Miners' Circular 57
BUREAU OF MINES

# HEALTH AND MISCELLANEOUS HAZARDS AT METAL AND NONMETALLIC MINES

Metal- and Nonmetallic-Mine Accident-Prevention Course—Section 7

(Revised June 1956)

U.S. BUREAU OF MINES

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## Metal- and Nonmetallic-Mine Accident-Prevention Course—Section 7

**Revised by Frank E. Cash[2]**

## PURPOSE AND SCOPE

The first metal-mine accident-prevention course was prepared and published in 1942–45 as a series of seven miners' circulars (Nos. 51–57). The scope of the course has been broadened, revised, and brought up to date, and it is being published as a similar series of seven miners' circulars (Nos. 51–57, revised) on accident prevention in metal and nonmetallic mines. These circulars are:

Accident Statistics (Miners' Circular 51), dealing with general statistics on accidents and injuries at metal and nonmetallic mines, including causes, costs, and the uses of investigations and reports of all accidents.

Falls of Rock or Ore (Miners' Circular 52), discussing the selection of mining methods to minimize the hazards of falling and sliding ground, the use of various types of support, and the protection of employees from falls of ground.

Hoisting and Haulage (Miners' Circular 53), presenting the hazards of hoisting and haulage in metal and nonmetallic mines and means of preventing accidents.

Explosives (Miners' Circular 54), giving information on accidents and injuries due to storing, handling, and using explosives in metal and nonmetallic mines and precautions for preventing them.

Fires, Gases, and Ventilation (Miners' Circular 55), explaining the causes of fires in metal and nonmetallic mines and the measures used to prevent, control, and extinguish them; describing gases found in mines and methods of detection and personal protection; and discussing necessity for and standards of proper ventilation.

Electrical and Mechanical Hazards (Miners' Circular 56), covering accidents and injuries from electricity and machinery and their prevention and injuries from falls of persons.

Health and Miscellaneous Hazards (Miners' Circular 57), including data on dust hazards; means of protection and sampling devices; protective clothing and equipment; and illumination, supervision,

[1] Work on manuscript completed June 1956.
[2] Mining engineer, Bureau of Mines.

discipline, and safety training for employees in metal and nonmetallic mines.

These seven circulars do not contain all the material that may be desired on every phase of accident prevention at metal and nonmetallic mines, but they will serve as bases for discussion. To these may be added supplementary material of particular interest in the field where the course is utilized. This accident-prevention course, offered to the mining industry by the Bureau of Mines, is compiled from studies by the Bureau and experience and knowledge gained by its engineers, to which is added information on safe-mining practices made available by mining companies and their officials.

This is the seventh (and last) section in the revised series of circulars that cover various phases of accident prevention in metal and nonmetallic mines; it deals with health, safety organization, and other accident-prevention factors in mines, including supervision, training in safe practices, illumination, and the use of goggles and protective clothing. Miscellaneous causes of injuries are also discussed; some deserve consideration because of their interesting aspects or possible serious consequences.

## ACKNOWLEDGMENTS

Much of the original text is retained in the revised course on Accident Prevention in Metal and Nonmetallic Mines.

The revision was under the general supervision of James Westfield, Assistant Director—Health and Safety, W. J. Fene, chief, Division of Safety, and Simon H. Ash, former chief, Safety Branch, Bureau of Mines. This section was revised by Frank E. Cash; supplemental material was supplied by the following Bureau engineers:

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The illustrations are from mining and manufacturing companies and Bureau of Mines publications.

# HEALTH

## HEALTH HAZARDS OF METAL AND NONMETALLIC MINERS

Although industrial hygiene in the field of public health work is a comparatively recent development, it is rapidly increasing in importance as appreciation grows of the responsibility to provide working conditions for industrial employees that are safe from danger to health as well as from chances of injury. The purposes of industrial-hygiene services are to protect the health, improve the efficiency, and prolong the life of workers. Although the recognition of occupational diseases as such dates back to antiquity, the growth of remedial measures has been slow up to recent times. Intensive efforts to determine health hazards and to eradicate them or supply protective methods are now being made in all industries. Health hazards in mining are being investigated and gradually reduced or eliminated by the mine operators, State and Federal Public Health Services, and the Bureau of Mines. Reasons for the attention given this subject in recent years are the desire to improve efficiency and economy of operation, promote higher standards of health and living, and secure the enactment of compensation laws that cover disability from occupational disease. In addition, great strides have been made in developing instruments for accurate study and control of conditions causing occupational diseases. Extensive research work and clinical and laboratory studies have definitely fixed the toxic threshold of maximum safe concentrations of many of the potentially harmful materials encountered in industry.

Disbelief may be the general attitude of mining men when told that occupational diseases take a greater toll in money, as well as in health, than do accidents, but the fact can be demonstrated for industry in general, and the situation in mining or a mining field will certainly bear investigation. The efficiency of a worker suffering from an occupational disease or an unrelated illness is diminished long before he reaches the point where he is unable to work or is awarded compensation. Absenteeism in mining caused by illness can only be estimated, and the proportion of lost time due to occupational disease or illness is also undetermined. Neither accurate figures nor reliable estimates can be obtained on the total costs of occupational health hazards in the mining industry, but attempts to estimate the costs show that, in general, they are much greater than those from accidents. Factors that should be included in such an estimate are time lost through sickness, inefficiency of affected workers on the job, accidents due wholly or in part to illness of workers, compensation, and medical care of disabled workers.

In 1945 Dr. R. R. Sayers, then Director of the Bureau of Mines, stated in an address at Charleston, W. Va., that the experience of the St. Joseph Lead Co. affords an example of the practical value of improving living and working conditions at mines. Improvements in living conditions included housing, water and food supplies, sanitation, schools, and recreation; particular attention was given to community health; and occupational hazards to health at the mines were surveyed and steps taken to remove or control them. As a result, the labor turnover was reduced in a few years from 250 to 3.6 percent, with an annual saving of about $250,000 for hiring and training new

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employees and about $40,000 for accidents. Accounts were not kept of costs directly chargeable to health hazards.

More occupational diseases are acquired by inhalation of materials carried in the air than by any other cause.[3] Occupational poisoning also may result from direct contact of some materials with the skin and from contaminated food or water. However, skin contact and ingestion are minor causes as compared to inhalation; therefore, main efforts of industrial hygiene are to prevent contaminants from entering the air or to remove them from the air before they can be breathed.

Daniel Harrington, former chief of the Health and Safety Branch, Bureau of Mines, summarized many years' study of the problem as follows:[4]

> Health is probably of greater value to the miner than to most people, as his occupation almost invariably demands the possession of far more than ordinary physical abilities. When his health fails, he is usually relegated to the scrap heap. The miner has numerous advantages, as well as some very definite disadvantages, as regards health, in comparison with persons engaged in other types of industrial endeavor. Practically all miners are forced to take considerable amounts of exercise; in general, the mine worker, in reasonably well-conducted mines, has almost ideal conditions in his working place as to temperature and humidity. There are, however, exceptions. Many deep mines have high temperatures, others have both high temperatures and high humidities, and open or shallow mines are exposed to extreme changes of weather.

## AIR TEMPERATURE AND HUMIDITY

Working under conditions of high temperature and high humidity is enervating and decreases the efficiency of workers as well as makes them more susceptible to disease. These effects and the relationship of abnormal atmospheric conditions are discussed in section 5 (Fires, Gases, and Ventilation). Studies of human comfort in relation to temperature and humidity, by the American Society of Heating and Ventilating Engineers in cooperation with the Federal Bureau of Mines and the Public Health Service, showed that the best working conditions were between 50° and 75° F., with the humidity between 20 and 95 percent.[5] The limiting conditions are shown in figure 1. The zones of comfort and discomfort shown by this chart are for heavy work in still air; movement causes the air to feel cooler because of the better transfer of heat from the body to the surrounding atmosphere. When the rate of transfer is too slow or too fast, the body temperature is raised or lowered to the point of discomfort. Under extreme conditions, weakness may be produced with impairment of breathing and pulse.

In metal and nonmetallic mines where efficient ventilation is not maintained, air may be encountered with less than 18 percent oxygen, more than 1 percent of carbon dioxide, or noxious gases such as carbon monoxide, oxides of nitrogen, or sulfur gases from blasting. An instrument that gives a continuous record of any carbon monoxide that is being introduced into a mine through the compressed-air lines is shown in figure 2. In mines producing certain metals, harm-

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[3] National Safety Council, Accident-Prevention Manual for Industrial Operations: Sec. 23, 1951, pp. 14–42.

[4] Harrington, D., The Miner's Health: Nat. Safety News, October 1933, p. 82.

[5] Sayers, R. R., and Davenport, Sara J., Review of Literature on the Physiological Effects of Abnormal Temperatures and Humidities: U. S. Public Health Rept., Reprint 1150, 1927, 63 pp.

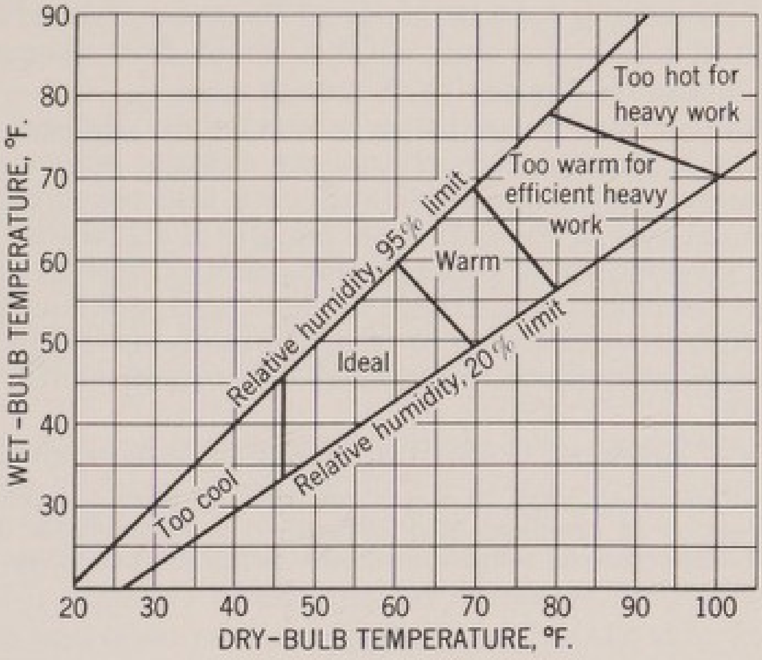


FIGURE 1.—Comfort Zones for Heavy Work in Still Air.

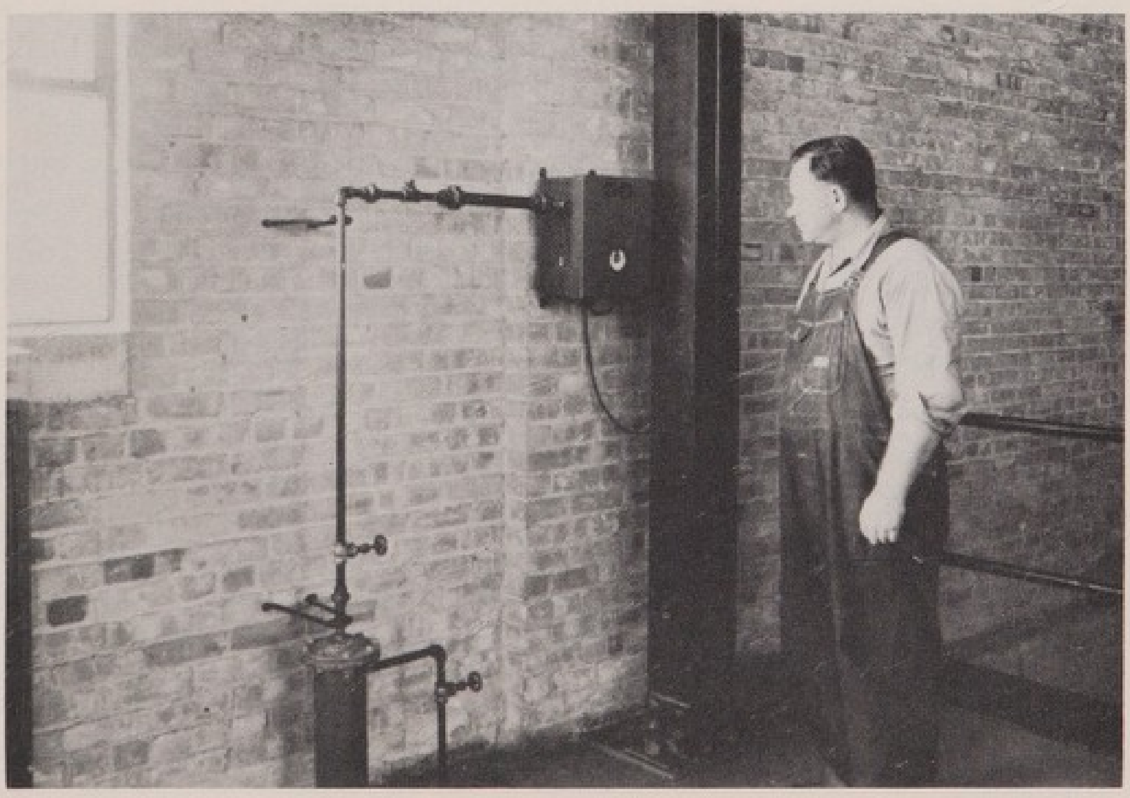

FIGURE 2.—Carbon Monoxide Recorder Connected to Compressed-Air Line in Compressor Room.

ful solutions may be present in the mine water or toxic dusts may be formed. Blasting, shoveling, hauling, timbering, dry drilling, chute loading, and other activities in dry mines are likely to be dust producers. Breathing certain kinds of dusts has harmful effects on the health, and much has been written about dust disease, which is the greatest menace to the health of miners.

Although the attention of those interested in diseases peculiar to mining has been focused recently on one disease, *silicosis*, other respiratory diseases may cause more suffering and economic loss. The increased occurrence of these diseases usually is attributed to exposure to abnormal air conditions underground, such as sudden changes from high to low temperatures, excessive dust, and noxious gases. The principal respiratory diseases to which miners are subject are bronchitis, influenza, pneumonia, pulmonary tuberculosis, anthracosilicosis, and silicosis.[6]

The Medical Research Council of Great Britain reported that:[7]

> Workers who are most often ill tend most often to have accidents, indicating that the prevention of accidents may depend to a considerable degree on the prevention of sickness and emphasizing the need for attention to industrial health programs.

## DUST

### EFFECTS OF INHALING DUST

Literature on the effects of breathing dust abounds in various experimental, theoretical, and factual data but lacks conclusiveness in almost every phase, except possibly that harm to health can be expected from prolonged inhalation of excessive amounts. There appears to be good reason to believe that this applies virtually to any or all dusts or combinations of dusts, organic or inorganic.[8]

It is well established that exposure to certain kinds of dusts, such as those containing considerable quantities of free silica, has increased the morbidity and mortality rate from respiratory diseases, and some metallic dusts, such as lead and its compounds, have been associated with general system poisoning. According to Drinker, four reactions are produced in man by inhalation of dust. The first (and most important) reaction is produced by the pneumoconioses, such as silicosis and asbestosis, which cause specific lung pathology and often are followed by pulmonary tuberculosis. The second reaction is caused by toxic dusts like lead, cadmium, and radium. A third reaction follows inhalation of finely divided, metallic, fume particles (such as zinc oxide) and is known as metal-fume fever. The fourth reaction, allergic in character, is caused by inhaling organic dusts, such as pollen and certain types of pulverized wood and flour. In all four the sole cause of the disability may be dust inhalation, but reactions from toxic dusts do result from swallowing dust as well as inhalation.[9]

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[6] Sayers, R. R., Pulmonary Diseases in the Mining Industry: Bureau of Mines Inf. Circ. 7146, 1941, 26 pp.

[7] American Medical Association, Proneness to Accidents: Jour. Am. Med. Assoc., Nov. 14, 1942, p. 841.

[8] Forbes, J. J., Davenport, Sara J., and Morgis, Genevieve C., Review of Literature on Dusts: Bureau of Mines Bull. 478, 1950, 333 pp.

[9] Drinker, Philip, The Causation of Pneumoconiosis: Jour. Ind. Hyg. and Toxicol., October 1936, p. 524.

Silicosis is the term now applied to the lung trouble of miners (in the past it was referred to as asthma, lung consumption, or miner's disease) that is due, it is agreed rather generally, to some form of the element silicon. A good proportion of the present-day authorities on dust disease think that silica dust is harmful chiefly because, in the finely divided form in which it enters the lungs, it goes into solution and causes attendant chemical reactions, impairing or destroying the lung tissue.[10] Formerly, it was believed that fibrosis (the formation of fibrous tissue in the lungs) was produced in response to the irritation caused by the hard, sharp, quartz particles, as well as by filling or partial filling of the lungs with dust; that is, the dust was supposed to act mechanically. A rational view seems to be that the harmful action is both chemical and mechanical.[11]

The numerous ill effects on human organs other than the lungs, owing to breathing more or less insoluble dust, need to be considered, as well as the harm to other organs (stomach, liver, kidneys, etc.) or to the nose, throat, and bronchial tubes from breathing more or less soluble or so-called poisonous dusts. Moreover, numerous dusts (both organic and inorganic) have harmful effects of various kinds on the eyes and ears and other parts of the body and on the skin from external contact; indeed, some dusts cause harm to health by absorption through the skin. Hence, although pulmonary diseases due to the breathing of airborne dusts are unquestionably of great present-day importance, their various ramifications (pneumoconiosis, silicosis, anthracosis, or these combined with tuberculosis), although vitally important, by no means constitute the only detrimental effect to human beings who come in contact with dust, externally or internally.[12]

There is no satisfactory medical answer at present to this dust problem, but an engineer is making a bad mistake if he lets men breathe heavy dust concentrations of any material. If no other reason for dust control can be found, then we should read transcripts of some of the recent suits at common law in which large damages were awarded for alleged silicosis to men who breathed dust containing little or no silica. The courts and compensation boards are not impressed with subtle distinctions between dusts with 10- and 40-percent quartz, especially when medical experts are reluctant to make definite statements as to the comparative significance of such differences.

It would be well to realize that men working in dusty atmospheres suffer more from respiratory troubles than do men who work in clean air—evidence that excessive dustiness of any kind is harmful is beyond argument.[13]

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[10] Harrington, D., Silicosis as Affecting Mining Workmen and Operations: Bureau of Mines Inf. Circ. 6867, 1936, 14 pp.
[11] See work cited in footnote 8.
[12] See work cited in footnote 8.
[13] Harrington, D., Methods of Protection Against Silicosis and When They Are Justified: Bureau of Mines Inf. Circ. 6989, 1938, 9 pp.

The Federal Bureau of Mines [14] made a careful study of industrial lead poisoning a number of years ago. The conclusions were that most cases of lead poisoning are contracted by inhaling air laden with lead carbonate dust and that the opportunity to contract lead poisoning varies in proportion to the solubility of the ore mined, the quantity of lead dust thrown into the atmosphere, and the ventilation afforded. Other metallic dusts may have harmful effects on the human system when breathed; soluble forms of certain metals may have toxic properties, and insoluble forms are likely to be irritating to the respiratory tract. Considerable is known regarding the hazards of metallic poisoning by inhaling fine particles as dust, swallowing dust or solutions, or absorbing dust through the skin. However, the particulars of these hazards are of interest chiefly to operations where such metals or compounds are encountered; references describing the hazards and their treatment are given in the suggested reading at the end of this publication.

### ALLOWABLE CONCENTRATIONS OF DUST IN MINING

The quantity of dust taken into the respiratory organs is a controlling factor in harmfulness of dust to the respiratory system, and common sense indicates that the quantity of dust breathed is one of the factors determining possible harmfulness from any kind of airborne dust.[15] Investigations over a period of years show that exposure to certain concentrations of harmful dusts for a known time causes

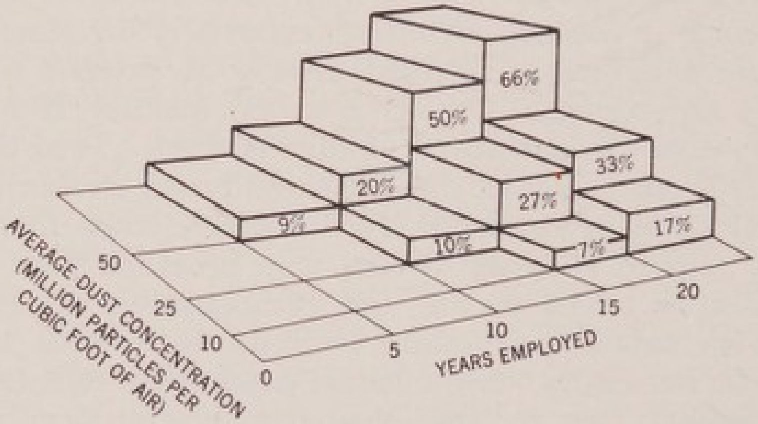


FIGURE 3.—Relation of Average Dust Concentration and Duration of Dust Exposure to Workers Having Pneumoconiosis.

varying degrees of respiratory disability and that below these concentrations disabling pulmonary diseases do not occur within a working lifetime.[16] The effects of concentrations of dust, as indicated by medical studies of some mine and quarry workers, are shown in figure 3.

[14] Murray, A. L., Lead Poisoning in the Mining of Lead in Utah: Bureau of Mines Tech. Paper 389, 1926, 40 pp.
[15] See work cited in footnote 8.
[16] Sayers, R. R., Pulmonary Diseases in the Mining Industry: Bureau of Mines Inf. Circ. 7146, 1941, 26 pp.

From the viewpoint of harmfulness to the respiratory tract, it is generally stated (though actual knowledge on this point is by no means certain) that the dust particles (such as free silica) that affect health adversely upon entering the lungs are less than 10 microns in size; different persons vary in their opinions as to what the maximum may be—10, 8, or 6 microns—and some say that the harm can be done by 2-micron particles or smaller.

As against this, it is stated that fibers of asbestos as long as 200 microns have been found in the lungs of men and that, undoubtedly, these long asbestos fibers exerted some detrimental effect. Since a micron is only about 0.00004 of an inch, or much smaller than the naked eye can see, it is usually assumed that the larger dust particles, which can be seen floating in air and settle relatively quickly, are not harmful to health. Certainly, this is questionable, as the larger particles suspended in the air (some of them 100 or more microns in size), if present in considerable quantities, clog the air passages leading to the lungs. Some of these air passages are so constructed that, under ordinary circumstances, they intercept larger dust particles before they can reach the lungs, and this clogging then allows the smaller and probably most dangerous dust particles to enter the lungs unimpeded. A commonsense opinion as to what constitutes an atmosphere so dusty that dust-prevention action should be taken is that any atmosphere in which dust can be seen by the naked eye is too dusty, not only for health but also, at least in many cases, for safety and efficiency. If visible dust is eliminated, much of the invisible or probably most dangerous dust will unquestionably have been removed also, and very likely the health hazard, as well as other hazards, will be much minimized or removed. After visible dust is removed, it may be necessary, under some conditions or with some types of dust, to make more intricate investigations as to the occurrence of invisible dust, using the impinger, konimeter, or other instruments.[17]

Analyses of the data collected by the Federal Public Health Service to determine safe limits of dust exposure indicate that employment in an atmosphere containing less than 50 million dust particles per cubic foot produces a negligible number of cases of silicosis when the quartz content of the dust is less than 5 percent; when the silica content is about 13 percent, 10 to 15 million particles appear to be a safe limit. The position of the threshold value below which no silicosis cases were found, the magnitude of the trends between percentages affected, and time and intensity of exposure vary in different sets of data, depending to a large extent on the chemical nature of the dust to which workers were exposed and possibly on the regularity of employment. It does not seem advisable to set up any mathematical guide, because only the survivors have been studied. There is no adequate way of determining whether or not the men who dropped out of industry were in a better or worse state of health as far as silicosis

[17] See work cited in footnote 13.

is concerned than the men who remained in the industry; thus, there is no way of introducing a correction in this element of selection by a mathematical calculation.[18]

Moreover, air with a certain number of dust particles per cubic foot, with a silica content of 1 percent (or any other percentage), could be far more harmful to one person than another, depending on individual susceptibility, exertion, etc. Dusty air would be more harmful to a person working in an atmosphere of 85° or 90° F., relative humidity 90 or 95 percent, than to one working in an atmosphere of 60° F., relative humidity 60 percent. Numerous other more or less similar contributing factors make it futile to establish regulations as to the allowable number of dust particles on a sliding scale in proportion to the silica content of the dust. In some industries, such as metal mining and tunneling, there may be as many different percentages of silica in the mine air as there are working places, and in many metal mines it is very unlikely that the percentage of silica in the air of a working place today will be at all close to the percentage of silica in that same place tomorrow.[19]

Regarding health, the outstanding and principal source of information is the pamphlet on threshold-limit values adopted from year to year by the American Conference of Governmental Industrial Hygienists.[20] Each value expresses the average concentration of a substance in the air to which an industrial worker can be exposed for 8 hours daily for an indefinite period without injury or occupational disease. With some differences, these values are used by all the State governments that have accepted values along these lines.[21]

Table 1 gives these threshold-limit values (1956) for gases and vapors; toxic dusts, fumes, and mists; and mineral dusts. Many, but not all, of these substances are encountered in metal and nonmetallic mining, processing, and refining.

