.

Such tables permit one to examine the degree to which particular pairs of findings are observed in association in the same man. For example, one can determine the number of instances in which the complaint of gastrointestinal disturbanaces was made by a man who also complained of neurological disturbances, the number of instances in which neurological disturbances and loss of weight occurred in the same man, or from a table in which three findings are paired, the number of instances in which basophilic stippling occurred in combination with pallor and high reticulocyte count. Association tables, not shown in this report, were prepared which failed to reveal a tendency for the signs and symptoms of abnormal lead absorption to occur in combination more frequently than would be expected on the basis of chance alone. In other words, the low degree of association of paired findings served to substantiate the observation of the medical examiners that the well-being of these men was not affected. The most severe form of toxic lead involvement was encountered in a machine man, 32 years of age, who was apparently convalescing from a mild episode. He complained of constipation and metallic taste, showed acid eructations and slight evidence of bone marrow irritation—1 percent reticulocytes, 40 stippled cells per 100,000 red blood cells, hemoglobin 12 grams, and had a urinary lead concentration of 0.04 milligram per liter. On the whole, this group of 75 workers was not a badly affected group.

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[12] For this type of statistical treatment, see p. 70 of Public Health Bulletin number 267 (84).

Some measure of the lead exposure and the degree of lead absorption of 178 metal mine workers may be observed in table 26, wherein the results of the lead content of the urine of these workers are compared with those of 195 coal miners (70) who had no industrial lead exposure. It is observed that all workers, even coal miners, showed lead in their urine. The important finding, however, is that 78.1 percent of the metal mine workers showed moderate and heavy amounts of lead in their urine, whereas only 10.8 percent of the coal miners showed more than faint traces. Attention is called to the fact, however, that urine was obtained for spectographic analysis on 178 or about 24 percent of the metal mine employees examined.

On the basis of the past history of plumbism among these metal mine workers and their present physical status, it is apparent that the lead hazard in Utah metal mines is less severe than it was 20 to 25 years ago. This decreased incidence and severity is probably related to the more general use of wet mining methods during the past 20 years, improved ventilation, more abundant mining of sulfide instead of carbonate ores, better respiratory protection, and probably closer medical supervision of the personnel.

TABLE 26.—*A comparison of the results of spectrographic tests for urinary lead content*

Study		Urinary lead concentration			
		Total	Faint trace	Moderate	Heavy
Coal mines (507 workers)	Number of tests	195	174	20	1
	Percent of total	100.0	89.2	10.3	0.5
Metal mines (727 workers)	Number of tests	178	39	136	3
	Percent of total	100.0	21.9	76.4	1.7

CARDIOVASCULAR FINDINGS

DISEASES OF THE HEART AND VASCULAR SYSTEM

Table 27 shows that 149 (20.5 percent) of the mine workers examined were 45 years of age or older. This older age group presents a special health problem which cannot be divorced from age, and, aside from silicosis, the one disease that stands out prominently on statistical analysis is cardiovascular disease of the arteriosclerotic-hypertensive type. As Stieglitz (85) has stated, "of all the diseases to which adult man is heir, the cardiovascular-renal diseases are the most frequent cause of death today. Heart disease is very often but a part of a generalized hypertensive arterial disease, and renal failure, likewise, is not uncommonly secondary to arterial disease."

Table 27 shows the frequency distribution of certain forms of heart disease, by age, compared with 1,627 white male pottery workers. Heart disorders were classified under broad, etiological headings in accordance with a scheme prepared by the Heart Committee of the New York Tuberculosis and Health Association (86) which was modified and discussed by Hedley (87).

TABLE 27.—*Incidence of heart disease among metal mine workers, classified according to age, and compared with pottery workers (51)*

Age	Metal mines							Pottery manufacture			
	Number in age group	Number with heart disease [1]			Percent with heart disease			Number in age group	Percent with heart disease [2]		
		Arterio-sclerotic hyper-tensive	Rheumatic	Functional	Arterio-sclerotic hyper-tensive	Rheumatic	Functional		Arterio-sclerotic hyper-tensive	Rheumatic	Functional
All ages	727	49	17	14	6.7	2.3	1.9	1,627	4.5	1.0	0.1
15 to 24	83	4	2	1	4.8	2.4	1.2	350	--------	1.1	.3
25 to 34	323	4	6	6	1.2	1.9	1.9	549	.9	.7	-------
35 to 44	172	13	4	1	7.6	2.3	.6	370	2.2	1.1	-------
45 to 54	104	14	4	5	13.5	3.8	4.8	221	11.3	1.8	-------
55 and over	45	14	1	1	31.1	2.2	2.2	137	25.5	--------	-------

[1] One case of syphilis of heart or aorta, and 1 of toxic heart disease were also found among metal mine workers.
[2] Three cases of syphillis of heart or aorta and 1 case of toxic heart disease were also found among pottery workers.