## TYPES OF MINE DUST INJURIOUS TO HEALTH

As a result of investigations in South Africa and other mining districts of the world, so much attention was focused on one particular dust (silica) as the most harmful encountered in industry that most investigators had accepted other dusts as harmless or of negligible importance as health hazards in industry and considered the disease silicosis resulting from breathing silica dust as the only important dust disease.[22] Other dusts, such as silicates (asbestos for example), have been found almost as harmful as silica dust; but the effect on the lungs is somewhat different from that of silica, and the hazard is not so widespread.

[18] See work cited in footnote 16.

[19] Forbes, J. J., Davenport, Sara J., and Morgis, Genevieve G., Review of Literature on Dusts: Bureau of Mines Bull. 478, 1950, 333 pp.

[20] Reprinted and copyrighted by the American Medical Association, 535 Dearborn Street, Chicago 10, Ill.

[21] Barkley, J. F., Accepted Limit Values of Air Pollutants: Bureau of Mines Inf. Circ. 7682, 1954, 6 pp.

[22] See work cited in footnote 19.

Table 1.—*Maximum allowable concentrations of (industrial) atmospheric contaminants, 1956*

| Substance | Concentration |
|---|---|
| Gases and vapors: | *P. p. m.* |
| Acetaldehyde | 200 |
| Acetic acid | 10 |
| Acetic anhydride | 5 |
| Acetone | 1,000 |
| Acrolein | .5 |
| Acrylonitrile | 20 |
| Allyl alcohol | 5 |
| Allyl propyl disulfide | 2 |
| Ammonia | 100 |
| Amyl acetate | 200 |
| Amyl alcohol (isoamyl alcohol) | 100 |
| Aniline | 5 |
| Arsine | .05 |
| Benzene (benzol) | 35 |
| Benzyl chloride | 1 |
| Bromine | 1 |
| Butadiene (1, 3-butadiene) | 1,000 |
| Butanone (methyl-ethyl ketone) | 250 |
| Butyl acetate (*n*-butyl acetate) | 200 |
| Butyl alcohol (*n*-butanol) | 100 |
| Butyl amine | 5 |
| Butyl cellosolve (2-butoxy-ethanol) | 200 |
| Carbon dioxide | 5,000 |
| Carbon disulfide | 20 |
| Carbon monoxide | 100 |
| Carbon tetrachloride | 25 |
| Cellosolve (2-ethoxyethanol) | 200 |
| Cellosolve acetate (hydroxyethyl acetate) | 100 |
| Chlorine | 1 |
| Chlorine trifluoride | .1 |
| Chlorobenzene (monochlorobenzene) | 75 |
| Chloroform (trichloromethane) | 100 |
| 1-Chloro-1-nitropropane | 20 |
| Chloroprene (2-chlorobutadiene) | 25 |
| Cresol (all isomers) | 5 |
| Cyclohexane | 400 |
| Cyclohexanol | 100 |
| Cyclohexanone | 100 |
| Cyclohexene | 400 |
| Cyclopropane | 400 |
| Diacetone alcohol (4-hydroxy-4-methyl pentanone-2) | 50 |
| Diborane | .1 |
| o-Dichlorobenzene | 50 |
| Dichlorodifluoromethane | 1,000 |
| 1, 1-Dichloroethane | 100 |
| 1, 2-Dichloroethylene | 200 |
| Dichloroethyl ether | 15 |
| Dichloromonofluoromethane | 1,000 |
| 1, 1-Dichloro-1-nitroethane | 10 |
| Dichlorotetrafluoroethane | 1,000 |
| Diethylamine | 25 |
| Difluorodibromomethane | 100 |
| Diisobutyl ketone | 50 |
| Dimethylaniline (N-dimethylaniline) | 5 |
| Dimethylsulfate | 1 |
| Dioxane (diethylene dioxide) | 100 |
| Ethyl acetate | 400 |
| Ethyl alcohol (ethanol) | 1,000 |
| Ethylamine | 25 |
| Ethyl benzene | 200 |
| Ethyl bromide | 200 |
| Ethyl chloride | 1,000 |
| Ethyl ether | 400 |
| Ethyl formate | 100 |
| Ethyl silicate | 100 |
| Ethylene chlorohydrin | 5 |
| Ethylene diamine | 10 |
| Ethylene dibromide (1,2-dibromoethane) | 25 |
| Ethylene dichloride (1,2-dichloroethane) | 100 |
| Ethylene imine | 5 |
| Ethylene oxide | 100 |
| Fluorine | .1 |
| Fluorothrichloromethane | 1,000 |
| Formaldehyde | 5 |
| Gasoline | 500 |
| Gases and vapors—continued | *P. p. m.* |
| Heptane (*n*-heptane) | 500 |
| Hexane (*n*-hexane) | 500 |
| Hexanone (methyl-butyl ketone) | 100 |
| Hexone (methyl-isobutyl ketone) | 100 |
| Hydrazine | 1 |
| Hydrogen bromide | 5 |
| Hydrogen chloride | 5 |
| Hydrogen cyanide | 10 |
| Hydrogen fluoride | 3 |
| Hydrogen peroxide, 90 percent | 1 |
| Hydrogen selenide | .05 |
| Hydrogen sulfide | 20 |
| Iodine | .1 |
| Isophorone | 25 |
| Isopropylamine | 5 |
| Mesityl oxide | 50 |
| Methyl acetate | 200 |
| Methyl acetylene | 1,000 |
| Methyl alcohol (methanol) | 200 |
| Methyl bromide | 20 |
| Methyl cellosolve (methoxyethanol) | 25 |
| Methyl cellosolve acetate (ethylene-glycol-monomethyl-ether acetate) | 25 |
| Methyl chloride | 100 |
| Methylal (dimethoxymethane) | 1,000 |
| Methyl chloroform (1,1,1-trichloroethane) | 500 |
| Methylcyclohexane | 500 |
| Methylcyclohexanol | 100 |
| Methylcyclohexanone | 100 |
| Methyl formate | 100 |
| Methyl-isobutyl carbinol (methyl amyl alcohol) | 25 |
| Methylene chloride (dichloromethane) | 500 |
| Naphtha (coal tar) | 200 |
| Naphtha (petroleum) | 500 |
| Nickel carbonyl | .001 |
| p-Nitroaniline | 1 |
| Nitrobenzene | 1 |
| Nitroethane | 100 |
| Nitrogen dioxide | 5 |
| Nitroglycerin | .5 |
| Nitromethane | 100 |
| 2-Nitropropane | 50 |
| Nitrotoluene | 5 |
| Octane | 500 |
| Ozone | .1 |
| Pentane | 1,000 |
| Pentanone (methyl-prophyl ketone) | 200 |
| Perchlorethylene (tetrachloroethlene) | 200 |
| Phenol | 5 |
| Phenylhydrazine | 5 |
| Phosgene (carbonyl chloride) | 1 |
| Phosphine | .05 |
| Phosphorus trichloride | .5 |
| Propyl acetate | 200 |
| Propyl alcohol (isopropyl alcohol) | 400 |
| Propyl ether (isopropyl ether) | 500 |
| Propylene dichloride (1, 2-dichloropropane) | 75 |
| Propylene imine | 25 |
| Pyridine | 10 |
| Quinone | .1 |
| Stibine | .1 |
| Stoddard solvent | 500 |
| Styrene monomer (phenylethylene) | 200 |
| Sulfur dioxide | 10 |
| Sulfur hexafluoride | 1,000 |
| Sulfur monochloride | 1 |
| Sulfur pentafluoride | .025 |
| p-Tertiary butyl toluene | 10 |
| 1, 1, 2, 2-Tetrachloroethane | 5 |
| Tetranitromethane | 1 |
| Toluene (toluol) | 200 |
| o-Toluidine | 5 |
| Trichloroethylene | 200 |
| Trifluoromonobromomethane | 1,000 |
| Turpentine | 100 |
| Vinyl chloride (chloroethene) | 500 |
| Xylene (xylol) | 200 |

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TABLE 1.—*Maximum allowable concentrations of (industrial) atmospheric contaminants, 1956*—Continued

| Substance | Concentration | Substance | Concentration |
|---|---|---|---|
| Toxic dusts, fumes, and mists: | *Mg./m.³* | Toxic dusts—continued | *Mg./m.³* |
| Aldrin (1,2,3,4,10,10 - hexachloro - 1, 4,4a,5,8,8a-hexahydro - 1,4,5,8 - dimethanonaphthalene) | .25 | Parathion (0,0 - diethyl - 0 - *p* - nitrophenyl thiophosphate) | .1 |
| Ammate (ammonium amidosulfate) | 15 | Pentachloronaphthalene | .5 |
| Antimony | .5 | Pentachlorophenol | .5 |
| Arsenic | .5 | Phosphorus (yellow) | .1 |
| Barium (soluble compounds) | .5 | Phosphorus pentachloride | 1 |
| Cadmium oxide fume | .1 | Phosphorus pentasulfide | 1 |
| Chlordane (1,2,4,5,6,7,8,8-octachloro-3a,4,7,7a - tetrahydro - 4, 7- methanoindane) | 2 | Picric acid | .1 |
| Chlorinated diphenyl oxide | .5 | Selenium compounds (as Se) | .1 |
| Chlorodiphenyl (42 percent chlorine) | 1 | Sodium hydroxide | 2 |
| Chromic acid and chromates (as $CrO_3$) | .1 | Sulfuric acid | 1 |
| Crag Herbicide (sodium - 2,4, dichlorophenoxyethyl sulfate) | 15 | TEDP (tetraethyl dithionopyrophosphate) | .2 |
| Cyanide (as CN) | 5 | TEPP (tetraethyl pyrophosphate) | .05 |
| 2,4 - D (2,4 - dichlorophenoxyacetic acid) | 10 | Tellurium | .1 |
| Dieldrin (1,2,3,4,10,10 - hexachloro - 6,7, epoxy - 1,4,4a, 5,6,7,8,8a - octahydro - 1,4,5,8 - dimethanonaphthalene) | .25 | Tetryl (2,4,6 - trinitrophenylmethylnitramine) | 1.5 |
| Dinitrotoluene | 1.5 | Titanium dioxide | 15 |
| Dinitro-*o*-cresol | .2 | Trichloronaphthalene | 5 |
| EPN (ethyl- *p* - nitrophenyl thionobenzenephosphonate) | .5 | Trinitrotoluene | 1.5 |
| Ferrovanadium dust | 1 | Uranium (soluble compounds) | .05 |
| Fluoride | 2.5 | Uranium (insoluble compounds) | .25 |
| Hydroquinione | 2 | Vanadium: | |
| Iron oxide fume | 15 | ($V_2O_5$ dust) | .5 |
| Lead | .15 | ($V_2O_5$ fume) | .1 |
| Lindane (hexachlorocyclohexane, gamma isomer) | .5 | Zinc oxide fumes | 15 |
| Magnesium oxide fume | 15 | Mineral dusts: | *M. p./ft.³* |
| Malathon (0,0-dimethyl dithiophosphate of diethyl mercaptosuccinate) | 15 | Aluminum oxide | 50 |
| Manganese | 6 | Asbestos | 5 |
| Mercury | .1 | Dust (nuisance, no free silica) | 50 |
| Mercury (organic compounds) | .01 | Mica (below 5 percent free silica) | 20 |
| Methoxychlor (2,2, diparamethoxyphenyl-1,1,1, trichloroethane) | 15 | Portland cement | 50 |
| Molybdenum: | | Silica: | |
| (soluble compounds) | 5 | High (above 50 percent free $SiO_2$) | 5 |
| (insoluble compounds) | 15 | Medium (5 to 50 percent free $SiO_2$) | 20 |
| | | Low (below 5 percent free $SiO_2$) | 50 |
| | | Silicon carbide | 50 |
| | | Slate (below 5 percent free $SiO_2$) | 50 |
| | | Soapstone (below 5 percent free $SiO_2$) | 20 |
| | | Talc | 20 |
| | | Total dust (below 5 percent free $SiO_2$) | 50 |

After more than 25 years of general underground experience in mines of all types and from extensive study of dusts for 8 years, Harrington [23] concluded that:

Any dust insoluble in the fluids of the respiratory passages and in sufficiently finely divided form to float in the air and be breathed by underground workers will ultimately be harmful to health if the dust is in the air in large quantities and if breathed by workers for considerable periods of time. This applies to nonmineral as well as mineral dusts or mixtures of them and includes coal dust or mixtures of coal and other dusts. There are also definitely harmful mine dusts which are soluble, and some dusts experts appear to believe that so-called insoluble dusts under certain conditions become soluble and are harmful only when soluble.

Silica dusts are stated to be the most harmful of the ordinary dusts to breathe, and considerable quantities of free silica ($SiO_2$) and com-

[23] Harrington, D., Dust and the Health of Miners: Pres. at AIME meeting, New York, N. Y., February 1924, 5 pp.

bined silica are likely to be found in the dust of most hard-rock mines. The percentages of various constituents of rock from mines where dust is known to have caused silicosis are listed in table 2.

The analyses in the table show only that silica is a principal constituent of the rocks at most metal and nonmetal mines. In only one of the samples has the total silica content been separated into free silica and silicates. Exact analyses have little importance because of local variations of rock in mines and because the fine, suspended atmospheric dust does not ordinarily have the same percentages of constituents as the rock from which it comes.

### DUST PRODUCED BY MINING OPERATIONS

Nearly all of the ordinary mining and milling processes tend to produce or disseminate dust unless water is applied or the material and surroundings are naturally wet. Certainly blasting, shoveling, hauling, timbering, dry drilling, chute loading, and other activities in dry metal or nonmetallic mines are likely to make and stir up dust.

The amounts of dust produced by various mining operations have been compared by the Bureau of Mines in investigations made at the Mount Weather, Va., testing adit. Samples of atmospheric dust were collected during the cycle of drilling, blasting, and mucking in a drift face.[24] The working face, in hard basalt, was ventilated only by the natural movement of air, except after blasting and during mucking, when 1,100 cubic feet of air per minute was brought to within 50 feet of the face through canvas tubing. The dust concentrations are given in table 3.

The Bureau of Mines has made studies of the dust concentrations during normal activities in many mines; the amounts listed in table 4 are more or less representative of the amounts of dust associated with various operations.

### DETERMINATION OF DUST CONCENTRATIONS

Because the range in dust concentrations in mining and treating ores and minerals is very great, the instruments used in sampling dusts should operate with efficiency in both high and low dust concentrations. These devices must also be capable of extracting reasonably accurate samples of dusts, which may vary greatly in size of particles. The instruments now in use are not ideal, but they are adequate for the purposes for which dust sampling is done, and one or another can be selected, depending on whether a routine check on dust-control methods or a detailed dust survey is being made.

The impinger apparatus, shown in figures 4 and 5, has been employed as standard apparatus for dust surveys. This instrument and the technique of sampling and enumerating described by the Bureau of Mines [25] [26] have been found of practical value for study-

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[24] Johnson, J. A., and Agnew, W. G., Relative Air Dustiness During Cycle of Operations at Mount Weather Testing Adit: Bureau of Mines Rept. of Investigations 3453, 1939, 7 pp.

[25] Brown, C. E., and Schrenk, H. H., A Technique for Use of the Impinger Method: Bureau of Mines Inf. Circ. 7026, 1938, 20 pp.

[26] Brown, C. E., Midget Microprojector for Dust Determinations: Bureau of Mines Rept. of Investigations 3780, 1944, 14 pp.

TABLE 2.—*Constituents of mine rocks* [1]

| Constituents | Joplin, Mo. | Tonopah, Nev. | Butte, Mont. | Wahai, New Zealand | Vermont | Rand, South Africa | Broken Hill, Australia | Country rock |
|---|---|---|---|---|---|---|---|---|
| Silica ($SiO_2$) | 98.8 | 78.9 | 61.5 | 90.8 | 69.9 | 87.4 | | 62.0 |
| Silica (free) | | | | | | | 12.2 | |
| Silicates | | | | | | | 44.6 | |
| Aluminum oxide ($Al_2O_3$) | .6 | 8.5 | 14.1 | 2.9 | 15.1 | 9.8 | | 16.5 |
| Iron (Fe) | | | 5.8 | | | 1.8 | | |
| Iron oxides | | 5.4 | | .8 | 2.5 | | | 7.0 |
| Iron sulfide (FeS) | | | | 2.5 | | | | |
| Magnesium oxide (MgO) | Tr. | .8 | | .2 | .7 | Tr. | | 1.0 |
| Manganous oxide (MnO) | | 1.6 | | .4 | | | | 2.5 |
| Lime (CaO) | .1 | .3 | | .7 | 2.1 | Tr. | | 1.3 |
| Soda ($Na_2O$) | | | | | 4.7 | | | 1.2 |
| Potash ($K_2O$) | | | | | 4.3 | | | 4.0 |
| Titanium dioxide ($TiO_2$) | | | | | | Tr. | | 2.1 |
| Copper (Cu) | | | 1.4 | | | | | |
| Sulfur (S) | | | 11.2 | | | 1.1 | | .1 |
| Sulfides | | | | | | | 1.3 | |
| Calcium carbonate ($CaCO_3$) | | | | | | | 14.8 | |
| Arsenic (As) | | | .5 | | | | | |
| Lead (Pb) | | | 1.7 | | | | | |
| Zinc (Zn) | | | 3.3 | | | | | |
| Galena | | | | | | | 15.9 | |
| Blende | | | | | | | 21.9 | |
| Other | .5 | 3.5 | | 2.7 | .5 | | .1 | 1.9 |

[1] Sayers, R. R., Silicosis Among Miners: Bureau of Mines Tech. Paper 372, 1925, pp. 6–7.

TABLE 3.—*Dust produced during work at face*

| Operation | Dust, millions of particles per cubic foot of air |
|---|---|
| Face idle | 0.5 |
| Setting up drill | 3.9 |
| Drilling (average) | 5.5 |
| Blowing holes | 16.5 |
| Charging holes | 3.0 |
| After blasting, 5 minutes, not ventilated | 3,300.0 |
| After blasting, 30 minutes, not ventilated | 750.0 |
| After blasting, 60 minutes, ventilated | 40.0 |
| After blasting, 140 minutes, ventilated | 6.0 |
| Mucking, dry, ventilated | 6.0 |
| Mucking, wet, ventilated | 1.5 |

TABLE 4.—*Dust concentrations, mine and mill*

| Operation | Range of dust concentration, million particles per cubic foot of air |
|---|---|
| Mill, crusher floor, dry ore, fan exhausting | 9.7– 15.4 |
| Mill, crusher floor, wet ore, fan exhausting | 7.8– 12.2 |
| Mill, crusher floor, water used, fan exhausting | 1.2– 2.9 |
| Mine, crusher floor, dry ore, fan exhausting | 6.2– 16.3 |
| Mine, crusher floor, water used, fan exhausting | 1.0– 3.2 |
| Haulage drift, wet ore, good ventilation | 1.5 |
| Grizzly on sublevel, wet ore, good ventilation | 1.7 |
| Scram drift, wet ore, good ventilation | 2.0 |
| Ore pocket, at shaft | 4.0– 9.8 |
| Subdrift, near stopes | 7.7 |
| Haulage drift | 4.3 |
| Mucking machine in drift | 24.8 |
| Drift face, wet drilling | 5.0– 18.9 |
| Drift face, dry drilling | 296.3 |
| Pulling chute | 3.4 50.0 |
| Drift, near face after blasting | 24.0–1,000.0 |
| Drift face, hand mucking, dry ore | 92.0 |

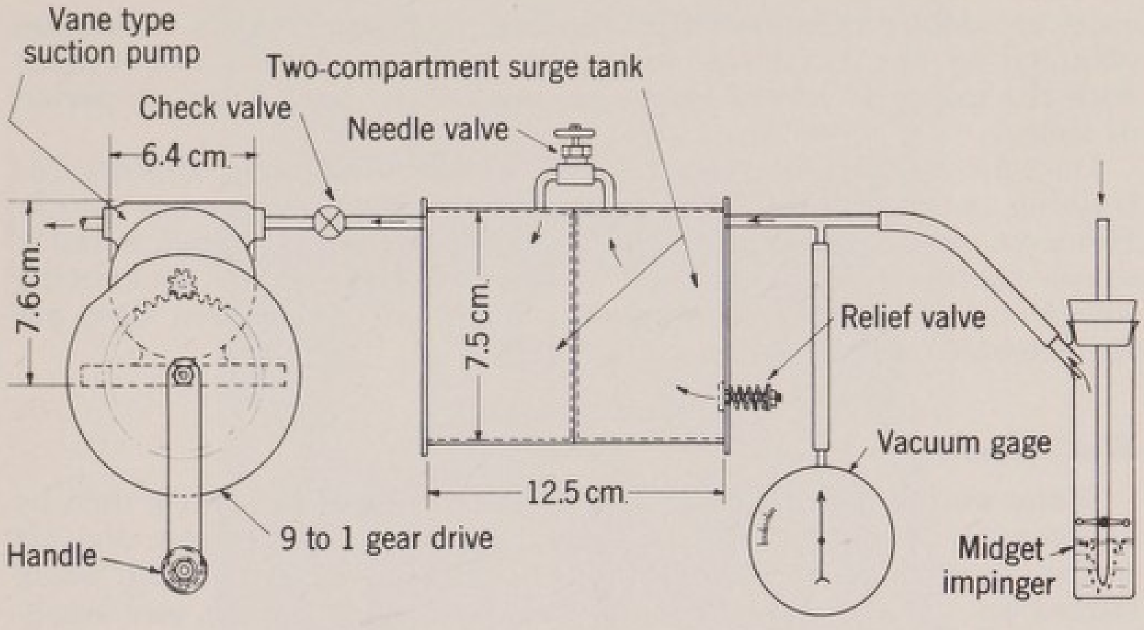


FIGURE 4.—Midget Impinger Sampling Apparatus.

FIGURE 5.—Dust Sampling With Midget Impinger.

ing the dust problem of mining operations. Other devices that also sample dusts over a continuous period are the electrical precipitator, the paper thimble, the electrostatic precipitator, and the hot-wire thermal precipitator.

The konimeter, which samples dust by impinging air at a high velocity against a sticky glass plate, has been described in detail by the Bureau of Mines.[27] The konimeter has been found to be efficient and may be employed for concentrations not exceeding 35 million particles per cubic foot of air; however, this limit usually is suffi-

[27] Littlefield, J. B., Brown, C. E., and Schrenk, H. H., Technique for Routine Use of the Konimeter: Bureau of Mines Inf. Circ. 6993, 1938, 6 pp.

cient in determining whether or not a hazard exists. Samples obtained by the konimeter are grab samples, whereas those taken with the impinger are of larger volumes of air over a longer period of time.

Dust-determination apparatus now available requires considerable training to use, and the laboratory processes involved are not simple. However, once a program of dust control has been adopted, a fairly simple routine sampling method will serve to keep a check on existing conditions. Certainly, atmospheric dust that can be seen does not require continued sampling and analysis.

## DUST CONTROL

### Wet Methods

Water and sometimes other liquids are employed to control dust by suppressing it at its point of origin, by removing it from the air surrounding the source, and by preventing settled dust from being stirred up. Water applied in drilling, loading, handling, and crushing rock or ore kills the dust to the extent of wetting accomplished; with some materials and very fine sizes of dust, other liquids may have to be put into the water to increase the wetting action. In some operations it may be found necessary to prevent dust-laden mist from escaping into the air, since dust-laden vapor may evaporate, leaving dust on the walls or in the air. Inhalation of such vapors introduces the contained dust into the lungs, sometimes in harmful amounts. Where mixtures of air and water pass through drill steel, dust escapes into the surrounding air, although in much smaller amounts than in dry drilling. Where water alone is used to clear the hole while drilling, very little dust is introduced into the air. Long-hole diamond drilling is less dusty than ordinary drilling, as the holes are deep and more water is used.[28]

Dust is washed out of the air by sprays or atomizers operated when excessive quantities are being produced, as at a face after blasting. Fine sprays or curtains of mist are probably more effective in removing microscopic particles than heavier streams, but the degree of improvement may be less than is anticipated. However, water sprays do reduce the dustiness, and the method is particularly useful underground. A tank car with spray nozzles for allaying dust in haulage drifts is shown in figure 6, and an automatically controlled spray for wetting the tops of loaded trips is pictured in figure 7. Figure 8 shows a water curtain in a drift, and figure 9, misting nozzles installed at the outlet of an exhaust-air duct to settle dust in mines.

Wetting surfaces on which dust settles to cake and hold fine particles or washing down these surfaces to remove accumulations will prevent redispersion of such dust into the air. Figure 10 is a view of a shrinkage stope where a pile of broken ore is being wet down with a hose stream. The details of an air-water blast for use in drifts and crosscuts during and after blasting are given in figure 11, and in figure 12 the device is shown installed at the face of a drift.

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[28] Johnson, E. W., and Cash, F. E., Diamond Drilling of Blast Holes, Lake Superior District Iron-Ore Mines: Bureau of Mines Inf. Circ. 7317, 1945, 11 pp.

FIGURE 6.—Fine-Spray Nozzles on Tank Car.

## Dry Methods

The interest in dry-dust collectors lapsed with the general adoption of wet drilling in metal and nonmetallic mining and other hard-rock operations. The recent advent of rock bolting for roof and wall support, with its attendant drill-dust problem, particularly in coal mines, has renewed interest in the dry dust collector, and several have been developed for use in connection with roof drilling in coal mines. Informal tests of some collectors by the Bureau of Mines aided in their development, and the Bureau has issued approval requirements under which dry-dust collectors may be approved for all types of rock drilling in coal mines.

The work on dry-dust collectors, reviewed by Berger in 1952,[29] described the types of collectors and stressed that proper maintenance and use of dry-dust collectors are essential if adequate protection against dust exposure is to be obtained.

Fixed installations, such as crushers or screens, where an unusual amount of dust is made, may be provided with exhaust systems that remove the major part of the dust directly from the unit so that it does not spread into the surrounding air. Dust-collecting systems

[29] Berger, L. B., Progress in Development of Dry Dust Collectors: Pres. at meeting of Coal Min. Sec., Nat. Safety Cong., Chicago, Ill., Oct. 22, 1952, 11 pp.
Berger, L. B., Types of Dust Collectors Used in Conjunction With Roof-Bolt Drilling: Pres. at meeting of Coal Min. Inst. America, Pittsburgh, Pa., Dec. 12, 1952, 9 pp.

FIGURE 7.—Car Spray With Automatic Control.

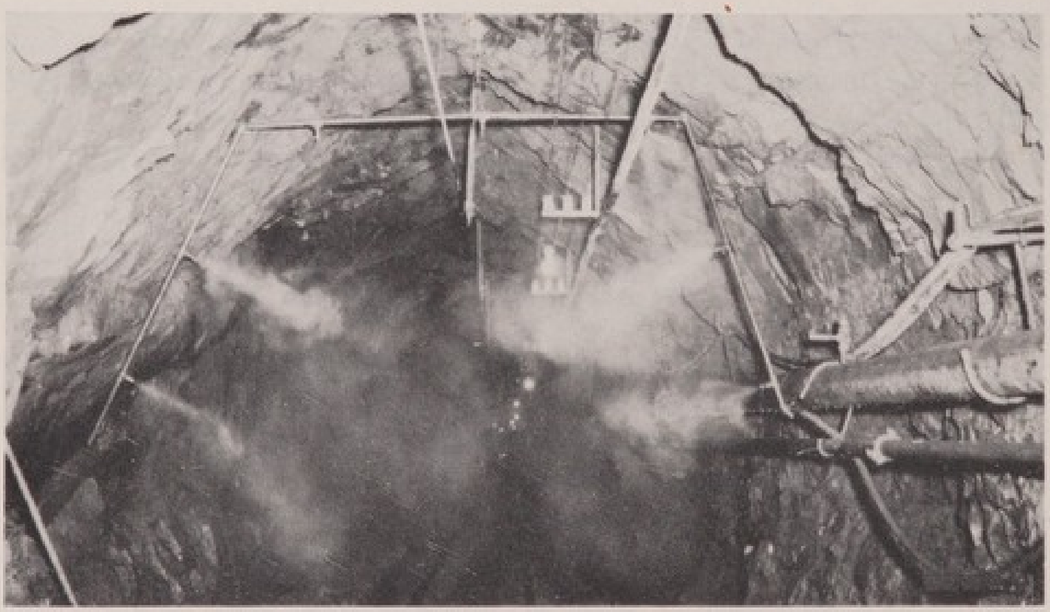

FIGURE 8.—Water Curtain in Drift.

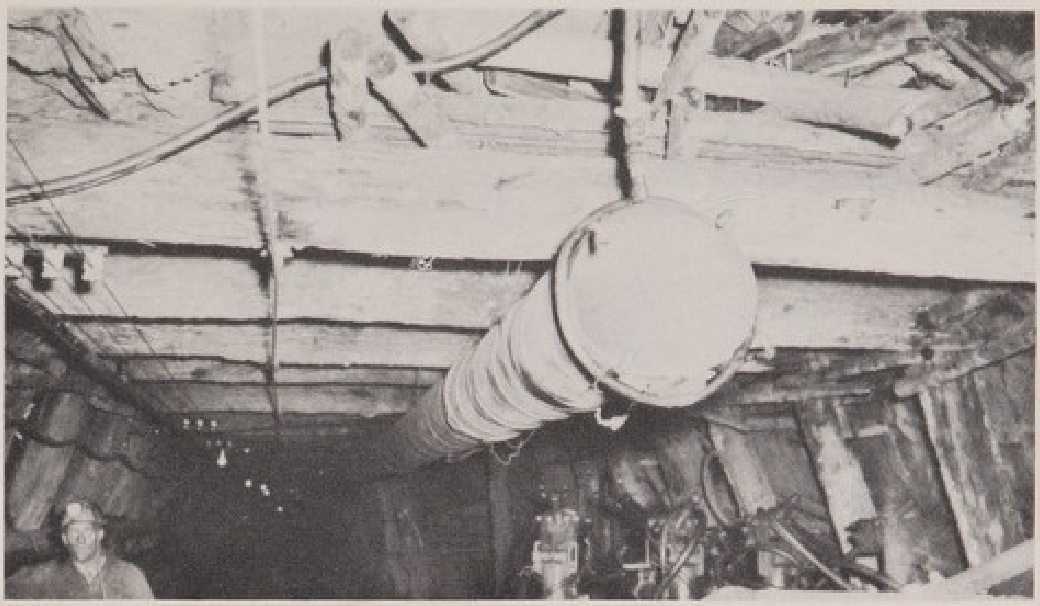

FIGURE 9.—Misting Nozzles at Outlet of Air Duct.

FIGURE 10.—Watering in Shrinkage Stope.

have been successfully applied to surface plants at many mines; for example, the installation shown in figure 13 removes the dust from over a conveyor belt in a shaft house.

Percussion-type drills are rarely operated dry when used underground, except when blockholing and sometimes when collaring holes. These practices create objectionable health conditions, because the dust-laden atmosphere usually is not removed by adequate ventilation. In the interest of health, dry drilling should not be done under any circumstances at an underground location. Devices de-

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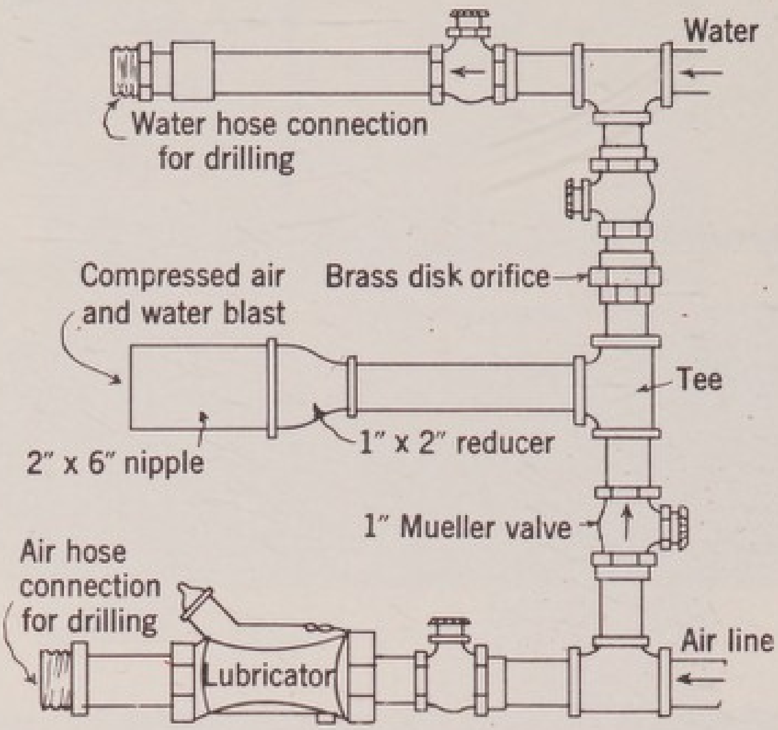


FIGURE 11.—Air-Water Blast for Drifts and Crosscuts.

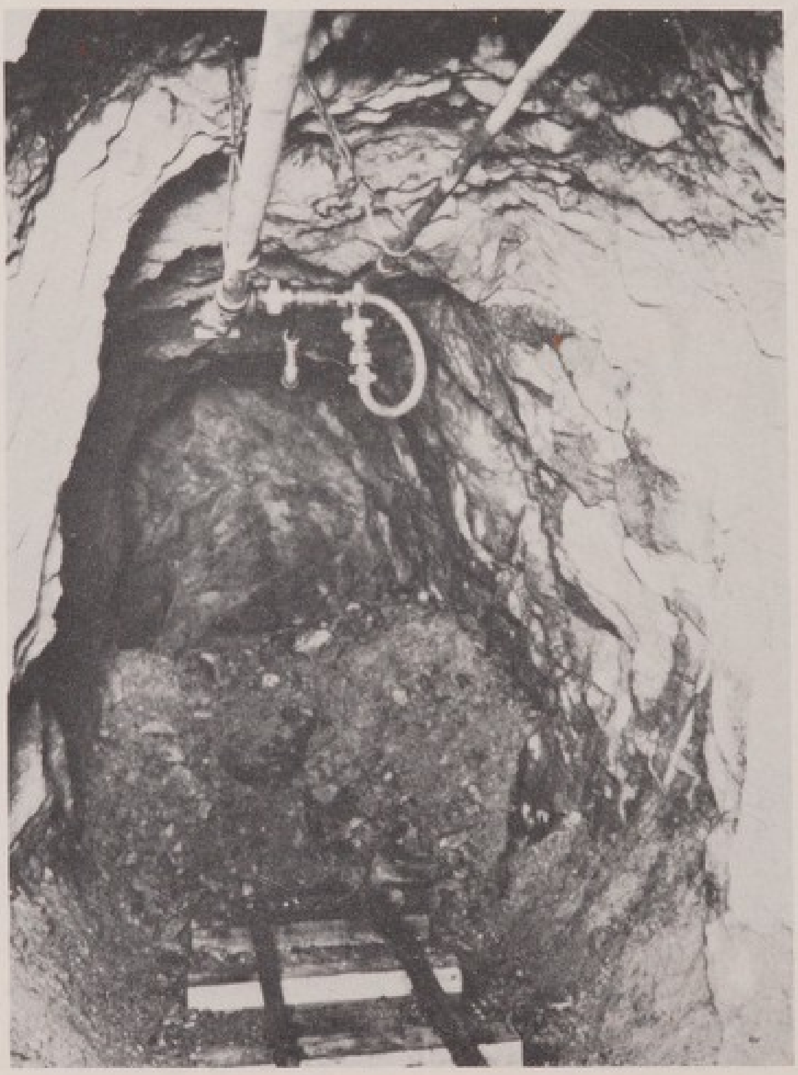

FIGURE 12.—Air-Water Spray at Face of Drift.

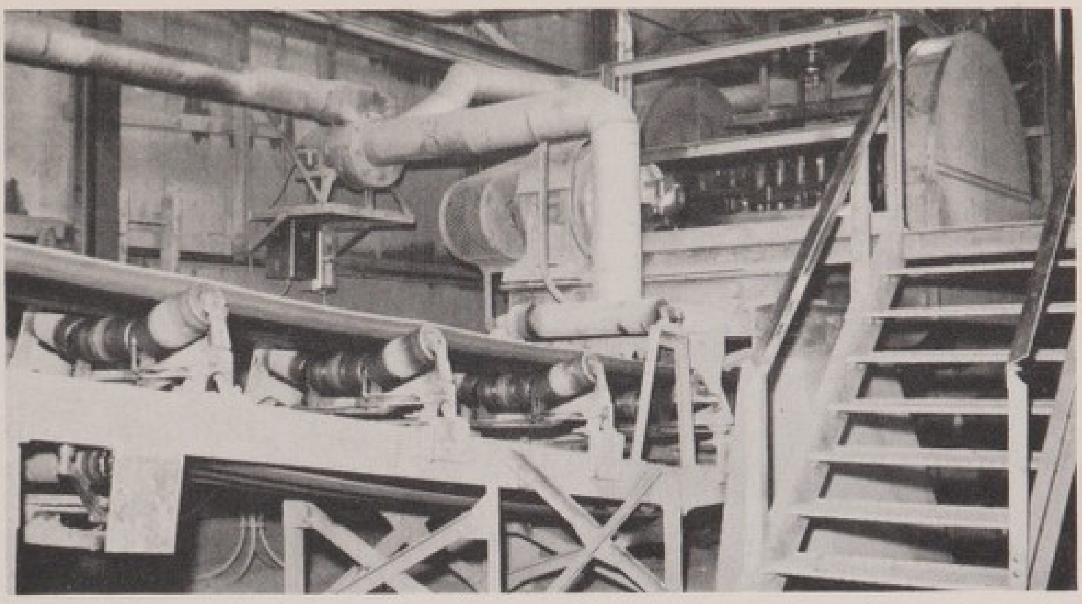

FIGURE 13.—Dust-Collecting System Over Conveyor in Shaft House.

signed to collect dust from drilling operations are not in general use either because of design or the time and effort required to service them; therefore, water, which usually is available in metal and nonmetallic mines, should be used in all underground drilling operations. Pneumatic drills with an axial water feed should be so constructed that the drill and water feed are operated simultaneously. Controlled and adequate ventilation is one of the most effective means of alleviating all objectionable dust conditions.

At least two companies (Ingersoll-Rand and Goodman Manufacturing) manufacture dry drills for which they claim dust counts as low as or lower than those obtained with wet drills. A demonstration of one of these machines was observed in Canada, and its operation was apparently dust-free. The information given by the mine management was that dust counts in the operator's breathing zone were approximately 40 percent less than those prevailing with wet machines where water was used while collaring and drilling. These drills are adapted for use with an offset or regular feed leg, with jack leg, or for shell mounting with automatic feed.

A dust collector, known as the Hunborn, in general use in Europe for drilling operations, is described in Mine and Quarry Engineering.[30] This article was abstracted and is presented as follows:

The compactness of the "dust extractor" enables it to be transported easily to inaccessible and distant parts of the mine; for working under low headroom conditions, special types have been constructed. For shaft-sinking operations, two dust extractors are fitted into a kibble (iron bucket used for hoisting rock) capable of servicing four drills.

The principle of operation of the standard-type extractor is that a constant vacuum is created by means of a compressed-air ejector built into a filter box; this is transmitted to the bit by means of a suction hose, the suction head, and the hollow drill steel. The bit is provided with two or more suction channels so that a constant stream of air enters the hole between the drill rod and the wall of the hole while it is being drilled. The drillings are carried away by the air stream via the holes in the bit and into the filter box. Dust is filtered from the air stream by passing through three cloth filtering bags, and the retained dust falls into the container, where it is either settled with water or collected into a bag. To avoid damage in normal use, the filters are protected

[30] Mine and Quarry Engineering, Drilling Dust Extractor: September 1954, pp. 416–417.

by a metal drum and a funnel prevents them from becoming clogged with water so that drilling is possible even in wet formations. The dust collector holds the drillings from approximately 80 feet of hole.

Apart from its application with any type of percussion drill, this unit can be used with rotary or other types of drills. It is claimed that dust-free dry drilling in all kinds of rock and ore is obtained and even when drilling vertically downwards the dust is exhausted from the hole without difficulty. Holes of 100 feet and more in length are stated to be within the capabilities of the extractor.

Tungsten-carbide-tipped bits are used with the dust extractor. Because the hole is kept clean, unnecessary disintegration of drill chippings is avoided, resulting, it is claimed, in an increase of drilling speed and bit life. Reverse cutting teeth on the periphery of the bit crush small pieces of stone that have fallen down the drilled hole, which would make retraction of the drill difficult.

The use of dust collectors or extractors would certainly be of material benefit in lessening the dust hazard for blockholing in opencut mines and quarries where water seldom is used.

## Ventilation

Circulation of clean air through working places in sufficient volume to dilute dust that remains in suspension, despite other means of control, has been found to be an effective method of keeping the dust concentration within safe limits. Air currents taken into working places, including air circulated from one active section to another, should be relatively free from dust.

Split systems of ventilation may be designed to remove dust from working faces and take it directly to return airways without passing through other active places. Blower fans and tubing usually are needed to bring the ventilating current of air close to the face at a velocity sufficient to sweep away the dust as it forms.

## Respiratory Protection

The primary consideration in controlling exposure to dust should be to prevent harmful contamination of air that is breathed. Where such measures cannot be applied or are ineffective, for any one of a number of reasons, respirators will be required for protection, either as a primary method or as a means of supplementing other methods. Respirators are classed by the Federal Bureau of Mines as: Supplied-air respirators, hose type; supplied-oxygen respirators; self-contained oxygen breathing apparatus; air-purifying respirators; chemical-filter and mechanical-filter types of gas masks; and dust and fume respirators.

Devices most commonly used for protection against dust hazards are the air line or hose type, supplying pure air from an outside source, and the mechanical-filter type that removes dust particles as air is breathed through a filter. These devices are efficient when properly maintained, but they are inconvenient and often uncomfortable to wear. Air-line respirators, supplying air at reduced pressure from the compressed-air line, have been used to protect drillers in mines; in most cases the equipment has later been discarded in favor of dust control by water and ventilation. Mechanical filter-type respirators are widely used both underground and on the surface where, for various reasons, other dust-control methods are not adequate. Figure 14 shows an attendant using a filter-type respirator at an underground shaft pocket.

Respirators should never be used as a primary method of controlling exposure to dust. To require their use as a sole means of protection

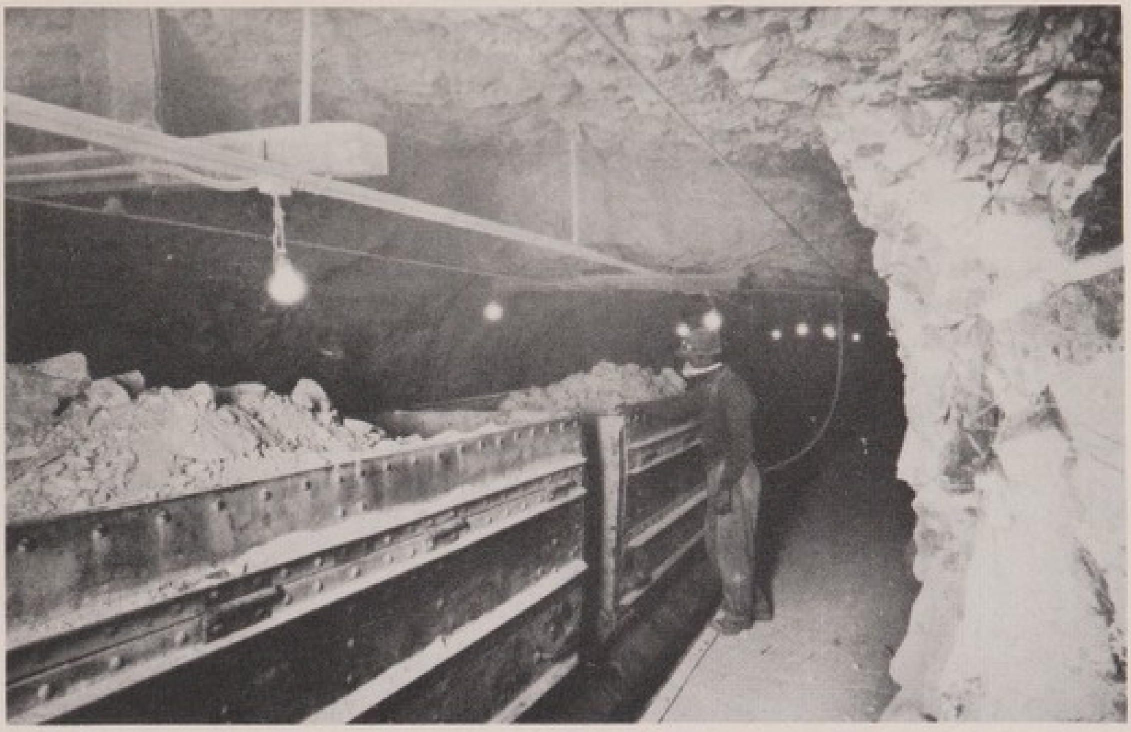

FIGURE 14.—Respirator Worn at Shaft-Pocket Ore Dump.

against harmful dust concentration is an admission on the part of management that proper controls are not used.