As in other studies by the Public Health Service of the health of employed industrial workers, it is the arteriosclerotic-hypertensive group of heart diseases which is the most prevalent. As Hedley (87) points out, this is a more heterogeneous group than any of the others, involving the interplay of a number of factors. The structural change of arteriosclerosis and the physiological alteration of increased arterial tension, resulting in a greater load on the myocardium, each play a part. Frequently it is impossible to ascribe to each its relative significance. It includes (*a*) the so-called "chronic myocarditis" in which myocardial degeneration due to coronary arteriosclerosis is accompanied by impaired cardiac function, usually by well-marked beading of the peripheral arteries and sometimes by arterial hypertension. At present (88) almost all of these degenerative diseases of the heart that were termed "chronic myocarditis" a generation ago are known to have as their basis disease of the coronary arteries or their branches. This disease of the coronary arteries leads to gradual or sudden impairment of the coronary circulation and to necrosis of smaller or larger areas of the muscle fibers, with resulting fibrosis and scarring. The term "myocardosis" has been suggested to distinguish myocardial degeneration from inflammatory conditions. Other forms of heart disease, included under the general etiological heading of arteriosclerotic-hypertensive heart disease, include (*b*) hypertensive heart disease, in which well-established, persistent arterial hypertension is associated with enlarged heart and in which there may or may not be discernible arteriosclerosis; (*c*) essential hypertension with no other signs of organic disease; and (*d*) less frequently, valvular heart disease due to sclerotic changes in the valve cusps and ring (usually of the aortic valve) with no demonstrable evidence of syphilis.

As would be expected, the incidence of the arteriosclerotic-hypertensive group of heart diseases increases with advancing age. Thus, 3.6 percent of the workers under 45 years of age are affected, as compared with 13.5 percent in the age group 45 to 54 years, and 31.1 percent in the group 55 years of age and over. The corresponding percentages for pottery workers are 1.0, 11.3, and 25.5, and for Utah bituminous coal mine workers the percentages are 2.3, 11.4, and 35.7. The general agreement in the percent of persons affected in different industries probably reflects a normal age trend in the prevalence of this type of cardiovascular disorder.

The rheumatic group of heart diseases on the basis of these data is slightly more prevalent among metal mine workers than among pottery workers; 2.3 percent as compared with 1.0 percent, but nearly the same, 2.8 percent, as Utah coal mine workers. This is consistent with Hedley's studies on heart disease mortality among persons 5 to 24 years of age (89). He found that the mortality rate for rheumatic heart diseases in the age group selected was much higher for Utah than for other States in the United States registration area. Viko in a study of 1,000 cases (90) also observed that, although the Rocky

Mountain States of Utah, Idaho, and Wyoming have a relatively low cardiac mortality rate, the incidence of rheumatic heart disease was higher in these States than in the remainder of the United States. Older metal mine workers with rheumatic heart disease probably represent persons who have survived acute cardiac phenomena of adolescence, but still present clinically demonstrable cardiac residuals.

The 14 cases classified under the functional type included several with cardiac murmurs and premature contractions. In addition, one man with a clinical history of infection, treatment, and positive serology showed roentgenographic evidence of syphilitic aortitis. Another man was classified as having toxic heart disease, toxemia apparently being due to thyroid disease. No frankly decompensated cases were observed among the 727 mine workers.

With the exception of the rheumatic group, cardiovascular diseases do not seem more prevalent in Utah metal mine workers than in potters (51) and in other large groups of employed industrial workers who have been studied by the Public Health Service (54). It is of interest to note that metal mine workers, as well as the comparison group of pottery workers, have some degree of exposure to lead or its compounds, and to siliceous dust, while Utah bituminous coal mine workers have a low siliceous dust and no appreciable lead exposure. However, there is little difference in the incidence of cardiovascular diseases between these industrial groups. Thus, on the basis of these findings, it would appear that the dust and lead exposure of the metal mine workers has no noticeable relation to cardiovascular diseases.