The Bureau of Mines has established standards of approval for respiratory protective devices of all types to aid manufacturers in developing and marketing safe and suitable equipment and to aid the purchaser in securing the type of equipment needed. A current list of respiratory protective equipment, which has been tested and approved, may be obtained from the Bureau of Mines,[31] in addition to other information on the subject.[32]

### MEDICAL CONTROL OF DUST HAZARD

## Physical Examinations

The effect of exposure to dusty atmospheres may be pronounced on some persons, whereas others will show no signs even after longer exposure. Every person employed under possibly hazardous dust conditions should undergo a thorough physical examination before entering on duty and at least yearly thereafter. Persons found to have developed symptoms of respiratory trouble should be removed from dusty air if possible to prevent aggravation of their condition. A. J. Lanza [33] observes that:

> It is not practicable to lay down definite rules. Obviously, no one with active or recently active tuberculosis should be exposed to silica dust, nor anyone suffering from other pulmonary diseases, especially if of an ineffective nature, which would tend to increase the hazard. On the other hand, there often is no good reason for rejecting an applicant who already has silicosis if the silica hazard in the work place involved is under control and if the workman's physical condition is properly supervised thereafter. This is an important consideration where the industry is a dominant one in its locality and other opportunities for work are limited.

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[31] Davenport, S. J., and Berger, L. B., List of Respiratory Protective Devices Approved by the Bureau of Mines: Bureau of Mines Inf. Circ. 7636, 1952, 16 pp.

[32] Schrenk, H. H., and Pearce, S. J., Selection, Use, and Maintenance of Respiratory Devices: Bureau of Mines Inf. Circ. 7236, 1943, 12 pp.

[33] Lanza, A. J., Silicosis and Asbestosis: London, Oxford Univ. Press, 1938, 439 pp.

### Possible Uses of Inert Dusts as Preventives

For many years, some investigators considered certain dusts (coal, hematite, shale, limestone, cement, and clay) not only harmless in themselves but as exercising a favorable effect when inhaled with more dangerous dusts. More thorough methods of investigation gradually revealed the fallacy of using the so-called protective dust to prevent or cure diseases caused by the dangerous dust.

As data accumulated tending to show that all dusts may be harmful if breathed in large amounts over long periods, the announcement in 1939 by Canadian investigators that inhalation of aluminum dust would prevent silicosis was received with skepticism by many persons familiar with the effects of exposures to dusts. By subsequent experimental study and practical application of the treatment to men afflicted with silicosis, it is claimed to be definitely established that aluminum is a harmless means of preventing silicosis in human beings and ameliorating the symptoms where this dust disease has gained a start.

A number of authorities on silicosis agree, however, that the only certainty about the use of aluminum is that it will inhibit the action of silica in experiments on animals. In man silicosis develops slowly in most instances, and only longtime, carefully controlled administration of the treatment will tell whether the results obtained with animals are applicable to man. It is admitted that aluminum powder cannot restore to normal lung tissue that already has undergone fibrotic change. The statement has been made, however, that its use is followed by beneficial results in a significant number of cases, chiefly in ameliorating symptoms and increasing capacity for work. All investigators have not obtained the same results with the treatment as have the men who developed the method.

British investigators have raised the point that, as 1 part of aluminum dust is required to render inactive 99 parts of quartz, increased amounts of aluminum would be needed to counteract the toxic effects of air containing heavy concentrations of siliceous dust. The proper remedy in such circumstances would be adequate dust control—not the use of more aluminum. Experiments have indicated that concentrations of aluminum hydrate used in the treatments had no effect on normal animals, but excessive concentrations sometimes had an unfavorable influence on native susceptibility to tuberculosis. Whatever the benefits of the treatment may be, it should not be employed as a substitute for established methods of ventilation and engineering control of dust. General application of aluminum treatment of workers exposed to silica dust probably should be delayed until careful experiment has shown, without a doubt, that the treatment is harmless and effective in preventing silicosis in men.

## SANITATION AND HYGIENE

Living and working places at mines should be kept clean to prevent infection and disease. Persons who live and work in these places should take the same care by applying commonsense principles of cleanliness. The measures usually advised by authorities for protection against metallic poisons and irritants, as well as against organic infections and disease, stress proper care of persons.

## DRINKING WATER

Pure drinking water may be defined as water that contains no substance injurious to health.[34] Water in and about mines may be contaminated at any point from its source to the user; and it can be purified by distillation, boiling and filtering, or chemical treatment. Where men do not carry containers from which to drink, some kind of drinking fountain should be installed, constructed so that the mouth of the drinker does not touch the outlet.

Where the climate is warm or the mine temperatures high and men perspire freely while working, salt tablets should be provided and workers should be encouraged to use them.

## HOOKWORM

A Bureau circular[35] describes hookworm as usually limited to people who work on the surface in tropical or subtropical climates, but in some regions of the temperate zone it has been a disease among miners. The disease spreads under conditions that favor the hatching of hookworm eggs and the growth of the larvae. Eggs from the excrement of infected persons may develop into larvae in the dirt of a mine where temperature and moisture are favorable. If the larvae come in contact with a man's skin, they may pierce it, especially between the toes or fingers. Infection is prevented by sanitary sewage disposal and avoiding contamination.

## ATHLETE'S FOOT

An article in Safety Engineering, August 1939, states:[36]

The disease popularly known as "athlete's foot" is caused by a varied group of skin parasites. It is not known why the disease was given this name, but perhaps a firm with a remedy to sell and little knowledge of the conditions coined it. As a matter of fact, athletes are no more frequently affected than others. In studies made, the youngest recorded case was 7 months and the oldest, 90 years. Men are affected more frequently than women. The greatest number of cases in men may be attributed to the fact that they wear more bunglesome, more poorly aerated shoes, and their occupations require considerable standing with greater perspiration of the feet.

Various remedies have been used in cure and prevention of the disease. Difficulty in cure arises largely from inability of the antiseptic to contact the organism. Salicylic acid has been used to soften the skin so that various preparations of sulfur, etc., in salves could contact and kill the organism. Foot baths so placed that those leaving showers and pools walk through them have been widely used as a measure to control the condition. A dusting powder for the feet, containing boric acid, has yielded good results.

For athlete's foot, foot and skin hygiene are essential. Frequent cleansing of feet, change of socks, and airing of shoes are of great importance. Putting a clean pair of socks on dirty feet may do more harm than good, for in removing the socks one may remove byproducts of the organism that may hold its growth in check. It is necessary to wash the feet first, for then the dead scales and tissue are removed on which the organism grows and flourishes. The feet should be kept as dry as possible for moisture encourages the growth of the organism.

The question of use of the foot bath was reconsidered by the medical and safety departments of a large mining company after several years' experience. It was concluded that prevention of athlete's foot was a matter of individual responsibility in care of the feet, and that too much dependence was placed on the foot baths. Therefore, they were no longer maintained, and the men were advised to use wooden sandals in the showers and in walking over the

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[34] Sayers, R. R., Sanitation in Mines: Bureau of Mines Miners' Circ. 28, 1924, 16 pp.

[35] Williams, R. C., Miners' Safety and Health Almanac for 1919: Bureau of Mines Miners' Circ. 24. 1918, 48 pp.

[36] Williams, Dr. J. W., Athlete's Foot: Safety Eng., vol. 78, No. 2, August 1939, p. 44.

floors of the "drys." Thorough drying of the feet and use of foot powders and antiseptic solutions are advised, particularly if signs of infection appear. Daily changes of socks and shoes are also advocated for affected persons.

This article on athlete's foot is just as true today as it was in 1939.

### BOILS

Dr. A. L. Murray of the Bureau of Mines reported that the occurrence of boils among employees of mines in a western mining district was influenced by the following factors.

1. Abnormally high temperatures throughout the mine working, together with a nearly saturated atmosphere, which caused profuse sweating and retarded heat elimination.
2. Acid mine water, sulfur gases, and arsenic fumes. The water was high in iron sulfate, and oxidation started on exposure of the water to air.
3. Clothing rubs, slight bruises, infiltration of dirt particles into the skin, and lowered body resistance from general atmospheric conditions were other causes of boils.

The condition can best be prevented by lowering the wet-bulb temperature, by cleanliness, and by removing irritating dusts and gases.

### SEWAGE DISPOSAL

Improper or faulty methods of sewage disposal underground help to spread intestinal diseases, notably typhoid fever, dysentery, hookworm, and other parasitic infections. Underground and surface privies should be constructed so as to prevent the spread of disease germs by flies, mice, rats, or water. Tight cans or cans that can be removed and cleaned are provided at many operations; a disinfectant is usually put in the container to kill germs and odor. Flush toilets rarely are installed underground, but satisfactory installations of this type have been made in some metal and nonmetallic mines.

Septic tanks, either steel or concrete, are connected to the toilets by 3- or 4-inch lines; the tanks operate indefinitely without cleaning unless the action of the bacteria is stopped by acid water entering the tank or by some other accident. Action of bacteria in the tank is started or increased at any time by adding a yeast mixture or spoiled meat. Clear water overflow from the tanks flows by gravity to the mine sumps.

### CHANGE HOUSES

Included in change houses or change rooms are not only those items necessary for biological or sanitary reasons, such as toilets and lavatories, but also those facilities that add to the comfort and convenience of the worker or are deemed essential by nature of the occupation, such as drinking fountains and locker- and shower-room equipment.[37] If, however, these facilities are not kept clean and attractive, employees will be discouraged from taking advantage of them, and the very purpose of the installation will be defeated.

The installation of adequate bathing and toilet facilities for mine employees contributes to both health and efficiency.[38 39 40] Laws of

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[37] Bureau of Mines, Accident Prevention in Nonferrous-Metal Processing Plants. 3. Smelters, Refineries, and Reduction Plants: Handbook, 1955, 380 pp.
[38] Harrington, D., and East, J. H., Jr., Change Houses at American Mines: Bureau of Mines Inf. Circ. 7423, 1947, 44 pp.
[39] Cash, F. E., and Stott, R. G., Change Houses in the Lake Superior District: Bureau of Mines Inf. Circ. 7489, 1947, 26 pp.
[40] Cash, F. E., and Petersen, M. S., Safe Equipment, Guards, and Practices, Lake Superior District Iron-Ore Mines: Bureau of Mines Inf. Circ. 7454, 1948, 98 pp.

many mining States provide for suitable change houses at mines. An example follows from the California mining law.

1. The operator of every mine, except as provided in paragraph 3, shall provide a dressing room or a change house at a place convenient to but not within 100 feet of the mine opening (if the dressing room or change house is made of combustible materials) for the purpose of drying the clothing of the persons employed in and about the mine, and such dressing rooms or change houses shall be provided with adequate means of heating and lighting. Such dressing rooms or change houses shall be available to the men at all times when they are going on or off shift and shall be equipped with shower baths having hot and cold water, at least one shower being provided for each 15 men on a shift working in the mine. Such change houses shall be kept reasonably clean and in sanitary condition.

2. It is recommended that working clothes be either elevated by suitable means, such as chains, to the upper air of the change house, or that separate rooms be used for working and street clothes.

3. Mines employing less than 10 men and having unsuitable water on the property for washing and bathing purposes shall be exempt from the shower-bath provision of paragraph 1 of this article; but such mines shall provide their employees with washing and bathing facilities that are reasonably clean and sanitary.[41]

The logical location for change rooms is along the route to and from work and near the entrance to the mine. Some underground mines have separate change rooms for underground and surface employees, and several have a covered travelway or tunnel from the change room to the shaft. Some opencut mines have separate change rooms for the overburden and ore crews.

Change houses or rooms should be lighted adequately by natural or artificial means and heated and ventilated preferably by air-conditioning units. If stoves or radiators are used for heating, the stoves should be guarded and the radiators elevated. The interior arrangement is largely a matter of choice and governed by the individual mine.

Details of desirable features and equipment in change houses can best be given by descriptive photographs.

Figure 15 shows a boot bath in a tunnel or protected travelway connecting the shaft and work-clothes room. The boot bath facilitates cleaning and drying the boots and keeping the room clean.

Figure 16 shows a portion of the shower room in a modern change house. The water-supply lines are enclosed within the walls, reducing the hazard of burns from hot-water lines to a minimum. The shower heads and valve stems extend through the walls. This room is piped for liquid soap, and the dispensers are between the shower valves. The concrete floor has a nonslip surface, and footrails are provided.

Figure 17 shows two types of basins used in change houses: *A* is the circular or semicircular type operated by hand or foot valve, with the soap dispenser over the basin. *B* is the conventional lavatory; usually, the circular-type lavatory is used in the work-clothes room, and the conventional type is installed in a section off the street-clothes room.

A few mines furnish towels for their employees. At some mines (fig. 18) a room is provided between the showers and the street-clothes room for dispensing towels. The change-house attendant puts the clean towels on the numbered rack and collects the used towels from a laundry bin in the street-clothes room. The employee's work number is on a towel and the rack, and one towel, laundered daily, is used by him until worn out.

[41] Department of Industrial Relations, Mine Safety Orders: Industrial Accident Commission, State of California, Order 1764, p. 76.

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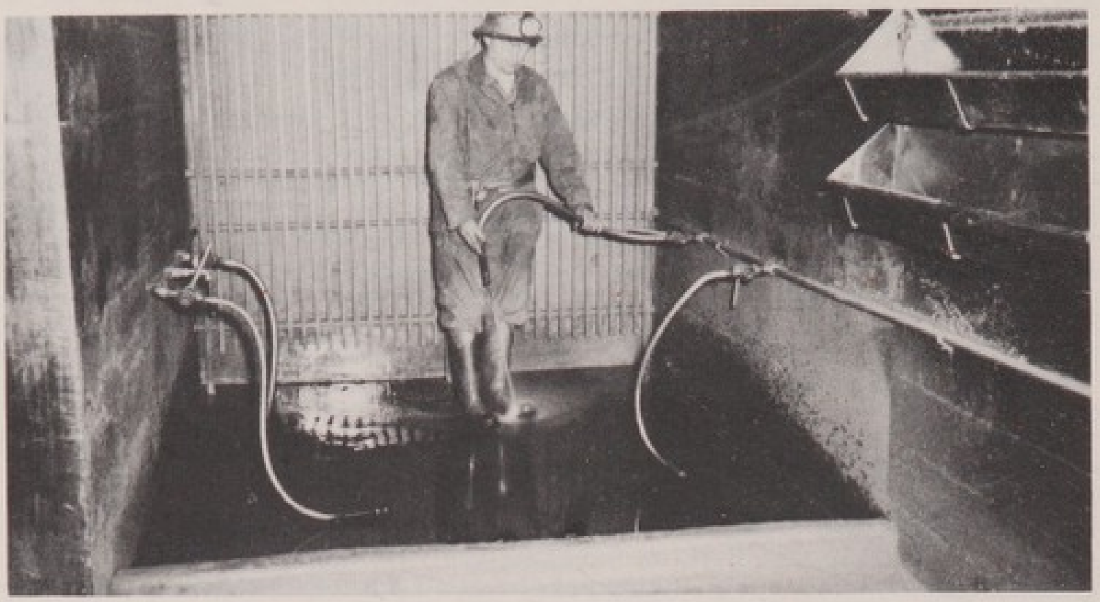


FIGURE 15.—Boot Bath.

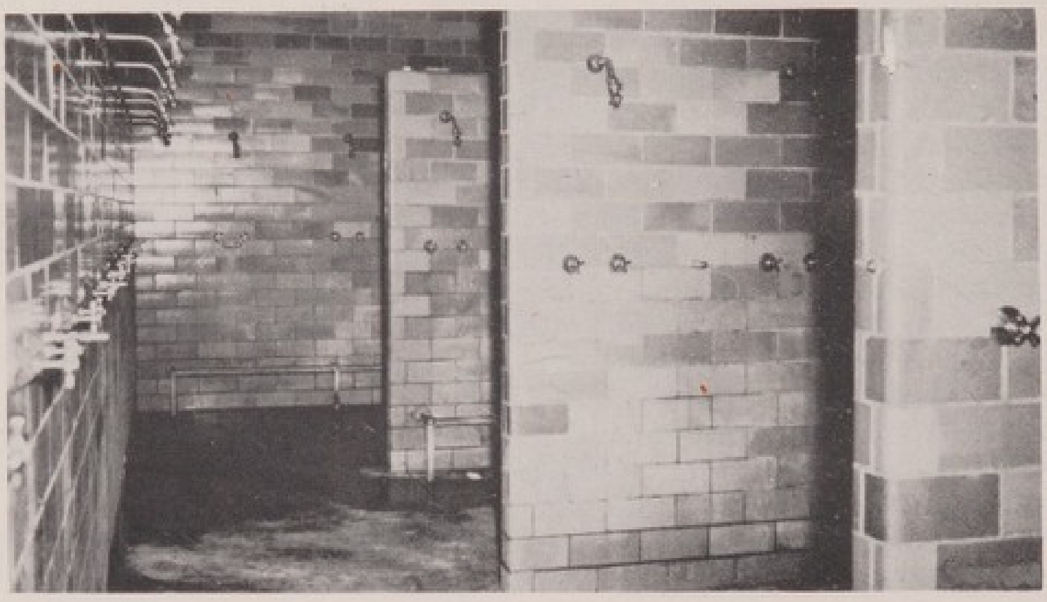
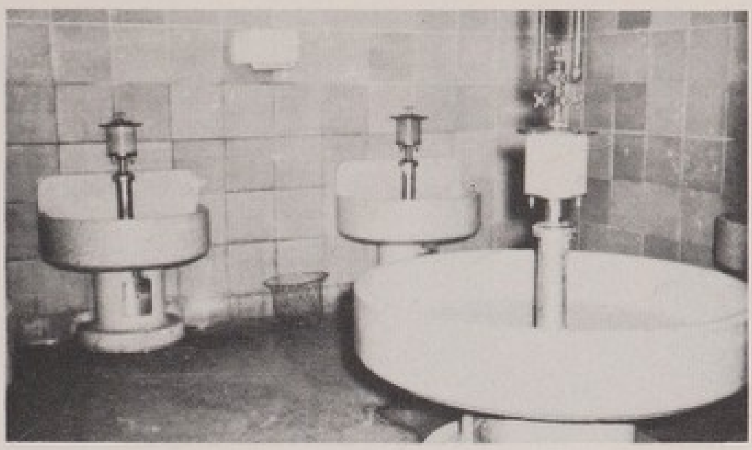


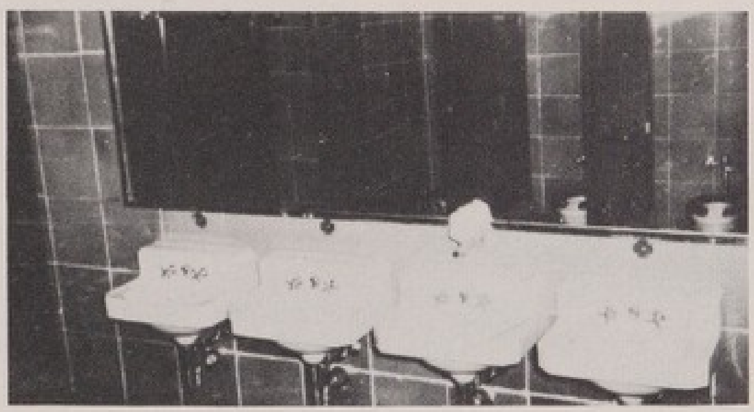
FIGURE 16.—Shower Room.

Generally, toilet facilities are provided in two rooms adjoining both the street- and work-clothes rooms. In figure 19 the wash basin is in the foreground, the stools and urinals in the rear, the paper-towel dispenser on the partition, and an improvised trash can on the floor.

Separate rooms for street and work clothes are desirable. Steel lockers should be provided for street clothes. The lockers should have solid, sloping tops, and screened doors and bottoms and be elevated to facilitate ventilation and cleaning the floor. Chain hangers should be provided for the work clothes, which should hang from the ceiling on a chain so that air from the ventilating ducts can dry the clothes. The floors should have a finish that will reduce slipping and should be washed after each shift and disinfected frequently.



*A*



*B*

FIGURE 17.—*A*, Circular or Semicircular Wash Basins Operated by Hand or Foot Valve; *B*, Conventional Wash Basins.

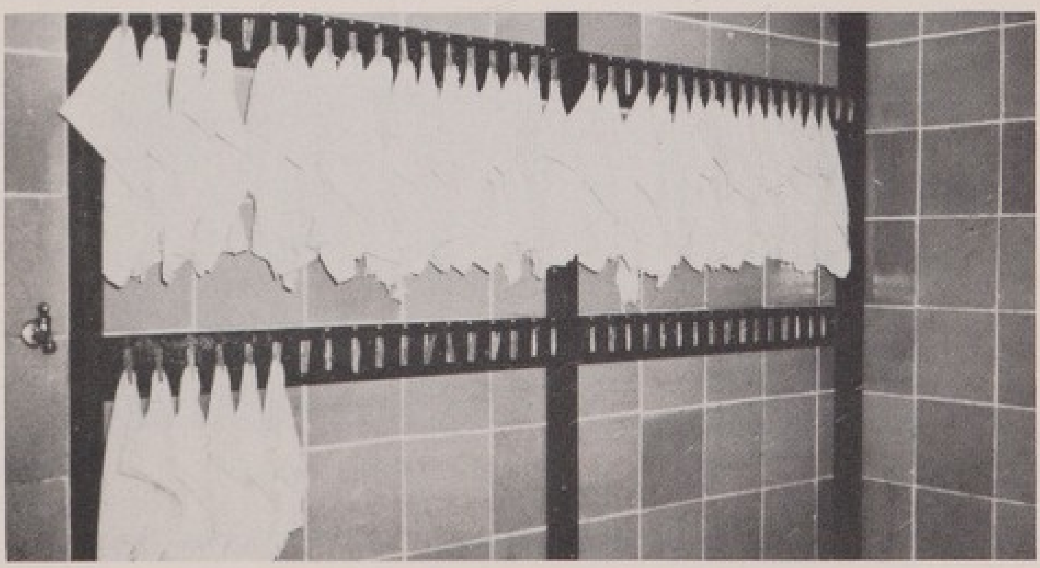
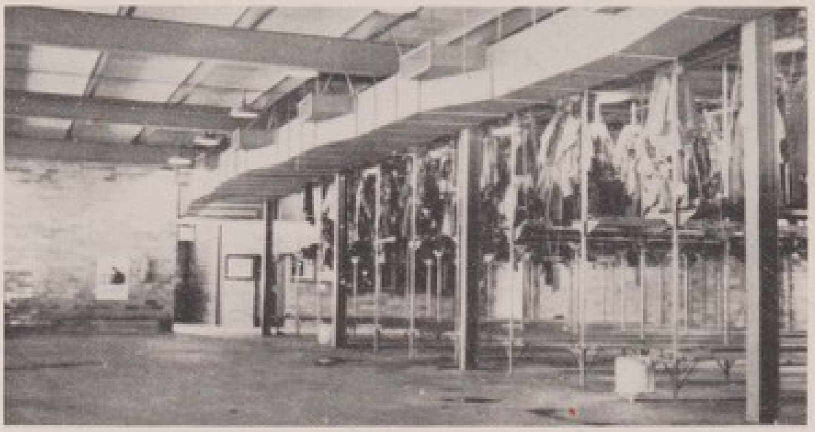
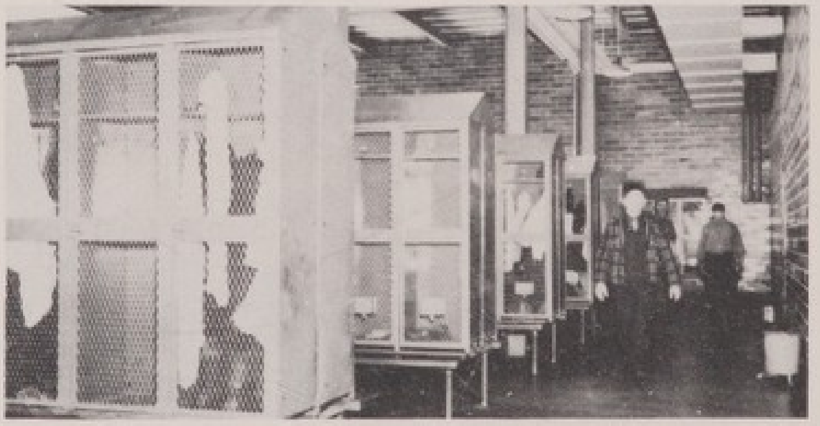


FIGURE 18.—Towel Rack.