BLOOD PRESSURE

Systolic and diastolic blood pressure determinations were made on each worker while in a sitting position with his arm lying relaxed on the examining table. The auscultatory method was used with a mercury sphygmomanometer. These readings were made after the occupational and medical history had been taken, so that the worker had a period of time in which he could rest and overcome the first feeling of nervous excitation caused by these examination procedures. Since this same method was followed in other industrial studies made by the Public Health Service, the results should be comparable for persons in specific age groups.

As shown in table 28, the average **systolic blood pressure** values for metal mine workers is lower for each age group above 25 years than the corresponding values found in a study of 10,000 male industrial workers (54). The difference is greatest in the 3 oldest age groups, which indicates that the increase of average systolic blood pressure of metal mine workers with age is not so rapid as might be expected from the study of 10,000 industrial workers. Indeed, among metal mine workers under 40 years old, no definite trend with age can be observed. Another group of Utah employees examined, namely, coal mine workers, (53) shows average systolic blood pressure values which correspond very closely with those for metal mine workers. Both Utah groups have slightly lower values than were found in previous studies of pottery workers (51) and truck drivers (65). The cause of this lowered systolic blood pressure cannot be explained, but the higher altitude at which Utah employees live and work may be a factor.

TABLE 28.—*Average systolic and diastolic blood pressures of metal mine workers, by age, compared with 10,000 male industrial workers (54)*

Age	Metal mine workers			10,000 male industrial workers		
	Average systolic blood pressure	Average diastolic blood pressure	Number of persons tested	Average systolic blood pressure	Average diastolic blood pressure	Number of persons tested
Under 25	124	78	82	123	72	1,264
25 to 29	123	78	167	126	75	1,122
30 to 34	122	77	151	127	77	1,055
35 to 39	122	78	98	128	79	1,026
40 to 44	127	84	74	130	80	782
45 to 49	127	83	61	135	81	613
50 to 54	132	85	43	139	82	365
55 and over [1]	138	88	45	147	84	440

[1] Includes 1 person over 65 years of age.

Diastolic blood pressure, in most age groups, is somewhat higher for Utah metal mine workers than was found among pottery workers or the 10,000 industrial workers. There is no ready explanation of these differences, but it is interesting to speculate that they are part of the same phenomenon, the increased diastolic blood pressure and the reduced systolic pressure, resulting in a lowered pulse pressure among Utah workers.

Arterial hypertension was defined, for purposes of this study, as arterial systolic tension in excess of 150 millimeters of mercury. This is generally in agreement with definitions suggested by Stieglitz and others (85) (91), who set standards of systolic tension in excess of 150 millimeters of mercury and diastolic tension in excess of 100 millimeters. It will be observed from table 29 that there is a consistently smaller percentage of these Utah metal mine workers with hypertension than was found in the study of 10,000 industrial workers. It is of interest to note in this connection that in the examinations of drafted men during the World War (92), the position of Utah as compared with the other States was found to be very favorable with respect to the proportion of registered men having arteriosclerosis and hypertension.

TABLE 29.—*Number and percent of metal mine workers with systolic blood pressure values in excess of 150 mm. Hg by age, compared with 10,000 industrial workers (54)*

Age	Metal mine workers			10,000 industrial workers		
	Number in age group	With systolic blood pressure in excess of 150 mm. Hg		Number in age group	With systolic blood pressure in excess of 150 mm. Hg.	
		Percent	Number		Percent	Number
All ages	721	5.4	39	9,540	10.9	1,041
20 to 29	246	3.3	8	3,248	4.2	136
30 to 39	249	1.6	4	3,293	7.3	240
40 to 49	135	6.7	9	1,947	16.4	320
50 to 59	70	17.1	12	818	28.5	233
60 to 69	18	33.3	6	234	47.9	112

ARTERIOSCLEROSIS

Arteriosclerosis was considered present in persons who showed thickening, beading, or tortuosity on palpation of the radial, brachial, or temporal arteries. Table 30 shows that seventy-one of the metal mine workers, or 9.8 percent, were found to have arteriosclerosis. The proportion was approximately the same as that found for Utah coal mine and smelter workers (70), the percentages being 10.3 and 12.9, respectively. When age is taken into account, the table shows that in the two oldest age groups almost one-third of all the persons are so affected. The severe grades of vessel involvement are present only in persons over 50 years of age.

TABLE 30.—*Number and percent of metal mine workers who were found to have arteriosclerosis, by age*

Age	Number in age group	With arteriosclerosis		Age	Number in age group	With arteriosclerosis	
		Percent	Number			Percent	Number
All ages	727	9.8	71	35 to 44	172	6.4	11
15 to 24	83	----------	0	45 to 54	104	24.0	25
25 to 34	323	3.4	11	55 and over	45	53.3	24

OTHER PHYSICAL FINDINGS

SYPHILIS

A State-wide survey (93) made by the physicians of Utah in 1936 placed the number of syphilitics in Utah at 10,000. On the basis of estimated population of 521,000 for that year, this would indicate an incidence rate of about 2 percent. Using positive serodiagnostic tests as an index, the incidence in the metal mine workers was even lower, 0.8 percent, though the rate for coal mine and smelter workers was 1.8 and 1.9 percent, respectively, or almost identical to the rate for the State as a whole.

Five of the six positive Kahn tests noted in metal mine workers were four-plus reactions and the other was three plus. Since no open lesions were observed, all of these cases are regarded as latent syphilis. These positive tests occurred only in men more than 40 years of age. A diagnosis of syphilitic aortitis (p. 93) was made in one case and another showed questionable widening of the aorta.

HEADACHE

Complaints of headaches were much more frequent among metal mine workers than among coal mine and smelter workers (70), the percentages being 16.0, 6.9, and 7.0, respectively. However, surface workers and all underground workers, except those working at the face in metal mines, did not show an appreciably greater incidence of headaches than that found for the other Utah industries studied. In these groups, between 5 and 10 percent complained of headaches.

Among metal mine workers occupied at the face, the percent with headaches was 23.7. This excess at the face suggests the possibility of inadequate ventilation which allows the accumulation of gases, dust, and fumes after blasting (p. 51). "Powder" headaches were often reported by metal mine workers. Although working conditions were somewhat different in the 3 metal mines studied, the percent of face workers complaining of headaches was nearly the same, varying from 21 to 27 percent.

DERMATOLOGIC CONDITIONS

Dermatitis and other dermatologic conditions were observed in 61 metal mine workers. These skin affections, in general, were of minor character, and were not extensive or prone to be disabling. Irritative and contact dermatitis cases, some of which were thought to be "sulfide rashes," were observed in 14 men, all of whom were face workers. Acne vulgaris was observed in 19 men and psoriasis in 8 men. Other skin affections observed included such conditions as scabies, pityriasis rosae, urticaria, impetigo, and furunculosis.

MISCELLANEOUS PHYSICAL FINDINGS

Inspection of the eyes revealed that 20.8 percent of the 727 metal mine workers had injection of the conjunctivae, (bloodshot eyes), a condition frequently associated with eyestrain, irritating atmospheric contaminants, inadequate or glaring illumination, and loss of sleep. Nearly the same percent of coal mine workers (53) (20.1 percent) were so affected. Truck drivers (65) showed a more frequent occurrence of injection of the conjunctivae (51 percent), while hatters (94) made a much more favorable showing (2.8 percent). Possibly the necessarily low illumination of coal mines and metal mines had some influence on the condition of the workers' eyes.

Inflammation of the nose or throat was observed among 13.3 percent of the men examined. This was slightly higher than for coal mine workers (9.5 percent), but only one fourth as high as among smelter workers (52.7 percent). Examination of the extremities revealed that 22 metal mine workers (2.8 percent) had missing members which usually consisted of one or more fingers. Nine persons had deformities, commonly due to accidental injuries of the hands and arms. There was evidence of increased knee jerks in 5.1 percent of those examined and of decreased knee jerks in 3.6 percent. Visible tremor of the hands, usually fine, was observed in 7.6 percent of the metal mine workers.

THE PHYSIOLOGICAL RESPONSE OF PERITONEAL TISSUE TO UTAH METAL MINE DUSTS

By J. W. MILLER, *Senior Pathologist*

Samples of mine dust from two levels of one of the mines studied which produced mostly lead and silver were examined by the intraperitoneal injection method of Miller and Sayers (95) to determine their pneumoconiosis-producing potentialities.