FIGURE 19.—Toilet Facilities.



*A*



*B*

FIGURE 20.—*A*, Work-Clothes Room; *B*, Street-Clothes Room.

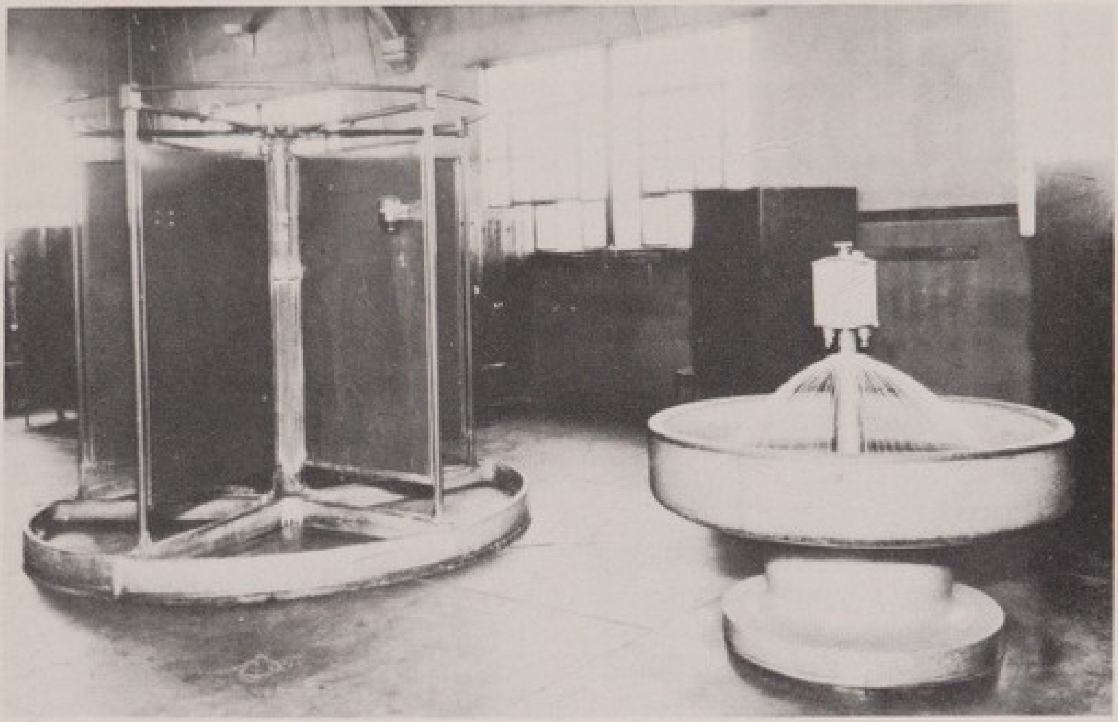


FIGURE 21.—Change Room for Small Mine.

Figure 20 shows the work- and street-clothes rooms in two change houses: *A* is the work-clothes room equipped with hook-and-basket hangers. *B* is the street-clothes room with steel lockers; the lockers are at seat level above the floor to facilitate cleaning the floor and have sloping tops to prevent storing anything on them. (Note the ventilating ducts near the ceiling.)

For a small mine all facilities may be housed in one room, except that the toilets may be enclosed with curtain walls or half partitions, as shown in figure 21.

Based on the maximum number of employees on any one shift, the following equipment is suggested for a change house or room: [42]

1. Separate accommodations for street and work clothes, preferably a steel locker for street clothes and a chain hanger for work clothes.
2. One adjustable shower head for each 10 employees, with a minimum of 2 heads.
3. One toilet for each 20 employees, with a minimum of 2 toilets.
4. One upright urinal for each 20 or fewer employees.
5. One lavatory or equivalent basin space for each 20 or fewer employees.
6. At least two sanitary drinking fountains.

## MISCELLANEOUS HAZARDS

Disabling occupational injuries in the United States totaled approximately 2 million in 1952.[43] Of these, about 1,500 were fatal, and 85,000 resulted in some permanent impairment. Table 5 shows the

[42] Cash, F. E., Suggested Standards for Change Houses: Pres. at annual meeting, Am. Pub. Health Assoc., San Francisco, Calif., Oct. 31, 1951, 14 pp.

[43] National Safety Council, Accident Facts: 1953, pp. 30, 31, and 37.

approximate number of injuries involving different parts of the body, percentages of the total injuries, and percentages of all compensation paid. The average compensation was $369 per injury, and the more frequent sources (with percentages) were: Handling objects, 22 percent; falls of persons, 17 percent; machinery, 16 percent; falling objects, 13 percent; handtools, 7 percent; vehicles, 7 percent; and other sources, 18 percent.

TABLE 5.—*Occupational injuries, percentage of total injuries, and percentage of all compensation paid, 1952*

| Part of body | Number of injuries | Percentage of total injuries | Percentage of total compensation paid |
|---|---|---|---|
| Thumbs and fingers | 320,000 | 16 | 13 |
| Legs | 240,000 | 12 | 12 |
| Arms | 180,000 | 9 | 12 |
| Hands | 180,000 | 9 | 6 |
| Feet | 160,000 | 8 | 6 |
| Head, except eyes | 120,000 | 6 | 9 |
| Eyes | 80,000 | 4 | 3 |
| Toes | 80,000 | 4 | 2 |
| Trunk | 540,000 | 27 | 28 |
| General | 100,000 | 5 | 9 |

## HANDLING MATERIALS

Handling materials and equipment is the greatest source of injuries in most industries. In metal and nonmetallic mining 13.6 percent of all injuries from 1932 to 1954 were charged to handling materials. Records of the Bureau of Mines (tables 6 and 7) show 51 fatal injuries at underground mines and 5 at opencut operations during the 23 years; 13 percent of the nonfatal injuries at underground mines and 20 percent of those at opencut mines were from handling materials.

Injuries (fatal and nonfatal) from handling materials at underground metal and nonmetallic mines declined from an average of 1,416 a year between 1932 and 1941 to 1,180 a year between 1942 and 1951. In these decades injuries from all causes declined from 11,375 to 8,772.

The injury-frequency trend from handling materials at underground mines (fig. 22) was upward, with an increase of 15 percent from 1932 to 1954. There were during these 23 years, 51 fatal and 29,902 nonfatal injuries (total, 29,953), which is 13.6 percent of the total injuries from all causes.

From 1950 to 1954, the trend was sharply upward, with an increase of 54 percent in injuries. There were during these 5 years 16 fatal and 5,970 nonfatal injuries (total, 5,986), or 17.2 percent of the total injuries from all causes. (See table 6.)

A review of injuries from handling materials (other than ore and rock) in the iron-ore mines of the Lake Superior district for

1944–54 [44] [45] revealed that there were 2 fatal and 1,531 nonfatal injuries, which is approximately 16.3 percent of the total injuries from all causes. These (1,533) injuries resulted in a time charge of 67,613 days, which is 3.8 percent of the total days charged to injuries from all causes. One of the fatal and 1,128 of the nonfatal injuries occurred at underground mines where approximately 55 percent of the men were employed.

The injuries (fatal and nonfatal) from handling materials at opencut metal and nonmetallic mines increased from an average of 154 a year between 1932 and 1941 to 225 a year between 1942 and 1951. In those decades injuries from all causes increased from 665 to 1,008; injuries from handling materials increased by 66 percent during the 20 years. (See table 7.)

The injury-frequency trend from handling materials at opencut mines (fig. 23) was downward, with a decrease of 54 percent from 1932 to 1954. There were during the 23 years 5 fatal and 3,888 nonfatal injuries (total, 3,893), which is 20.2 percent of the total injuries from all causes. From 1950 to 1954 the trend was also downward, with a decrease of 61 percent in injuries. There were during the 5 years 1 fatal and 815 nonfatal injuries (total, 816), or 18.7 percent of the total injuries from all causes. (See table 7.)

When handling materials manually, injuries may be caused by lifting, falls, mashing or cutting hands or feet, eye wounds, and burns.

Strains from lifting may account for over half of the injuries that occur in handling materials where such work is done mainly by hand labor. Although injuries of various kinds result from improper lifting, back strains probably are the most numerous. As a rule, these strains come about because of failure to lift in such a way that most of the load is imposed on the strong leg muscles rather than the weaker one of the back. To lift safely, a person should (fig. 24):

1. Make sure that there is secure footing, that a good hold can be obtained, and that there is room to lift.
2. Stand close to the object with feet not too far apart; bend the knees; keep the arms and back as straight as practicable.
3. Lift steadily without jerking; never try to lift while in an unbalanced position.

The human body is well designed for lifting, but unless used correctly it will break down, often with serious damage. Wrong lifting may cause a back muscle to stretch beyond its strength and tear. Such an injury is known as a strain, and many times recovery is slow and difficult. Persons with weakness in abdominal muscles are subject to hernia; medical authorities disagree as to whether a lifting strain will bring one about, but straining and pulling from an awkward position or slipping while lifting have caused this type of injury.

Injuries from falling material other than ore and rock are frequently connected with but not included in injuries from handling materials.

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[44] Cash, F. E., Accident Experience, Iron-Ore Mines—Lake Superior District, 1940–45: Bureau of Mines Inf. Circ. 7410, 1947, 11 pp.; Accident Experience, Iron-Ore Mines—Lake Superior District, 1940–47: Bureau of Mines Inf. Circ. 7510, 1949, 16 pp.

[45] Lake Superior Mines Safety Council, Review of Accidents in the Lake Superior District: Proc. Lake Superior Mine Safety Conf., 1949, pp. 21–34; 1950, pp. 16–30; 1951, pp. 90–107; 1952, pp. 150–164; 1953, pp. 121–137; 1954, pp. 72–88; 1955, pp. 104–117.

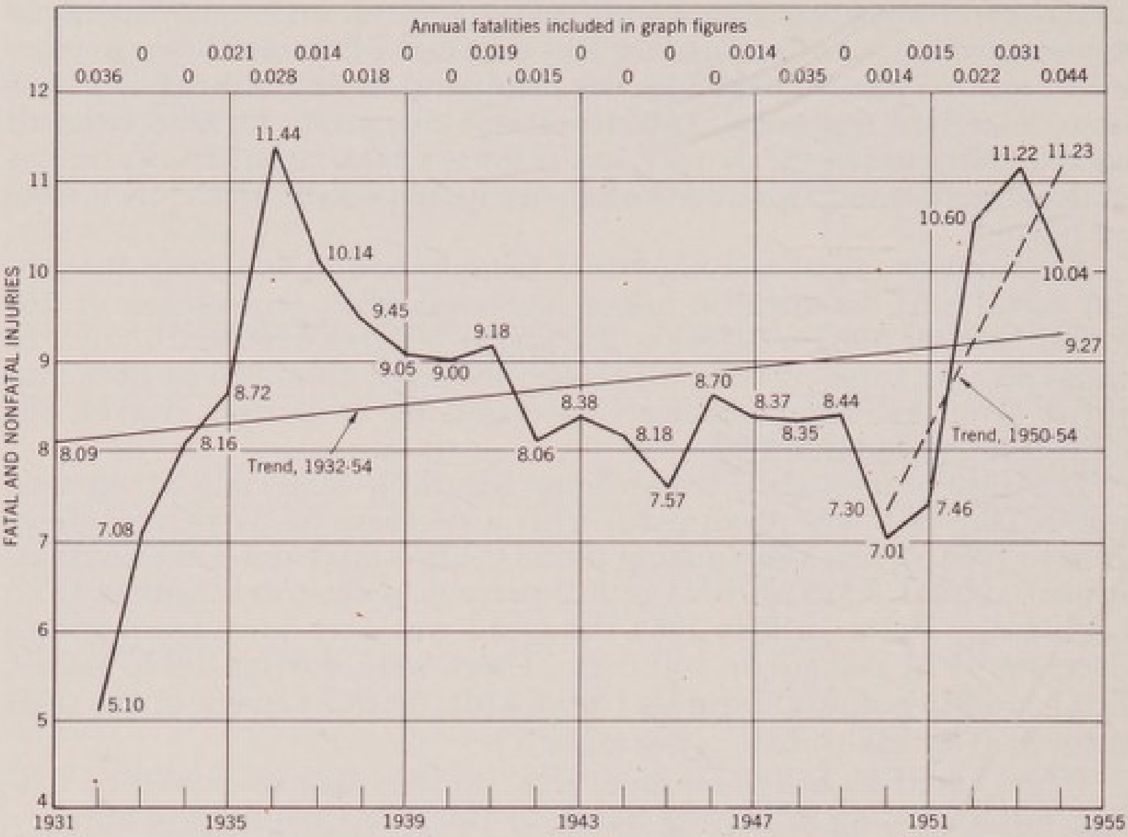


**Figure 22.—Injury-Frequency Trend From Handling Materials at Underground Metal and Nonmetallic Mines, 1932–54.**

A review of injuries from falling material in the opencut iron-ore mines of the Lake Superior district for 1944–52 [46] revealed that there were 11 fatal and 618 nonfatal injuries (total, 629), which is approximately 7.7 percent of the total injuries from all causes. These 629 injuries resulted in a time charge of 93,064 days, which is 5.6 percent of the total days charged to injuries from all causes. Ten fatal and 466 nonfatal injuries occurred at underground mines where approximately 55.5 percent of the men are employed (13-year average).

Certain accident-prevention measures are applicable to handling materials, just as to machinery, air contaminants, and falls of persons. Employees must be trained in the safe procedures of their respective jobs, they must be properly supervised, mechanical handling devices must be substituted where practicable, and protective equipment must be provided and used.

Materials such as pipe, rail, timber, etc., should be piled neatly and safely in storage yards for ease in handling and so they will not fall on persons. Warehouse and shop storage should include rack and floor loading strength having a safety factor of at least 2 and protection against accidental movement (fig. 25). Figure 26 shows good storage and housekeeping practices at an iron mine.

[46] See works cited in footnotes 44 and 45.

TABLE 6.—*Injuries from handling materials at underground metal and nonmetalic mines, 1932–54* [1]

| Year | Fatal | | | | | Nonfatal | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Million man-hours | All causes, total | Handling materials | Percent of total | Frequency rate [1] | All causes, total | Handling materials | Percent of total | Frequency rate [1] |
| 1932 | 83.5 | 105 | 3 | 2.9 | 0.036 | 4.767 | 423 | 8.9 | 5.06 |
| 1933 | 81.8 | 90 | | | | 5,555 | 579 | 10.4 | 7.08 |
| 1934 | 101.1 | 101 | | | | 7,440 | 825 | 11.1 | 8.16 |
| 1935 | 141.1 | 154 | 3 | 1.9 | .021 | 9,677 | 1,228 | 12.7 | 8.70 |
| 1936 | 177.7 | 185 | 5 | 2.7 | .028 | 13,916 | 2,027 | 14.6 | 11.41 |
| 1937 | 210.3 | 207 | 3 | 1.4 | .014 | 17,191 | 2,131 | 12.4 | 10.13 |
| 1938 | 166.8 | 145 | 3 | 2.1 | .018 | 12,052 | 1,573 | 13.1 | 9.43 |
| 1939 | 181.6 | 157 | | | | 13,019 | 1,643 | 12.6 | 9.05 |
| 1940 | 201.6 | 200 | | | | 13,982 | 1,814 | 13.0 | 9.00 |
| 1941 | 207.0 | 201 | 4 | 2.0 | .019 | 14,601 | 1,896 | 13.0 | 9.16 |
| 10-year total | 1,552.4 | 1,545 | 21 | | | 112,200 | 14,139 | | |
| 10-year average | 155.2 | 155 | 2 | 1.4 | .014 | 11,220 | 1,414 | 12.6 | 9.11 |
| 1942 | 198.8 | 206 | 3 | 1.5 | .015 | 12,682 | 1,599 | 12.6 | 8.04 |
| 1943 | 183.8 | 189 | 1 | .5 | (2) | 11,758 | 1,538 | 13.1 | 8.38 |
| 1944 | 146.9 | 127 | 1 | .7 | (2) | 9,100 | 1,201 | 13.2 | 8.18 |
| 1945 | 126.5 | 101 | 1 | 1.0 | (2) | 7,213 | 958 | 13.3 | 7.57 |
| 1946 | 121.7 | 101 | | | | 7,817 | 1,059 | 13.5 | 8.70 |
| 1947 | 139.9 | 128 | 2 | 1.6 | .014 | 8,632 | 1,170 | 13.6 | 8.36 |
| 1948 | 142.3 | 99 | 5 | 5.1 | .035 | 7,849 | 1,183 | 15.1 | 8.31 |
| 1949 | 128.6 | 73 | 1 | 1.4 | (2) | 7,242 | 1,085 | 15.0 | 8.44 |
| 1950 | 139.9 | 101 | 2 | 1.9 | .014 | 6,995 | 979 | 14.0 | 7.00 |
| 1951 | 134.7 | 94 | 2 | 2.1 | .015 | 7,212 | 1,002 | 13.9 | 7.44 |
| 10-year total | 1,463.1 | 1,219 | 18 | | | 86,500 | 11,774 | 13.6 | 8.05 |
| 10-year average | 146.3 | 122 | 2 | 1.5 | .012 | 8,650 | 1,178 | | |
| 1952 | 133.9 | 115 | 3 | 2.6 | .022 | 6,959 | 1,417 | 20.4 | 10.58 |
| 1953 | 128.9 | 98 | 4 | 4.1 | .031 | 6.683 | 1,443 | 21.6 | 11.19 |
| 1944 | 112.9 | 74 | 5 | 6.8 | .044 | 5,292 | 1,129 | 21,3 | 10.00 |

[1] Per million man-hours.
[2] Less than 0.01 injury.

NOTE.—Prepared by Accident Analysis Branch, Health and Safety Division.

Mechanical handling of supplies and materials (figs. 27, 28, and 29) has greatly reduced the hazard of hernia and back injuries. A novel device for unloading rail from a cage is shown in figure 30, *A* and *B*.

Timber, drill rods, scaling bars, rails, and pipe should not be thrown while being moved onto or from cars or trucks. One end of timber, pipe, and rail should be lowered to the floor or ground before the other end is released. Drill rods and scaling bars thrown into or from cars have a tendency to rebound and ricochet, resulting in numerous injuries to nippers as well as others who may be in the vicinity. When handling any heavy material on sloping surfaces, such as the floor of a stope, those occupying positions below the object should first obtain secure footing in a position that will permit them to step into the clear in the event the object should slide or roll. Most material handled underground will be wet and slippery; because of this, an object should be gripped firmly, and after it is raised no attempt should be made to shift the grip.

One of the most important phases of unloading material is to store it so as not to create tripping or stumbling hazards.

Warehouse, shop, and mine storage should include racks and bins for the various kinds of materials.

TABLE 7.—*Injuries from handling materials at opencut metal and nonmetallic mines, 1932–54* [1]

| Year | Fatal | | | | | Nonfatal | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Million man-hours | All causes, total | Handling materials | Percent of total | Frequency rate [1] | All causes, total | Handling materials | Percent of total | Frequency rate [1] |
| 1932 | 8.5 | 2 | | | | 247 | 54 | 21.9 | 6.34 |
| 1933 | 12.3 | 5 | | | | 370 | 70 | 18.9 | 5.69 |
| 1934 | 15.1 | 15 | | | | 452 | 119 | 26.3 | 7.89 |
| 1935 | 20.2 | 10 | | | | 529 | 117 | 22.1 | 5.79 |
| 1936 | 24.7 | 14 | | | | 734 | 169 | 23.0 | 6.85 |
| 1937 | 29.2 | 12 | | | | 864 | 194 | 22.5 | 6.65 |
| 1938 | 21.4 | 11 | | | | 670 | 147 | 21.9 | 6.87 |
| 1939 | 25.3 | 16 | 1 | 6.3 | 0.040 | 691 | 128 | 18.5 | 5.06 |
| 1940 | 29.2 | 23 | 2 | 8.7 | .069 | 784 | 162 | 20.7 | 5.55 |
| 1941 | 46.7 | 29 | | | | 1,171 | 239 | 20.4 | 5.12 |
| 10-year total | 232.5 | 137 | 3 | | | 6,512 | 1,399 | | |
| 10-year average | 23.3 | 14 | (2) | 2.2 | .013 | 651 | 140 | 21.5 | 6.01 |
| 1942 | 52.4 | 31 | 1 | 3.2 | .019 | 1,275 | 225 | 17.6 | 4.29 |
| 1943 | 50.9 | 31 | | | | 1,246 | 252 | 20.2 | 4.95 |
| 1944 | 41.9 | 20 | | | | 1,077 | 197 | 18.3 | 4.70 |
| 1945 | 39.4 | 11 | | | | 854 | 183 | 21.4 | 4.64 |
| 1946 | 35.6 | 15 | | | | 897 | 207 | 23.1 | 5.81 |
| 1947 | 45.9 | 10 | | | | 969 | 207 | 21.4 | 4.51 |
| 1948 | 47.0 | 20 | | | | 958 | 221 | 23.1 | 4.70 |
| 1949 | 42.7 | 6 | | | | 823 | 182 | 22.1 | 4.26 |
| 1950 | 36.3 | 2 | | | | 854 | 193 | 22.6 | 5.32 |
| 1951 | 54.8 | 18 | 1 | 5.6 | .018 | 963 | 222 | 23.1 | 4.05 |
| 10-year total | 446.9 | 164 | 2 | | | 9,916 | 2,089 | | |
| 10-year average | 44.7 | 16 | (3) | 1.2 | (3) | 992 | 209 | 21.1 | 4.67 |
| 1952 | 53.7 | 16 | | | | 896 | 152 | 17.0 | 2.83 |
| 1953 | 58.2 | 16 | | | | 914 | 134 | 14.7 | 2.30 |
| 1954 | 47.2 | 21 | | | | 658 | 114 | 17.3 | 2.42 |

[1] Per million man-hours.
[2] Average less than one injury.
[3] Less than 0.01 injury.

NOTE.—Prepared by Accident Analysis Branch, Health and Safety Division.