The results of this biological method of dust testing are interpreted from the response of the peritoneal tissue to a dust introduced into the peritoneal cavities of guinea pigs. Three well-defined types of reaction are produced in the peritoneum by different dusts. Certain dusts are completely **absorbed** and none of the dusts of this group is known to cause disabling pneumoconiosis. Another group of dusts produces a **proliferative reaction,** characterized by the formation and growth of a nodule due to a stimulation in production of fibrous tissue. Free silica in most of its forms is known to cause this type of response and dusts of this group are known to cause nodular pulmonary fibrosis. Such dusts should be considered as definitely harmful. In a third group the dust remains **inert** in the peritoneal tissues. The term **inert** is used to describe the observable response of the peritoneal tissue and should not be interpreted to mean innocuous. Dusts of this group, such as asbestos (52), are known to produce a diffuse interstitial pulmonary fibrosis, and these dusts cause an inert reaction in peritoneal tissue. Dusts that show this tendency to remain inert in the tissues should be considered potentially harmful, though not as dangerous as those causing a proliferative reaction. Silica (which produces a proliferative reaction) when mixed with a dust of the inert group produces nodules of modified appearance with distinguishable features of both types of reaction. Pathological correlation with such a mixture is best illustrated by anthracosilicosis (33) where both nodular and diffuse pulmonary fibrosis are encountered.

The samples of mine dusts described below are representative of such dusts in metal mines found in this region.

Mine dust.—Sample taken from exhaust fan from lower mine levels where sulfide ores predominate and consisted mostly of sulfide ores. Petrographic examination showed about 35 percent quartz, a form of free silica. Chemical analysis showed total silica, 48.6 percent; mixed oxides, 26.5 percent; calcium oxide, 1.9 percent; lead, 1.8

percent; ignition loss, 17.9 percent. This produced a combined **proliferative** and **inert** reaction.

Mine dust.—Sample taken from outlet side of exhaust fan from higher mine levels where oxidized ores predominate and consisted mostly of carbonate ores of lead and silver. Petrographic examination showed about 8 percent quartz. Chemical analysis showed total silica, 43.0 percent; mixed oxides, 15.6 percent; calcium oxide, 12.0 percent; lead, 2.1 percent; ignition loss, 16.7 percent. A distinct **inert** reaction was produced.

It will be noted that the amount of total silica is essentially the same in the sample taken from the upper levels and the sample from the lower levels, but the quartz content, as shown by petrographic examination, is much less in the former sample. This suggests the possibility that the dust from the upper levels produced an inert reaction because a large proportion of the silica was in combined form rather than as quartz. On the contrary, dust from the lower levels contained silica principally as quartz, which is in sufficient quantity to produce a proliferative reaction, while the combined silica remains inert in the nodule and adjacent peritoneal tissue.

These results are comparable to those obtained by similar tests with two widely different samples of chat from Oklahoma and Missouri lead mines. One, a highly siliceous chat which contained about 70 percent quartz determined petrographically, produced a well-defined, rapid, proliferative response. The other, a dolomitic chat, caused an absorptive reaction with some inert material remaining in the tissues after the dolomite had disappeared.

In view of the results obtained from the biologic tests of these Utah metal mine dusts, that from the higher levels should be considered as potentially harmful while that from the lower levels is definitely hazardous.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the splendid cooperation of the officials of the nonferrous metal mines studied, and the officials and members of the International Union of Mine, Mill, and Smelter Workers. The Utah State Board of Health gave the invaluable assistance of its medical and engineering staff, and, in addition, made sputum tests for tubercle bacilli and Kahn tests for syphilis in its own laboratories. The dental division of the State Board of Health furnished the services of a dentist for the oral hygiene studies, and the Division of Sanitary Engineering carried out a survey of the mines and the surrounding communities in which the workers lived. The State Industrial Commission should be commended for having assumed leadership in initiating this investigation.

Acknowledgment is due the United States Bureau of Mines for performing analyses on gas samples obtained in the environmental study.

The State district health officers, Drs. L. M. Farner, E. L. Van Aelstyn, and E. H. Silverstone, assisted materially in making physical examinations.

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APPENDIX

DEFINITIONS OF OCCUPATIONS

In order to show the various duties involved in different occupations, it seems appropriate to give brief definitions of the more important occupations in the industry.

OFFICE AND GENERAL SUPERVISION.

The *superintendent*, *assistant superintendent*, *general foreman*, and/or *general manager* are responsible for all surface and underground operations. However, they usually spend a minor portion of their time underground.

The *mining engineer*, *safety engineer*, *civil engineer*, and *surveyor* perform the engineering duties inherent in their profession and may spend from one-fourth to one-half of their time underground.

The classification of *office worker* has been given to all those occupations, such as *executives*, *clerks*, *timekeepers*, *telephone operators*, *physicians*, *draftsmen*, *etc.*, whose duties do not require them to spend any appreciable part of their working time outside the main offices of the mine.

FACE OPERATIONS, UNDERGROUND.

Mine foreman, *shift boss*, and *level boss* are occupations requiring the the supervision of all underground operations. They also require the assumption of responsibility for safety and health conditions underground.

Miners, in the operations studied, are practically all machine men operating jackhammers, Leyner drills, stopers, or drifters. While some differences in the amount of dust generated by these different drills have been shown, the individual miner's occupational histories show no clear-cut differentiation in the type of work done. In most Utah mines, a miner and a mucker work as partners and alternate jobs. The only apparent difference between a miner and a mucker is that the miner is the more experienced man and is permitted to charge holes and fire explosives. Miners bar down overhang, do a large part of the timbering in the stopes or drifts in which they work, lay track and pipe, and even assist in hand tramming ore cars to the switch stations.

Muckers assist miners in setting up drills, and may also operate drills and jackhammers. They also bar down overhang (loose roof-rock left after blasting); hand load ore into cars with shovels, or operate mechanical mucking machines; tram the loaded cars to the nearest switch, hoist, or dumping station; and tram the empty cars back to the stope.

Samplers collect specimens of rock and ore from each working face and send these samples to the assay office for analysis. Sampling may also be done by the geologist, foreman, miner, or the ore handler at the shaft station or bins.

TRANSPORTATION, UNDERGROUND

The movement of the ore cars from the face to the hoist may be accomplished by hand tramming, by mule train, or by trains hauled with electric locomotives. In this study, a differentiation between hand trammers and muckers was not practicable.

Mule skinners, also known as *drivers* or *horse trammers*, drive mules or horses used for moving ore cars and supplies between the shaft stations and the active working faces. Only one of the mines studied used animals for tramming, and in this mine they were rapidly being replaced by tram locomotives.

Motormen operate electric locomotives (called motors) which are either of the trolley or storage battery type. These locomotives are not only used to move trains along the haulage drifts on the various mine levels, but are also used to haul ore from the inside shaft station to the outside railroad siding in adit or tunnel mines. Motormen are assisted by *motormen's helpers* who couple and uncouple cars at the switch stations, open brattice doors, and act as tool nippers by delivering steel, bits, timber, and wedges to the various stopes and headings.

Underground hoistmen operate electric hoists in sub-shafts and winzes; and operate compressed air hoists at temporary hoisting stations, or for operating tuggers, slushers, or drag-line scrapers. In some mines, the main shaft collar is at the inside end of a haulage tunnel, or adit, which makes the main hoist operator an underground hoistman. The location and duties of each hoistman were considered in weighting his dust exposure.

Station tenders act as signal men at the various shaft stations and may be responsible for the routing of ore cars and supplies. They are assisted by *carmen*, who place loaded mine cars on the hoist cages and remove empty cars from these cages. They also couple and uncouple mine trains at the hoist stations. In skip hoisting, they may act as *skip loaders* or *skip tenders*.

Cagers or *cage riders* load hoist cages with tools, steel, timber and other miners' supplies. They may ride up and down with these cages and unload the materials at the proper stations. They act as *signal men* in the hoisting of ore, and as cage tenders in the hoisting of men.

Nippers, *tool nippers*, *supply men* or *material men* deliver tools and supplies to the active working faces.

Powdermen deliver explosives, percussion caps and fuses to the active working faces. The actual loading and firing is done by the miners at the end of each shift.

Bin tenders, *car loaders* or *skip tenders* operate the gates on underground storage bins for ore or waste rock, which may be loaded into either mine cars or skip buckets.