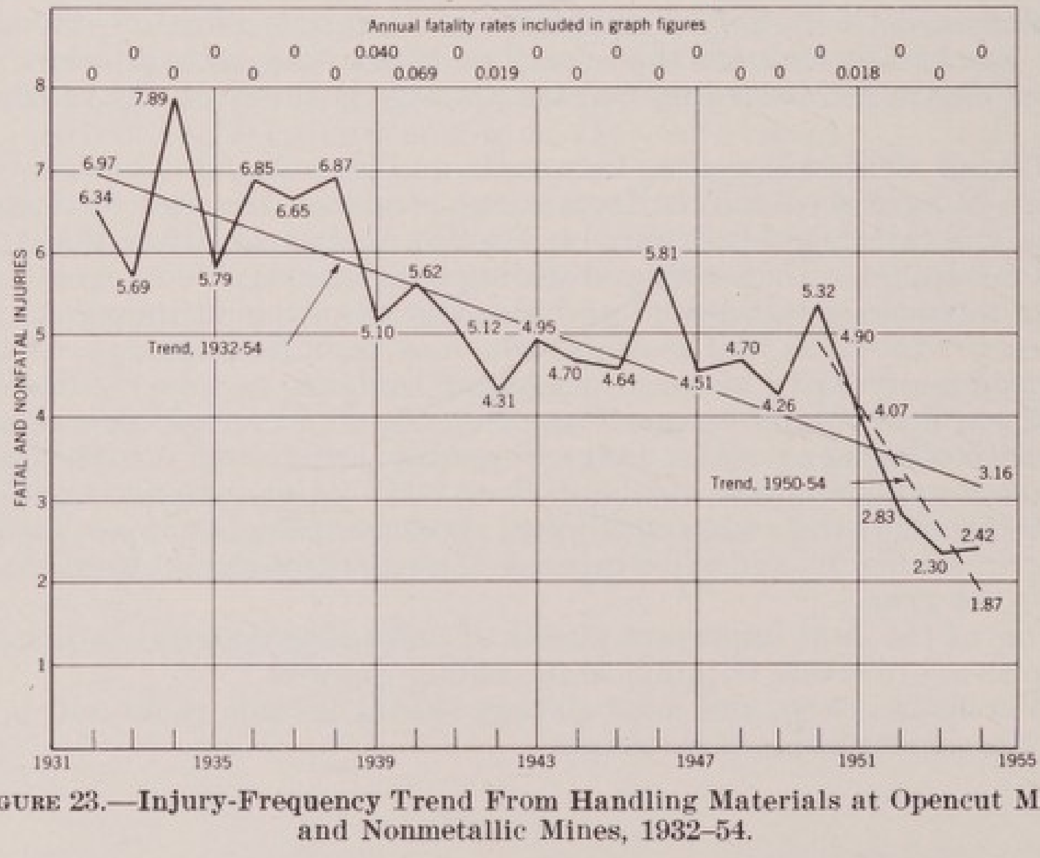


FIGURE 23.—Injury-Frequency Trend From Handling Materials at Opencut Metal and Nonmetallic Mines, 1932–54.

FIGURE 24.—Correct Position for Lifting.

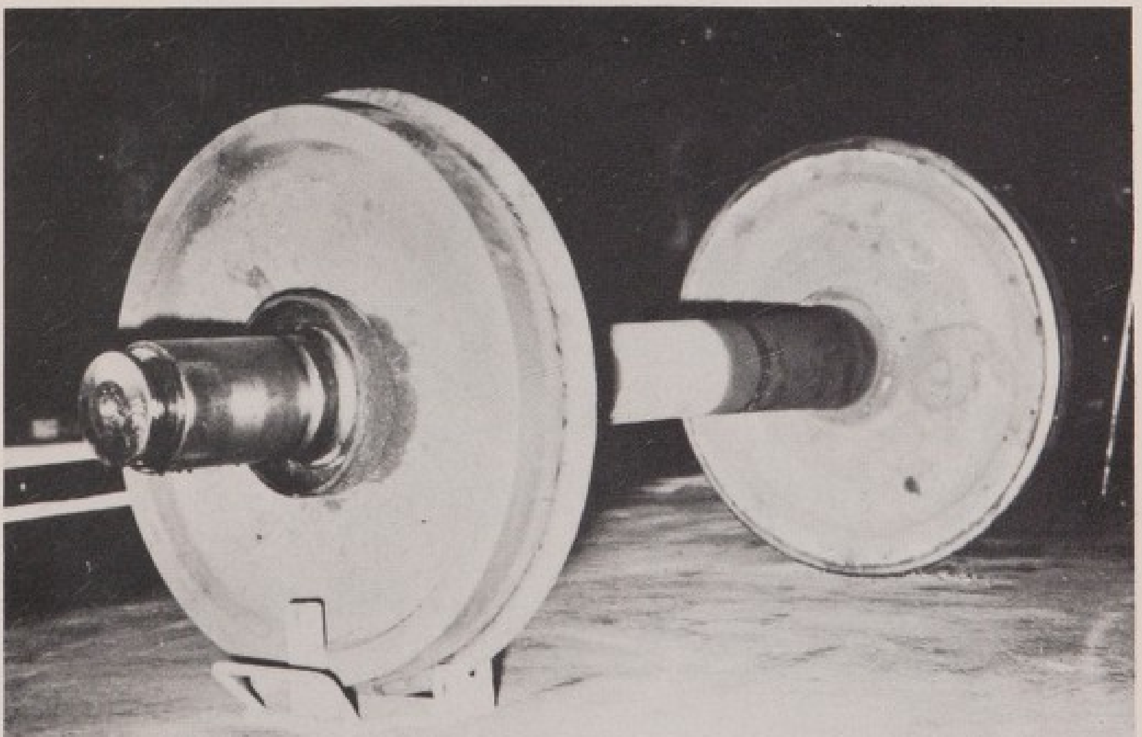

FIGURE 25.—Wheel Block in Car-Repair Shop.

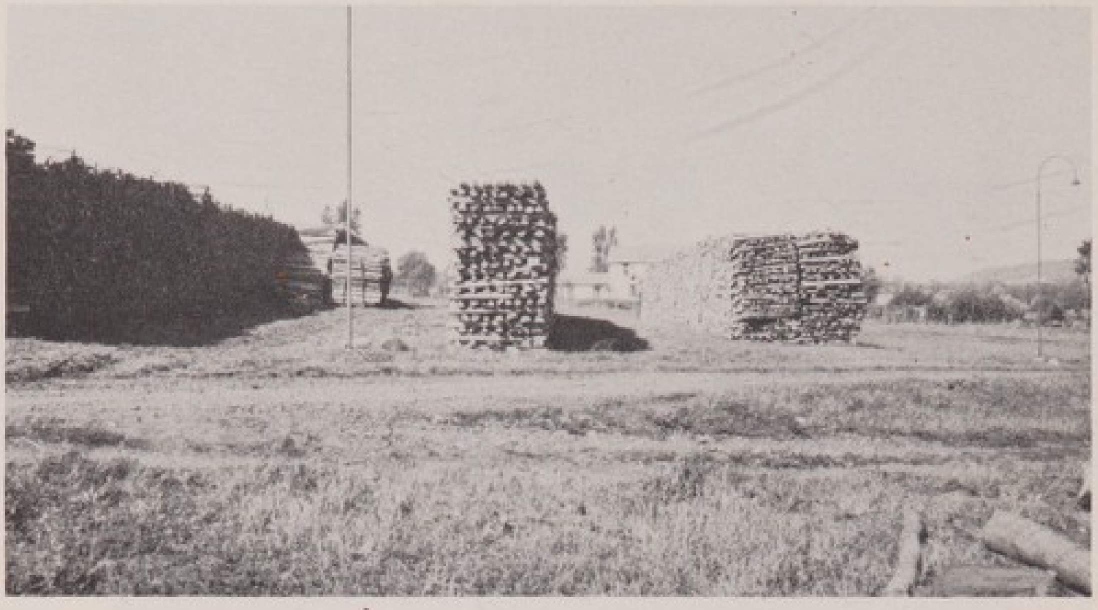

FIGURE 26.—Timber Storage on Surface.

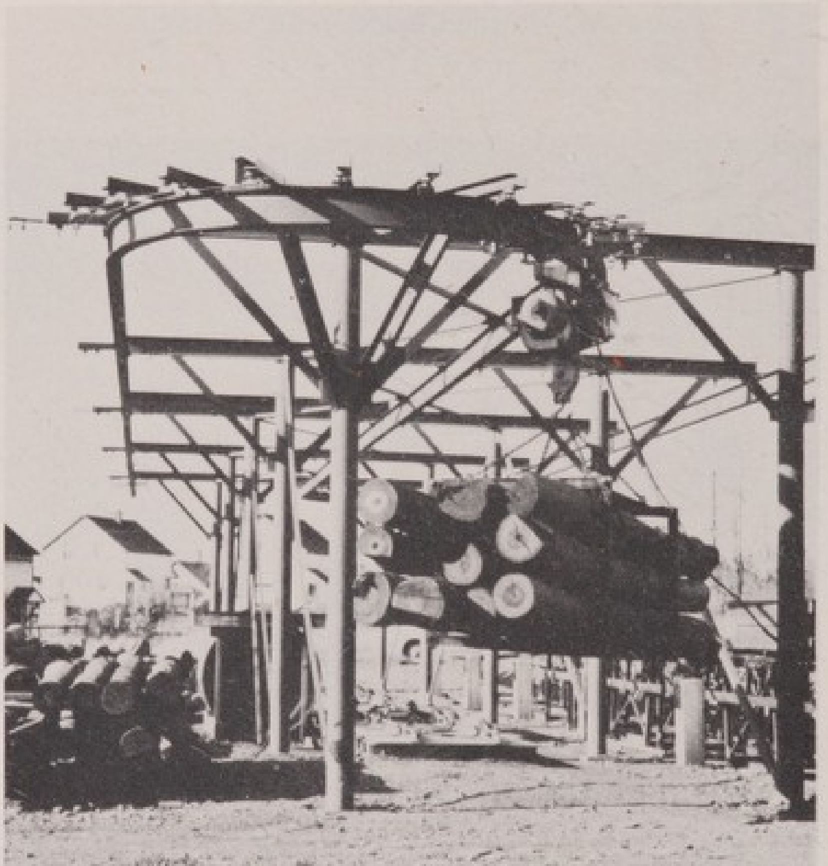

FIGURE 27.—Cradle of Timber Handled by Traveling Crane on Monorail.

**Figure 28.—Unloading Timber Truck From Cage by Air Hoist and Cable.**

Experience has shown that a fair proportion of injuries from handling materials occurs in mine shops. Cradle mounts and stands for heavy equipment being overhauled or repaired have proved their worth in reducing accidents of this type. Some companies provide nonslip aisles well marked by luminous paint in their shops and warehouses. Advance planning for placing shop machinery and equipment has paid well in safety dividends. Such planning should also include preventive maintenance of material-handling equipment and provision for good-housekeeping measures.

Where acids or caustic liquids are handled at bulk loading and unloading points, protective clothing and eye protection should be provided and worn. Where danger of spillage or spraying of such liquids may occur, emergency showers should be provided and located strategically.

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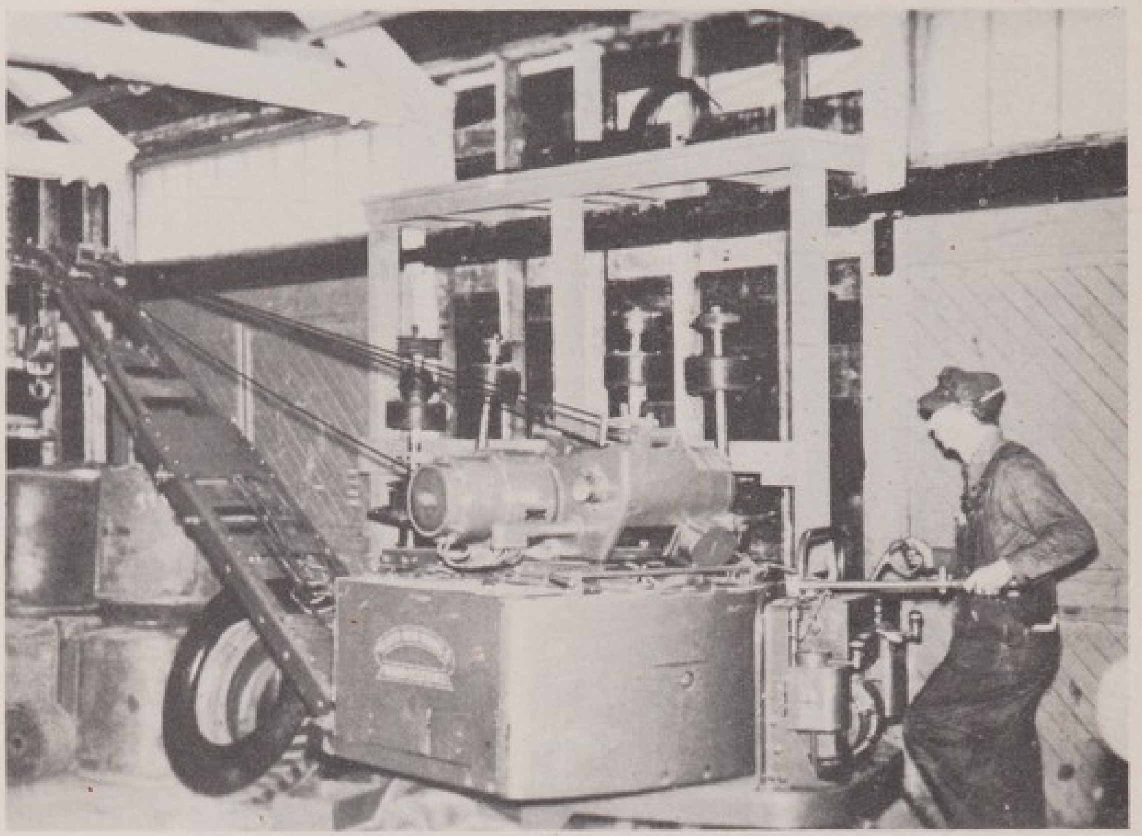

FIGURE 29.—Crane on Battery-Driven Truck for Use in Warehouse.

## STEPPING ON NAILS

Generally, one of the first preventive measures at any industrial operation is to remove or bend down protruding nails. This precaution may be the only safe practice called to the attention of supervisors and workers where there is no organized program. There rarely is a safe-operating code formulated that does not include rules concerning nails; yet, after years of recognition, this hazard is important enough to rate mention by itself in lists of accident causes at metal and nonmetallic mines.

Injury-frequency statistics for stepping on nails in mines are not available, but in nonferrous mills and concentrators [47] the trend was downward, with a decrease of 84.61 percent from 1937 to 1949. From 1945 to 1949, however, the trend was upward, with an increase of 14.63 percent. From 1937 to 1949, there were 1 fatal and 261 nonfatal injuries, or 1.88 percent of the total injuries from all causes. From 1945 to 1949, there were no fatal and 44 nonfatal injuries, or 1.11 percent of the total injuries.

The reduction or even the elimination of nail injuries may be expressed in one sentence: Management must insist on and provide good housekeeping, supervisors must see that the operation is kept clean and orderly, and all employees must cooperate by practicing good housekeeping and by wearing shoes with substantial soles.

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[47] Bureau of Mines, Accident Prevention in Nonferrous-Metal Processing Plants. 2. Mills and Concentrators: Handbook, 1954, 380 pp.

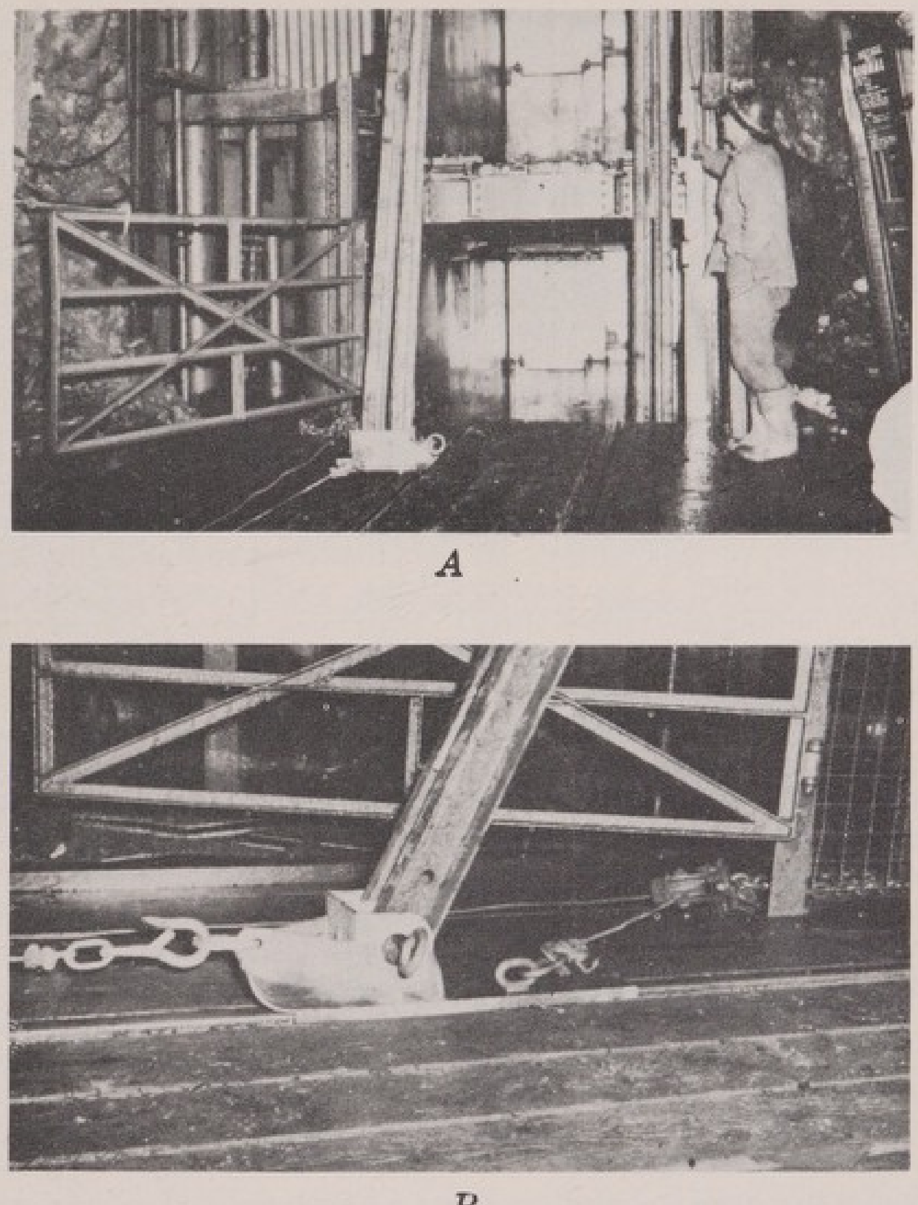

FIGURE 30.—*A*, Unloading 30-Foot Rail From Cage by Air Hoist and "Shoe"; *B*, Closeup of Shoe.

## INRUSH OF WATER

Dramatic and often tragic experiences are related in mining communities from the sudden flooding of mine workings by water or fluid mud and sand. These inrushes may come from lakes or other bodies of water overhead, from watercourses penetrating the formations, from breaking into abandoned workings that have filled with water, or even from cloudbursts.

The following incomplete list of acidents caused by flooding in mines (table 8) is compiled from Bureau of Mines records and other published accidents.

The following details of a selected group of flooding accidents are from published accounts; they show the condition that permitted their occurrence and indicate ways for their prevention.

TABLE 8.—*Accidents caused by flooding metal and nonmetallic mines*

| Date | Product | Mine | Location | Killed | Cause |
|---|---|---|---|---|---|
| Sept. 28, 1893 | Iron | Mansfield | Crystal Falls, Mich | 28 | Inrush of water from raise under river. |
| Aug. 29, 1895 | Gold | Sleepy Hollow | Sleepy Hollow, Colo | 12 | Mine flooded. |
| Dec. 13, 1909 | Iron | Negaunee | Negaunee, Mich | [1] 0 | Inrush of water and sand; cave of slice. |
| 1910 | | Bagley Tunnel | Animas Forks, Colo | 4 | Inrush of water. |
| Oct. 19, 1911 | Iron | Wharton Shaft | Hibernia, N. J | 12 | Do. |
| Sept. 4, 1912 | do | Ruddy | Biwabik, Minn | 3 | Flooded by cloud-burst. |
| July 14, 1914 | Copper | Balkan | Palatka, Mich | 7 | Rush of sand and water into raise. |
| June 10, 1915 | Lead-zinc | Longacre-Chapman. | Neck City, Mo | 2 | Inrush of water. |
| Jan. 31, 1917 | Copper | Isle Royal | Houghton, Mich | 2 | Do. |
| Apr. 21, 1917 | | Treadwell | Treadwell, Alaska | 1 | Flooded by sea water after cave-in. |
| Aug. 15, 1917 | | Telluride | Telluride, Colo | 1 | Inrush of water from old workings. |
| Feb. 21, 1918 | Iron | Amasa-Porter | Crystal Falls, Mich | 17 | Cave-in caused by inrush of water from surface. |
| Mar. 27, 1918 | | Vermillion | Somer, Mich | 4 | Inrush of water from surface. |
| May 29, 1923 | Copper | Inspiration | Globe, Ariz | 1 | Flood of water and mud. |
| Feb. 5, 1924 | Iron | Milford | Crosby, Minn | 41 | Inrush of water from lake. |
| Aug. 1, 1924 | do | Horner | Iron River, Mich | 3 | Inrush of water and sand. |
| June 24, 1925 | | Ajax | Burke, Idaho | 4 | Inrush of water. |
| Nov. 3, 1926 | Iron | Barnes Hecker | Ishpeming, Mich | 51 | Mine flooded after cave-in. |
| Mar. 14, 1929 | do | Bruce | Chisholm, Minn | 1 | Inrush of mud and water. |
| Aug. 2, 1933 | Gold | Asuncion | Mexico | 9 | Do. |
| 1937 | Iron | Pioneer | Ely, Minn | 2 | Inrush of water. |
| July 4, 1937 | Salt | Carey | Winnfield, La | 0 | Do. |
| Aug. 31, 1941 | Copper | Copper Queen | Bisbee, Ariz | 0 | Do. |
| Mar. 16, 1942 | Iron | Merritt | Crosby, Minn | 0 | Do. |
| Jan. 18, 1943 | | Argo Tunnel | Idaho Springs, Colo | 4 | Do. |
| 1944 | Iron | Pioneer | Ely, Minn | 1 | Inrush of mud and water. |

[1] Three men rescued.

## FLOODING OF MANSFIELD MINE

In September 1893 workings of the Mansfield mine, Crystal Falls, Mich., were raised so high in following a rich vein of ore under the bed of a river that the river broke through, filling the entire mine in less than 5 minutes. Twenty-eight miners were trapped and drowned. In 1896 the river was diverted around the area and the mine reopened. Only two bodies were recovered, as no attempt was made to reenter some of the old stopes. The cause of this accident was stated as neglect to take the necessary precautions.

## FLOODING OF WHARTON SHAFT

In October 1911 the new No. 13 shaft of the Wharton Steel Co., Upper Hibernia, N. J., was being sunk and had reached a depth of about 1,500 feet on the variable dip of the ore. At the same time, a drift several levels above the shaft bottom was being driven from the shaft to tap some old workings supposed to be about 250 feet away. These workings were abandoned and filled with water so that their exact extent could not be determined. On October 19 the drift was thought to be over 100 feet from the old workings, but blasting of a round in the face broke through, allowing water to enter and flood the drift and the shaft below its level. Miners working in the drift and adjacent levels escaped, but 12 men in and near the bottom of the shaft were drowned.

Accurate maps of the area were not available, and an idea of the distances involved underground was obtained by measuring between surface openings. Test holes were not drilled ahead of the drift face, and men were allowed to remain on the lower levels while the drift round was blasted because it was estimated that the old water-filled workings were still over 100 feet from the drift. After the mine was unwatered, a drift was run safely on a lower level to tap the flooded workings. Test holes were kept ahead, and the works were unwatered through boreholes.

### LONGACRE-CHAPMAN MINE FLOOD

On June 10, 1915, nine men were working in the old Longacre-Chapman lead and zinc mine, Neck City, Mo., removing ore from the stope bottoms and pillars. They were working on a lease held by eight of the men. The mine workings, which were continuous with those of the adjoining Century Zinc Co., were reached through 2 shafts 200 feet deep. No work was being done in the Century mine, but old tailings were being reworked in the mill, and the residue was run into the old caved stopes through the surface breaks. This stoped area underground was cut off by bulkheads and cribs from the connecting drifts. The mine was very wet, the slimes contained much water, and the season had been rainy. Water had probably gathered to a considerable height in the old stopes. At 9:30 p. m. on June 10 the cribbing gave way, and an avalanche of water, tailings, boulders, and timbers swept through the drifts and into the shaft bottoms. Two of the men reached one of the shafts ahead of the flood and made their way to the surface; another was rescued from near the bottom of one of the shafts; but the other six were trapped.