MAINTENANCE AND CONSTRUCTION, UNDERGROUND.

Timbermen and *timbermen's helpers* erect timbers and braces for supporting the roof in mined areas. In general, the miners did their own timbering in stopes, while the timbermen did the timbering in permanent haulageways and did difficult jobs in stopes, drifts, and raises.

Shaftmen are expert timbermen assigned to shaft construction and maintenance.

Pipemen extend water and compressed air lines to within a short distance of the working faces. In the mines studied, these duties were frequently assumed by miners, trackmen, or by pipemen assigned to surface maintenance crews.

Trackmen maintain main haulage lines and lay new track. The extension of temporary track in the stopes may be done by the miners and muckers.

Ventilation men install and maintain ventilation fans, pipes, flexible ventilation tubing, brattice doors, and brattice walls.

Wiremen or electricians do underground wiring. Ordinarily electric lighting is used only at shaft stations and in hoist houses (where it is required by law) and electric trolley wires are used only in the main drifts and tunnels. In the mines studied, this classification was not used and electrical maintenance was done by repair mechanics or surface maintenance men.

Mechanics, *repairmen*, and *oilers* service and maintain underground equipment. In many mines, this is done by men detailed from the surface maintenance crews.

Sanitation men, *inspectors*, or *general utility men* are responsible for the care and maintenance of underground latrines and toilets.

Compressormen operate electrically driven air compressors. While this occupation is occasionally encountered underground, air compressors are usually located on the surface.

General labor or *miscellaneous labor* includes such construction or maintenance jobs as timber handling, concrete construction work, and guniting; and also includes relief men who replace all men except miners and muckers.

TRANSPORTATION, SURFACE.

Hoistmen operate the machinery for lifting the cages, or skips, in the main shafts. Electric hoists were used in the mines studied, although auxiliary steam hoists were sometimes available.

Top carmen or *topmen* remove the loaded ore cars from the cages at the shaft collar, tram them to the ore bin dumping station, dump them, and return the empty cars to the cage station.

Surface motormen haul trains of ore from the inside shaft collar through the entrance adit or tunnel to the outside. These men were usually carried on the company pay roll as inside motormen.

Tramway operators operate aerial cable-car tramways for conveying ore from the mine portal to a railroad siding located at some distance down the mountain. Duties consist of loading cable cars, dumping cars, and operating control switches.

Waste dumpmen and *dump trackmen* maintain track on waste rock dumps, and dump cars of waste rock. This occupational designation did not occur in the mines studied, although waste rock was dumped by top trammers in some instances.

Binmen, ore loaders, ore dumpers, and *yard labor* are grouped together since they all have similar duties in these mines, and are primarily engaged in the storage and the loading of ore into railroad cars.

Truck drivers and *truck drivers' helpers* operate and load automobile trucks used in delivering supplies to the mine.

Tractor operators and *teamsters* are self-explanatory occupations, which did not occur in the mines studied.

MAINTENANCE AND CONSTRUCTION, SURFACE.

This classification contains several occupations, the duties of which may necessitate that the worker spend part of his time underground.

Electricians maintain surface electrical wiring and motors. They also act as emergency repairman or wiremen underground, and may make repairs on underground motors, although such repair work is usually done on the surface.

Timber framers are employed in cutting and preparing timber for use underground. *Carpenters* may act as timber framers, but also do surface construction and repair.

Batterymen charge and maintain the electric storage batteries used in cap lamps, and/or the heavy duty batteries used in the tram locomotives.

The remaining occupations listed in this section appear to be self-explanatory.

MILLING OPERATIONS.

Crushing and concentrating mills are frequently operated in conjunction with mines, as well as with smelters, or independently, since the crushing and concentrating of ore is an intermediate step between mining and smelting. None of the mines studied were carrying on milling operations at the time of the study, but a sufficient number of employees had had previous employment in ore mills to make the consideration of the dust exposure in these mills significant. The broad occupational classifications used in this section appear to be self-explanatory.

ASSAYING.

The *assayer* or *chemist* makes fire and chemical analyses of the pulverized ore samples to determine their mineral content. In the smaller assay offices he may also assume the duties of a bucker.

Buckers grind and quarter the samples and prepare them for analysis.

MISCELLANEOUS.

The occupations listed in this section are self-explanatory.