Four of those working in a winze near the place where the water broke through were able to struggle through the rush of water and debris and reach a high place over the drift. There, they could sit on top of a pile of timbers with their feet in the water.

Rescue operations were organized, and pumps were placed in the caved pit on the surface and on the shafts. The mud, rock, and debris that choked the drift leading to the place where the men had been working were loaded into buckets and hoisted from the shafts. On June 15 the four men imprisoned over the drift were found alive and removed safely. On June 24 the bodies of the two other men were found where they had been drowned at their working place.

The conclusions reached by authorities who investigated the disaster were that slimes and water should not be conducted into caves in the vicinity of active mines and that strong bulkheads should be utilized to protect the men near old workings where water might be standing. In old mines where men work on the leasing system such hazards often are overlooked.

### TREADWELL CAVE-IN AND FLOOD

The ore shoots formerly mined at Treadwell, Alaska, extend under the Gastineau Channel, pitching downward from the outcrop near the shore. Company reports for 1916 noted a settling of the surface over stoping areas, and in April 1917 the appearance of new cracks and settling of the foundations of buildings previously erected over the spot indicated a renewal of subsidence, climaxed on April 21 by the entrance of salt water from the channel. This inflow was noted on the surface; and, as it increased in volume, the men were removed from the Treadwell and connecting mines. At 2:15 a. m., on April 22, the caving of some large blocks of ground below caused water to spout over 200 feet above the headframe of the Combination shaft. At 2:30 a. m. the mine was full; this inflow took about 3½ hours. The surface caved because the hanging wall over partly emptied shrinkage stopes settled; and, as the rush of water carried the broken rock to lower levels, more cave-ins occurred. Although the men had been called out of the mine, it was claimed later that one man was missing.

A bulkhead 34 feet thick had been placed in a level connecting the adjoining Ready Bullion mine. This bulkhead held the water, but for additional security it was increased to a thickness of 60 feet.

### AMASA-PORTER MINE DISASTER

In 1918 the shaft of the Amasa-Porter iron mine, near Crystal Falls, Mich., was bottomed at the 550-foot level, the only level being worked. The backs of the open stopes on the 200-foot level had been sloughing for several months; and, as these stopes were beneath surface deposits of mud, sand, and gravel, saturated with water, a cave-in or washout was feared should the rock remaining over the opening give way entirely at any point. As a precaution, concrete bulkheads were constructed on the 200-, 300-, and 400-foot levels. On the 200- and 300-foot levels, the bulkheads were 70 feet from the shaft and on the 400-foot level 125 feet from the shaft. These bulkheads were 6 feet thick reinforced and hitched 2 feet into the rock.

On February 14 a cave-in to the surface opened a hole in the overburden 250 feet in diameter and 75 feet deep, containing 10 feet of water over the ledge. Rushes of water and air underground caused the withdrawal of all men, except two pumpmen. Overhanging sides of the cave-in were blasted down from the surface with dynamite. Two pumps were placed in the pit in an attempt to remove the water, and the bulkheads and lower workings were inspected. On February 18 operations were resumed.

About noon on February 21, the men were going back underground after eating. Ten men went down on the first cage; as the second trip was being lowered with nine men, there was a rush of water and sand into the shaft from the 200-foot level. The cage was forced to the bottom in spite of the efforts of the hoistman to bring it up, using a full throttle of steam. The manager was summoned, and the ore skip was lowered to 18 feet above the 550 level, where it stuck in the sand. A considerable flow of water continued for half an hour. A volunteer rescue crew entered by the ladderway and found water at 50 feet above the 550 level; 4 men were found alive, 1 of them injured. This left 15 of the men just lowered and 2 pumpmen in the mine.

Pumps were placed in the shaft to attempt to lower the water, but at 7:55 p. m. on the 25th, another rush of water drowned the pumps and raised the level of the water in the shaft to 50 feet above the 400 level. The 17 men were given up as drowned, as the water then covered the stopes where they might have taken refuge. It was discovered that a fissure had opened in a soft-rock formation under the bulkhead on the 200-foot level. Water and sand had drained from the caved surface through the open stopes. It was decided to drain the surface by drifts from a new footwall-drainage shaft sunk to a depth of 112 feet. By the following July the mine was reopened, the bodies were recovered, and the operation was resumed.

### BARNES HECKER MINE FLOOD

On November 3, 1926, the back of one of the stopes of the Barnes Hecker iron mine, Ishpeming, Mich., caved to the overlying glacial drift material, and the mine filled with water and quicksand. Within approximately 15 minutes of the time the cave-in started, all the workings of the mine were completely filled; water rose in the shaft to within 185 feet of the surface, later receding to about the 540-foot level. Of the 52 men in the mine, only 1 escaped by climbing 800 feet of ladder in the shaft. The stope that caved had been worked by top slicing, starting 220 feet below the top of the ore body. Above this unmined thickness of ore was about 210 feet of glacial surface material, water-soaked and containing small ponds. Although the mine workings were wet when opened, the mining operations had drained most of the water from the ore stratum; the stope that caved had become dry enough to permit the use of scrapers. The amount of water handled by the mine pumps had dropped from over 3,000 to about 700 gallons per minute.

The only intimation of anything wrong noted by the man who escaped was a rush of air, which blew out his light. He was on the second level and rushed to the shaft, calling to others to follow. The rush of water wrecked the shaft manway below the 200-foot level and carried out many of the timbers dividing the compartments; but the wall and end plates and lagging, which were embedded in concrete, were not disturbed. The sudden flow of water prevented the use of prepared bulkheads and water doors; and although emergency escapeways, including a low-level connection to a neighboring mine, were provided, the men were engulfed before they reached safety. Sand came through the connection to the adjoining mine for 3,000 feet from the connecting raise to a point where the flow gradually decreased to nothing. A large depression formed in the overburden over the caved stope; the fine, sandy material was water-soaked, and the banks of the depression at one point reached the edge of a small muskeg swamp. The mine was sealed off and not recovered. Seven bodies were found in the connecting escape drift, and three others were recovered from the shaft when it was cleared to the first level. The officials concluded that the cavity over the stope gradually enlarged as slicing progressed downward, resulting in sudden failure of the block of ore that had been left to support the overburden.

### INRUSH OF WATER, ASUNCION MINE, MEXICO

In the Asuncion gold mine nine underground workers were drowned from a sudden inrush of water. The mine usually was dry, and no signs of water were seen, when suddenly a large mass of water, rock, and mud broke into the mine on the 150-meter level at a point a short distance back of the drift face where 4 men were working. In a few minutes the lower levels were filled, and, although 3 of the men below the 220-meter level were able to escape, 5 others were trapped. During recovery operations, it was found that the water came from some previously unknown workings and that a plug of rock 6 meters long, 2 meters thick, and 4 meters high, from the back of the drift, had broken loose, allowing the water to come through. No blasting had been done for several hours before the inrush; and, although the accumulated water evidently was only 4 meters above the 150-meter level, it was said that there were no signs of the proximity of water on the level.

It was known that some old workings might be encountered, and the following precautions were taken: (*a*) An escape raise had been driven to allow the men to climb and remain above water until rescued should the water break through; (*b*) a guide hole had been drilled in every round to prospect ahead for water; (*c*) no blasting was done until all the men were out of the lower workings; (*d*) extra-long fuse was used to permit the men to arrive at a higher level before the shots fired; and (*e*) all miners were requested repeatedly to report at once any seepage of water noticed, however small.

## FLOODING OF ARGO TUNNEL

This tunnel in the Kansas mine, Idaho Springs, Colo., was connected, for drainage and haulage, to older mines overlying it. Four men (lessees) were working a stope in the Kansas mine, reached by traveling 19,000 feet into the tunnel, 2,200 feet through a crosscut, and 300 feet up raises. The men prepared a round in this stope, lit the fuses, which were 6 to 8 feet long, and descended to the main tunnel level, which usually was reached at the time the shots started to fire. A motorman had taken an electric locomotive about halfway in from the portal when the power failed, and he walked to the outside to look for the trouble. He had just arrived at the compressor room when a flood of water came out of the tunnel portal. The tunnel was 10 by 12 feet in cross section, and the wall of water was 5 feet high. After the flow had subsided, the bodies of the four men were found in scattered locations in the tunnel and crosscuts from it. Great piles of rock and debris blocked the tunnel and had to be removed.

It was known that some water was in the old Kansas mine workings and that it sometimes issued from drill holes in the stope where these men were working. Evidently the last round broke through into water-filled workings of the old mine. In such conditions, long drill holes should be kept well in advance of the face, and blasting should be done electrically from a place where water could not reach.

## COPPER QUEEN MINE FLOOD

Development drifts in ground southeast of the Junction and Campbell shafts, Copper Queen mine, Lowell, Ariz., revealed this new territory to be full of water. Watercourses had been cut into on several levels, and development had been proceeding with a view to unwatering the area. Water doors had been put on every level leading into the section, and when rounds were blasted the doors were closed. Firing was done electrically from outside the doors.

On August 31, 1941, a round was blasted in the face of the 2,700 level, about half a mile inside the door. Several hours later, water came out through an open door on the 2,566 level, after it had backed up through raises behind the 2,700-level door. Men working on the 2,566 level waded against the heavy flow of water to close the door but could not remove a piece of lagging they had used to prop the door open to get ventilation. Water was waist deep. Attempts to put in bulkheads outside the door also failed; the water flowed into the shaft and filled the lower workings. Some equipment was removed before the pumps were inundated, and the shaft was then sealed at the 2,433 level.

### INRUSH OF WATER, IRON MINE, LAKE SUPERIOR DISTRICT

A sudden inrush of approximately 5 million gallons of water during blasting at an iron mine caused property damage estimated at $4,000, but no employees were lost or injured. The mine had a vertical shaft for men and supplies and an inclined shaft for hoisting ore. There were 2 producing levels, 1 at 164 and another at 264 feet, as well as 2 timber and supply levels at 105 and 238 feet, connected by inclines to the producing levels. The vertical and inclined shaft bottoms were about 15 feet below the 264-foot level. The ore deposits (20 to 30 feet thick) were being mined by the top-slicing method. The mine employed 96 men underground. A water hazard, consisting of several inland lakes, two abandoned mines, and several abandoned strip pits, was known to exist. The strata over the ore body were 50 to 80 feet thick and saturated with water.

A drift was being driven from the 164-foot level to connect with a level of an adjoining mine, which was idle and filled with water. When the drift was shown by mine maps to be 100 feet from adjoining mine workings, a 12-foot pilot hole was drilled in each round. Holes for blasting were drilled from 5 to 5½ feet deep.

When a round of holes was blasted after advancing 60 to 70 feet, water entered and inundated the pumps, causing work stoppage. Temporary pumps were installed, and the resulting expense, plus property damage, was about $5,000. All the men were supposed to be out of the mine except 2 working in the connecting drift; however, 5 other men were in the mine; 1 was near the pumps on the bottom level, and he escaped by climbing the ladder to the surface; 2 were in a raise that connected with the 164-foot level, and they escaped by this route; and 2 were in another raise not connected with the 164-foot level and were trapped. This raise was approximately 10 feet from connecting with the level, and the ground was broken, so these men were rescued in about 2 hours.

Investigation revealed that a 30-foot "monkey drift," which was not shown on the mine map, had been driven ahead and slightly to the right of the 149-foot level of the adjoining mine. The men who drilled and blasted the connecting round were indefinite as to the location of a pilot hole. The following conclusions were submitted after an investigation of the circumstances:

1. Adjoining mine workings should not be approached until all possible information on old workings has been secured and carefully studied.
2. Pilot holes (15 feet deep) should be drilled from the drilling breast, starting where the connecting drift is at least 150 feet from the known or suspected body of water being approached.
3. An official should be assigned the responsibility for the correct location, pointing, and depth of the pilot holes, and the holes should be approved before the round is blasted.
4. All the men should be removed to a higher level before blasting when the connecting drift is believed to be within 50 feet of the body of water.

5. Drill holes should be fired electrically, preferably from the surface, but at least from a level above that on which the connection is being made.

6. The mine can be protected from the possibility of flooding by constructing a bulkhead at least 50 feet from the proposed connection and by closing the opening when blasting.

## PRECAUTIONARY AND PREVENTIVE MEASURES

Where danger to the men and the mine is likely because of water in overlying strata, the chances of a sudden inrush may be lessened by employing precautionary methods that have been developed through experience and better understanding of the risks that prevailed in earlier years.

However, the hazard can be removed only by removing the water. Where barriers of unbroken ground remain or strong bulkheads are constructed, little or no danger will exist if the locations of old workings and the true thickness and condition of the barrier pillars are known. The necessity for precautions when approaching old or abandoned workings has long been recognized, as evidenced by the enactment of safety orders and laws that set forth more or less adequate rules and regulations to be followed when mine workings are driven in supposedly dangerous proximity to an abandoned mine or body of water.

The distance from old workings at which the drilling of test holes should start varies from 50 to 100 feet when exact distances are known; when exact distances are not known, the point at which drilling should start should be proportionately farther away.[48] Pilot holes (at least 20 feet deep) should be drilled ahead of the face when working places are known or suspected of being close to abandoned, caved, or old workings of unknown condition. Drill holes should be drilled at least 25 feet deep on an angle of 45° to 60° in each rib at least every 8 feet. In some instances it is advisable to drill angle holes in the back.

Because many accidents have resulted from using inaccurate maps or working without maps, it is obvious that every mine, regardless of size or type, should have an accurate map, which, in addition to showing all active workings, should show all connections with other mines, all abandoned and worked-out area, and all standing-water areas. A copy of the mine map should be deposited with a State agency when the mine is closed down, abandoned, or worked out so that it will be available for reference to anyone that might again work that property or an adjoining property.

Should water be encountered in drill holes in a place not known to be near old workings, it may indicate the proximity of a body of water; and pilot holes should be carried ahead of the face, especially if the strata generally are dry.

Methods have been developed in recent years to avert disasters from inrushes of surface water in the mines in the Lake Superior region. Generally, mining is deeper than in the past, and subsidence is not so marked; the broken ground has become less impervious to surface water, so that mining has resulted in a general draining of the overlying material. Drainage projects before and during development, together with diverting streams and draining lakes, have removed surface bodies of water. Underground bulkheads, such as those

[48] Harrington, D., and Warncke, R. G., Precautions to Be Taken When Approaching Old Mine Workings: Bureau of Mines Inf. Circ. 7288, 1944, 20 pp.

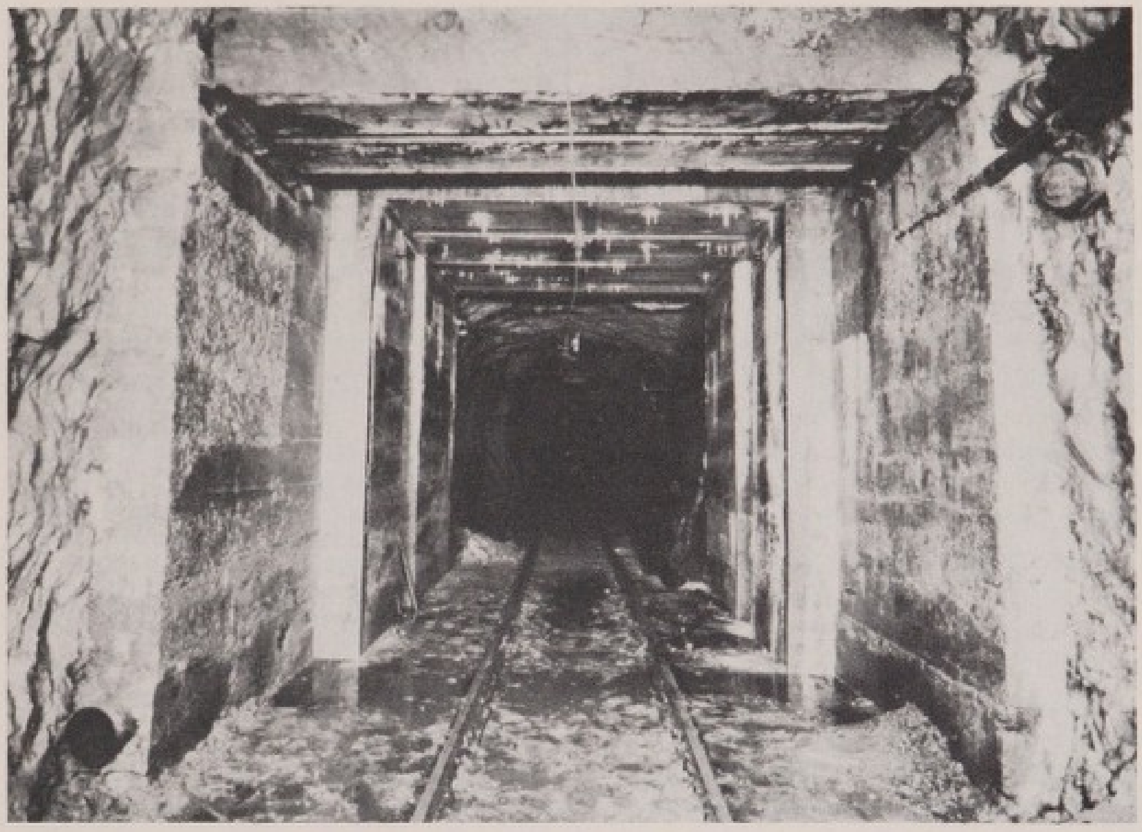

FIGURE 31.—Emergency Dam—Timbers Overhead.

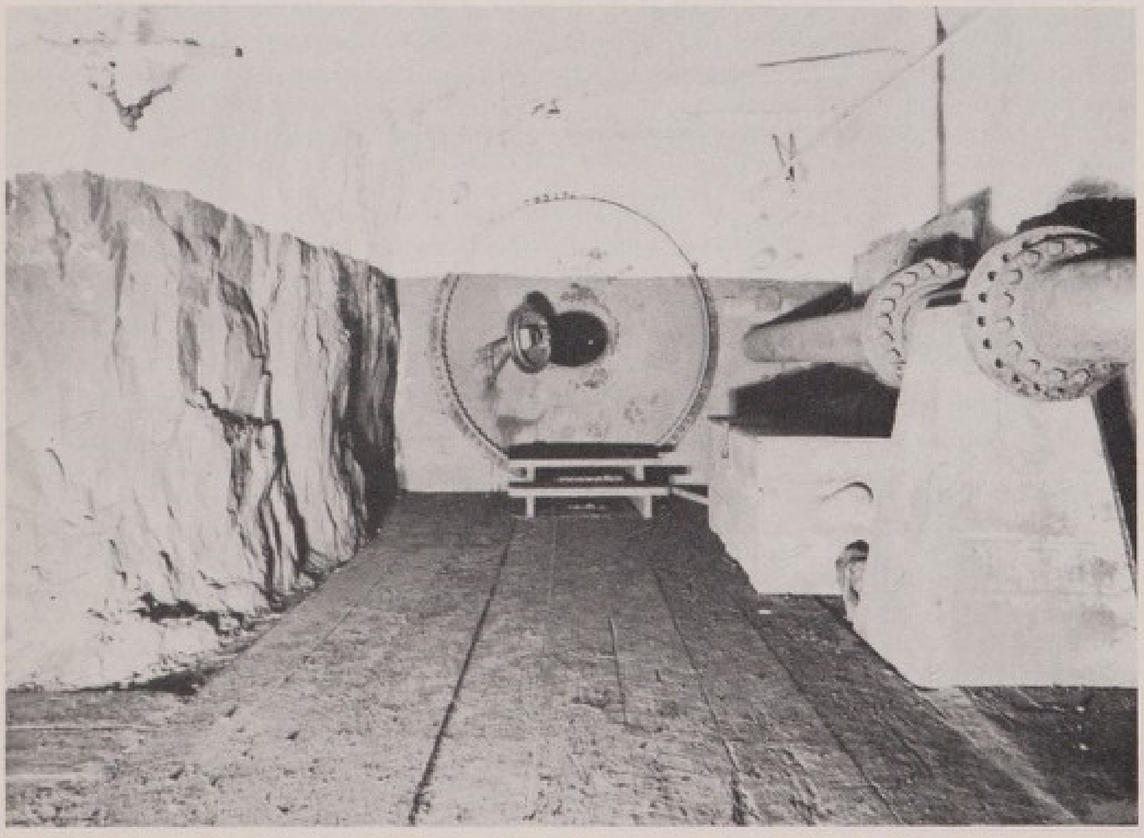

FIGURE 32.—Emergency Bulkhead to Sealed Pumproom.

shown in figures 31 and 32, and concrete dams have been constructed in conjunction with backfilling and the retention of large pillars. Engineering surveys and planning and the accumulation of pertinent data on surface conditions are employed to reveal and overcome existing hazards.

Before mining could be begun on a large scale at one underground iron-ore mine, the water problem had to be solved. The surface water was drained from overlying glacial drift by driving openings in the ledge and pumping from surface wells.[49] An average of 150 feet of water-saturated glacial drift over the rock ledge containing the ore bodies could not be drained through openings in the ledge because of clay seams in the lower part of the overburden. Wells were put down first to the top of the clay seam through which 5,000 g. p. m. of surface water was pumped at an average head of 110 feet. Later, more wells were sunk, some of them through the clay beds to the top of the rock ledge; the total pumping capacity of the wells was raised to 8,000 g. p. m., and the water level was lowered to the clay and in some places to the top of the ledge. Pumping has been reduced to a small, normal flow.

When driving the Delaware aqueduct, ground was encountered from which there was an extremely heavy flow of water.[50] Although one pilot drift had to be abandoned because of the flow of water directly from a creek above, the inflow of water at other points was reduced by grouting the surrounding rock with cement. Another feature was a safety bulkhead for protection against a sudden inflow of water or failure of pumping facilities. The safety bulkhead, constructed of concrete 20 feet thick, was well keyed into good rock and provided with a hinged steel door. Necessary pipes for drainage, power cables, and other facilities were carried through the bulkhead.

## UNUSUAL ACCIDENTS

Strange combinations of circumstances sometimes cause accidents that ordinarily may not be foreseen; such unlooked-for consequences of apparently simple and commonplace acts have resulted in injuries and fatalities. Some of the accidents described below were not avoidable through previous experience or foresight:

1. Workmen were sorting and loading scrap metal onto a railroad car following a house-to-house scrap-gathering campaign. Someone attempted to remove a bronze valve from a steel cylinder by hitting it with a hammer. When the valve was broken escaping gas caused the cylinder to fly through the air until it struck and automobile and fell to the ground. Two men in its path were knocked unconscious; one was bruised and cut, and the other suffered a compound fracture of the leg. The cylinder, which contained compressed carbon dioxide, had been in the rear of an old building that once contained a drug store. The cylinder was unmarked and was assumed to be empty.

2. A report taken from a local newspaper read: "A miner, while working in or at the new opening in the Horse Pounds, went to where he had some dynamite caps wrapped in a cloth, and, as he stooped down to get them, he saw a snake nearby. He grabbed a rock and threw it at the snake, hit it, and to his utter amazement the snake exploded. It had swallowed the dynamite caps."

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[49] Mahon, R. C. Draining and Mining a Wet Mine: AIME Tech. Pub. 1834, Min. Technol., vol. 9, No. 4, July 1945, 16 pp.

[50] Ash, S. H., and Miller, P. S. Driving a Tunnel in Fractured Rock Formation Carrying Water Under High Static Pressure: AIME Tech. Pub. 1524, Min. Technol., vol. 6, No. 6, 1942, 16 pp.

3. A miner in a district where backward practices were deep-rooted was carrying some loose blasting caps in his pants pocket. One cap slipped through a hole down into his loose-fitting boots. Eventually, he felt something moving against his foot in the toe of the boot and kicked that boot against a rail. He lost three toes and ruined the boot.

4. A shop employee had washed a change of work clothes in gasoline and dumped them into a tub of boiling water in the boiler room to rinse them. In only a few seconds the gasoline fumes reached the open flame in the boiler, and there was a flash. The man was burned badly and lost 8 weeks' time.

5. A large oil tank was leaking around a valve joint, and one foggy morning it blew up with a terrific explosion just as the shift began. Fumes from the dripping fuel oil were held close to the ground by the lowering fog and drifted with the slight air currents to a campfire a quarter of a mile away where a hobo was cooking breakfast. A scorched path on the ground plainly showed the source of the ignition.

6. A farmer driving on a State highway failed to make a curve, crossed a ditch, cut off a 33,000-volt electric-transmission pole, wrecked and burned the car, and, after being knocked down three times by charged guy wires and a wire fence, came out with a few minor scratches. The guy wires on the transmission pole became charged and came in contact with a mining-company telephone line. An employee at the mine, 25 miles away, was shocked and knocked down and away from the telephone he was using; the exchange operator was shocked; and an employee at another mine, nearer the scene of the accident, stepped on a 12-inch pipe, touched a wire fence that was charged, and was badly burned on his hands, arms, legs, and feet.

7. The entrance to a small underground mine in a steep-walled canyon was about 50 feet above a road cut into the location. A small air-pressure tank was used to supply water for rock drills. This tank was set near the compressor alongside the road to save carrying water up to the mine. All water was brought to the mine in steel drums painted green. One morning the superintendent arrived at the mine after the men had gone to work and was told that a gas explosion had occurred in the mine, fortunately without injuring anyone. According to the men, the explosion was caused by a carbide lamp igniting gas as it issued from a hole they were drilling. As it was unlikely that the rock formation was making the gas, an investigation was made for other possibilities, and it was found that the pressure tank had been filled with gasoline from a red-painted drum. The gasoline forced through the drill steel into the hole was mixed with air and vaporized. It was fortunate that the explosion occurred before the working place had been filled with an explosive mixture, which, if ignited, might have wrecked the mine and killed everyone in it; as it was, the air and water valves were closed when the flash occurred.

8. An exact appraisal of the chances of damage to mine workings by an earthquake would involve much research into the passage of vibrations through various kinds of rock formations, and the findings would not be beneficial, as the history of such accidents has not shown a need for considering this hazard when planning and supporting mine workings. Apparently, there are occasions when earthquakes do affect mine workings, but these occurrences rarely cause death or injury to men underground, at least in the mines in this country. An example is reported from an iron mine in New York in 1944.[51] At the time, steel beams were being put in the steeply inclined shaft at a pocket on the 1,226 level where the ground was cut by dikes and maintenance had become difficult. The region was shaken by an earthquake about 7 p. m. on May 29, 1944, when 11 men were in the mine—4 at the pocket. Efforts to call underground by telephone failed to bring response so a rescue squad was lowered on the man-skip for 900 feet to where broken concrete-divided walls had blocked the track. The crew traveled by ladderway to the pocket where the shaft was completely blocked and 3 men were trapped; 2 of the men were rescued, and the body of the third was recovered. It was found that the shaft was caved for 500 feet through the zone cut by dikes.

9. A mechanic was overcome while working inside an oil-storage tank to remove a suction pipe that needed repair. Before entering the tank, he was equipped with a handline, hose mask, and rubber boots; however, before he could loosen the pipe, he became unconscious and was pulled out through the manhole with the handline. He was resuscitated in about half an hour. It was discovered that, although air was coming to him at all times from the pump, fumes

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[51] Linney, W. J., Shaft Repaired in 11 Days: Eng. and Min. Jour., July 1945, pp. 70–71.

from the open manhole were carried by a light breeze to the intake of the hose mask, and he was breathing impure air through the mask.

10. A motorman was fatally injured when he was struck by a large piece of rock that "popped" from the back of a haulageway as a locomotive with a trip of ore cars was passing. The haulageway in this iron mine is under such pressure that pieces of rock fly out without warning. The place where the fall occurred had been tested and scaled 3 days before the accident. No feasible method of support has been proposed.

11. A mucker in a gold mine was fatally injured by an old stick of 40-percent gelatin dynamite that exploded. He had found the stick while cleaning the ditch in a haulageway and had put it in his jacket pocket to take to the level magazine. When he was found his clothes were burning, and he had severe internal injuries of the chest and side. His hands were uninjured. He stated that he had rolled and lit a cigarette, and the explosion occurred. The detonation of only part of the stick in his pocket is unexplained. Smoking is considered unsafe when explosives are being carried or handled.

12. Four men died and one recovered from burns received when a pocket of acetylene gas was ignited by their carbide lights as they were being lowered down the shaft of a small silver mine. The ignition occurred at the beginning of the shift, after the mine had been idle over a weekend. The cage was 10 to 15 feet below the collar and a large can of waste carbide, dumped from the miners' lamps was about 10 feet from the collar of the shaft. Rain had saturated the waste carbide, and it was found that air currents on that morning were taking the fumes directly down the shaft.

13. Five miners sleeping in a frame bunkhouse were injured, four of them severely, when a strong wind rolled it over twice before it fell to pieces.

14. An electrician employed at a large copper mine was on a steel tower about 30 feet from the ground when the wind blew the unrolled end of a steel tape that he was carrying in his overalls to another powerline about 40 feet away. The shock caused him to fall to the ground, resulting in broken bones, as well as the burns that he received before he fell.

## PROTECTIVE EQUIPMENT

### EYE PROTECTION

Probably the greatest physical handicap that one can sustain is loss of vision. Injury to the eye is difficult to repair but easy to prevent. The eye is one of the most delicate organs of the body, and a slightly injured eye may develop an infection causing loss of vision in that or both eyes.

There is no such thing as a nonhazardous industry so far as eye injury is concerned. However, records of various industries show that the most serious eye injuries occur in metal and metal-products manufacturing, mining, and quarrying; building and construction; and lumber and wood-products manufacturing. The chief causes of eye injury, in order of their importance, are: (1) Flying particles, especially those set in motion by handtools; (2) abrasive wheels; (3) corrosive substances; (4) electric flashes; and (5) molten metal.

The National Safety Council [52] reported that among 750 companies representing 24 different kinds of work, 1 worker in every one of the 750 companies had a disabling eye injury in a year. For all the companies reporting, the average frequency rate for eye injuries was 0.67 per million man-hours. On particular work, however, the rates were much higher. The average rate for mining companies was 4.85; foundries, 3.99; and lumbering companies, 2.35.

In the Lake Superior iron-ore mines 4.3 percent of all injuries are from flying material, and most of these injuries are to the eyes.

[52] National Safety Council, Accident Facts: 1950, p. 39.

Mining involves hazards to the eyes in many routine tasks; in some the risk occurs at frequent intervals; in others, only intermittently. Many mining companies require the use of goggles or other eye protection around such operations as starting drill holes, blowing out holes, cutting hitches, breaking rock, chipping metals, handling certain chemicals or molten metals, sandblasting, and welding.

For general use, spectacle-type goggles with safety lenses will protect the eyes from injury and make it unnecessary to close them or turn the head away from falling or flying particles. The nuisance of fogged lenses should be dealt with in the best way that conditions allow; certainly refusal to use goggles for that reason when eye protection is needed is a poor practice. In many cases work will be easier with goggles in spite of frequent clouding or fogging. Surveys in companies that provide and maintain goggles for their employees reveal that up to 50 percent have defective sight. Safety lenses ground to prescription correct that fault, so that vision actually is improved for those who have not previously worn glasses. Goggles should be fitted individually to the wearer and maintained to make them comfortable to wear (fig. 33).

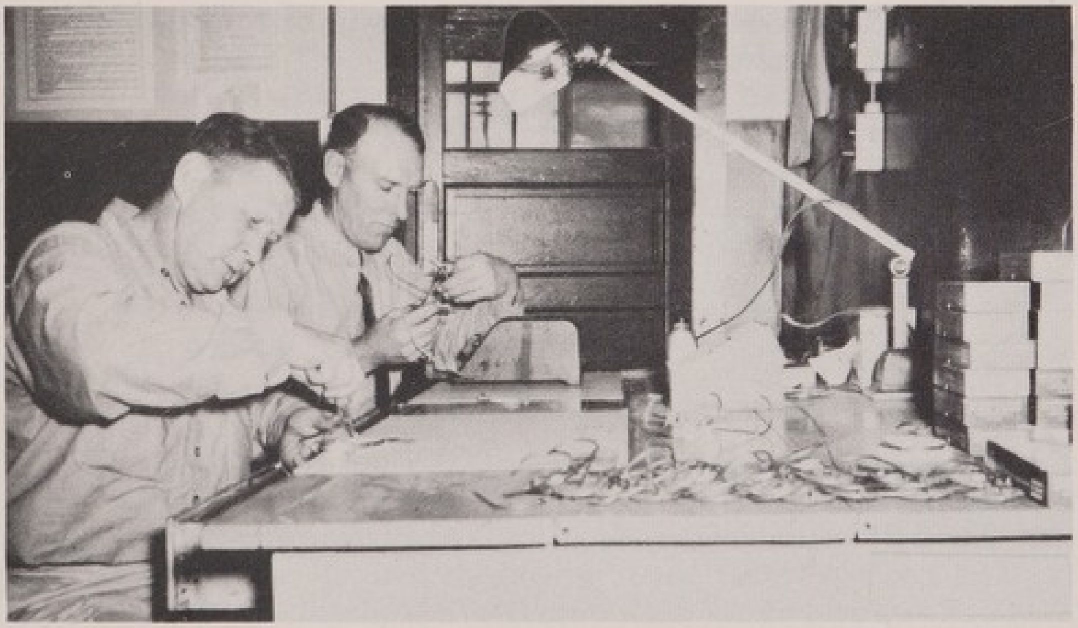

FIGURE 33.—Safety-Goggle Maintenance.

For tasks where safety goggles of the spectacle type do not give as complete protection as may be needed, enclosed goggles or a face shield can be used. Inmproved eye- and face-protective devices are perfected to a point where it should be possible to find one suitable to almost any requirement.

## FOOT AND TOE PROTECTION

At operations where employees do not wear protective shoes, foot injuries may be as numerous as those to hands and fingers. The extent to which safety shoes have reduced foot injuries in mining, as in other industires, has entirely justified their use as standard equipment. Foot injuries occur in handling tools, timber, ore, and rock, and in haulage.

Protective shoes and boots are now made in such variety that a suitable weight or type is available for almost any kind of work in and about mines or plants. The right type should be selected for the job, and shoes should be fitted properly to give comfort as well as service to the wearer.

### HEAD PROTECTION

The number of head injuries in metal mines has decreased to a great extent since the adoption of hard hats; such injuries constituted about 19 percent of all metal-mine injuries in 1920 [53] and only about 2 percent in 1940. These approximate percentages were derived from various available metal-mine accident records. The use of safety headgear is taken for granted as a necessary practice at most mines—so much so that it is no longer especially interesting or necessary to display split or dented hats that have saved men from death or injury. The fact that these hats save thousands of men from painful bumps almost daily is given little thought, so accustomed are the wearers to this protection.

In one recent accident from falling rock, a level boss in a large gold mine received a bruise on the crown of his head that would have been fatal had he not been wearing a safety hat. A chunk of ore 6 to 8 inches in size fell about 30 feet from a hangup of broken ore over a grizzly, cutting a gash in his hat.

### PROTECTIVE CLOTHING

Special clothing may be worn to guard the wearer from heat, cold, and wet and from flying particles or rough or sharp surfaces. Clothing without loose ends may be needed on certain jobs to avoid being caught in moving machinery.

## ILLUMINATION

### ROLE OF LIGHTING IN PREVENTING ACCIDENTS

Poor illumination is a work hazard that not only causes accidents but is an important factor in causing fatigue and lowering production. Entirely aside from promoting safety, its correction is profitable. The general belief that lighting is tied up with a certain percentage of accidents is of little practical help, and a better knowledge of good lighting is needed to stimulate its use as a safeguard to protect workers. Insurance experts charge 15 to 25 percent of industrial accidents to poor illumination. Improvements in lighting at plants and factories have brought about a marked reduction in accidents, and a sharp decrease in accidents in mines is evident where better systems of lighting are utilized. Bureau of Mines engineers have made detailed studies of the subject at various mines and estimate that approximately 35 percent of the accidents underground in the mines of the United States are caused by poor illumination. Perception with 2 foot-candles of illumination requires twice the time needed with 7 foot-candles; yet, in many mines the light provided is less than 1 foot-candle. Compare this with the 5 foot-candles considered the minimum for storage rooms, corridors, and stairways of industrial plants.

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[53] Adams, W. W., Mine Accident Statistics: Bureau of Mines Rept. of Investigations 2641, 1924, p. 6.

### LIGHTING REQUIRED FOR VARIOUS TYPES OF WORK

The American Standards Association has published a code for industrial lighting that gives the amount of light needed for best results in different lines of work.[54] Tests in different industries, extending over many years, have established the primary importance of illumination in accuracy of workmanship, increased production and decreased costs, ease of work, and greater safety. In close, precise work such factors as glare, diffusion, direction, and distribution of light are given careful attention. In the relatively rough work of mining the intensity of light is a general gage of illumination, although the other factors just mentioned are important and should also be considered. The intensity of light is measured in foot-candles:

*Foot-candle* is defined as the amount of illumination at a point on a plane 1 foot from a source of 1 candlepower and perpendicular to the light rays. Typical daylight readings:

| | *Foot-candles* |
|---|---|
| Direct sunlight at noon | 8,000 to 10,000 |
| Overcast sky or in shade | 500 to 1,000 |
| Indoors at window, bright day | 100 |
| Indoors, average room, 20 feet from window | 5 |
| Moonlight, full, at zenith | 0.2 |

The foot-candle unit expresses light intensity; it is a measure of incident light, or light that is directed onto the illuminated surface. Actual illumination is reflected light, which from surrounding surfaces is only a variable percentage of the incident light and is expressed in terms of foot-lamberts.

The reflecting qualities of surroundings, and particularly of surfaces that are directly illuminated, make a great difference in the amount of light necessary for effective illumination. For instance, a smooth, white surface reflects about 80 percent of the light falling on it, absorbing about 20 percent. A medium-gray surface reflects about 40 percent of the light and absorbs 60 percent. A black surface, such as coal, may reflect only 5 percent of the light. Thus, to produce the same effect, more than 15 times as much light might have to be supplied in a place where surfaces are dark as in one where they are light. On this principle, machinery and shop walls are now being painted light colors with suitable contrasts. The advantages of whitewashing or painting haulageways and underground stations with light colors can be noted in figures 34 and 35, which show the methods used to improve illumination in modern mines.

Where reflectors are used, the candlepower will be different at different angles from the axis of the cone of light so produced. The reflector may be shaped to give any desired concentration of light from 180° to a narrow beam that lights a rather small, circular area very brightly, the brightness decreasing abruptly outside the concentrated spot.

Abrupt changes in the intensity of light are hard on the eyes and make seeing difficult, as the eye cannot adjust itself readily to such sharp differences in light. Similar difficulties arise from glare.

Glare may come directly from an unshielded source of light or be reflected from a surface. Glare is not so much a matter of brightness

[54] American Standards Association, Standard Practice for Industrial Lighting: Standard A11.1, 1952, 40 pp.

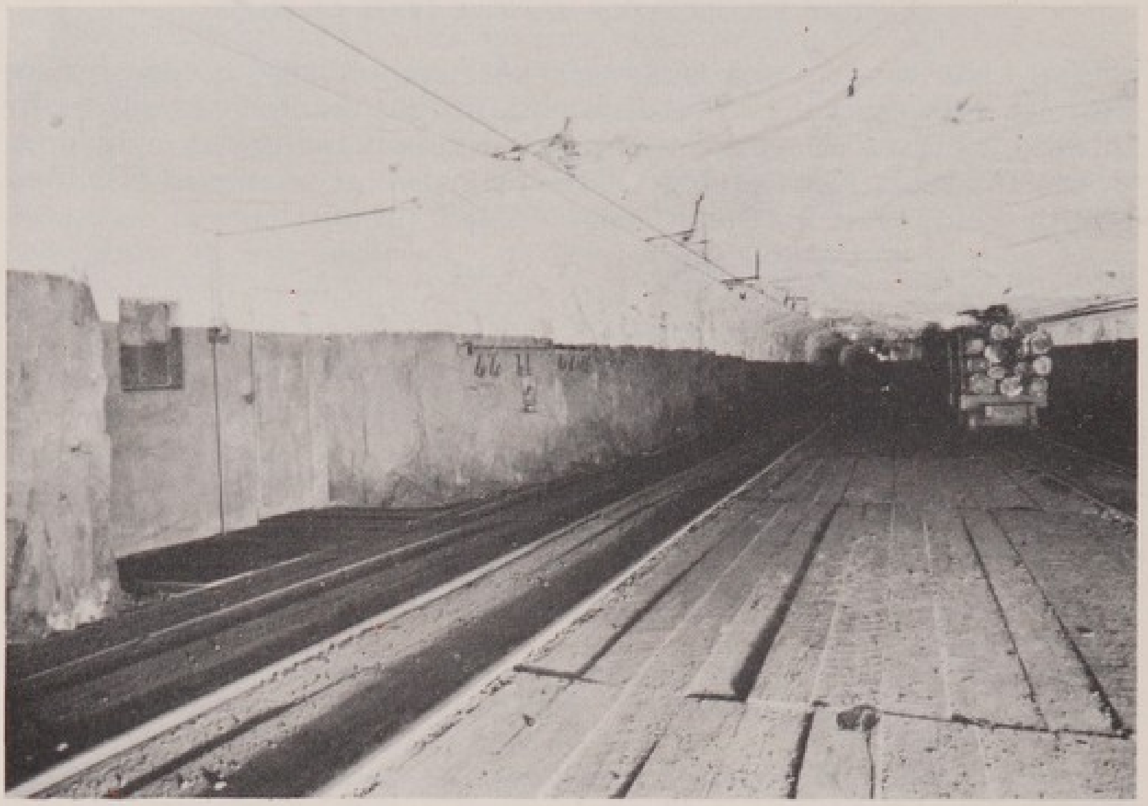

FIGURE 34.—Whitewashing Helps Illuminate Haulageway.

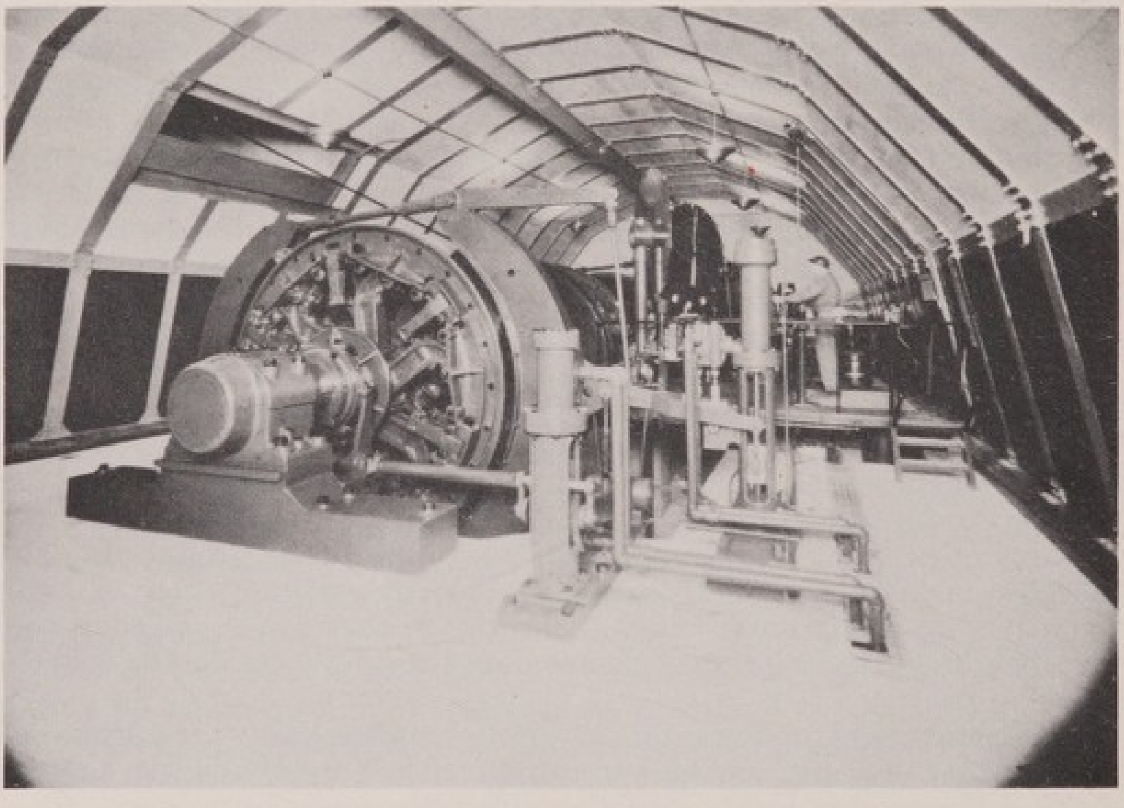

FIGURE 35.—Indirect Lighting in Underground Hoist Room.

FIGURE 36.—Lighting in Timbered Haulageway.

as a matter of contrast; hence, in dimly lighted places lights of relatively low intensity may produce irritating glare in contrast to dark surroundings. Even in a well-lighted mine haulageway, as shown in figure 36, some glare from unshaded lights is noticeable. Besides the annoyance, pronounced glare may so reduce visibility that serious accident hazards are created. Glare from lights installed in fixed positions can be reduced by providing shades, and that from electric cap lamps can be minimized by diffusing-type reflectors.

Recommended minimum standards of illumination for some industrial interiors and exteriors are given in table 9.[55]

The illumination levels in table 9 are for industries having conditions comparable to mining, and, although there are no minimum standards for underground work, a minimum level of at least 10 foot-candles should be the goal for underground workings. The minimum intensity of light considered for visual tasks is moonlight (0.02 foot-candle). The minimum recommended intensity of light is 1 to 2 foot-candles for observing large stationary objects or for walking. When the illumination level is about 1 to 2 foot-candles, work of any nature, especially if continuous, may result in eye strain. Underground illumination at present is above the minimum light level, but more should be provided for increased safety and health reasons.

The Bureau of Mines is currently investigating underground illumination with fluorescent lamps, and the results undoubtedly can be applied to metal and nonmetallic mines.

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[55] See work cited in footnote 54, pp. 12–17.

TABLE 9.—*Recommended minimum standards of illumination for some industrial interiors and exteriors*

| Type of work | Minimum foot-candles, 30 inches above floor | Type of work | Minimum foot-candles, 30 inches above floor |
|---|---|---|---|
| Yards | 2 | Building construction | 10 |
| Excavation work | 2 | Change rooms | 10 |
| Loading and unloading platforms | 5 | General indoor construction | 10 |
| Crushers and screens | 5–10 | Foundries | 10–50 |
| Chemical works | 5–20 | Machine shops | 20–100 |
| Powerplants, engineroom, and boilers | 5–30 | Grinding and chipping | 30 |
| | | Welding | 30 |

## HISTORY OF LIGHTING IN MINES

The history of lighting in mines dates back beyond the time of Pliny,[56] who wrote that in a silver mine in Baebelo, Spain, a mountain was excavated for a distance of 1,500 paces "and for this distance there are water bearers, lighted by torches standing night and day, bailing out water in turn, thus making quite a river."

This silver mine was operated about 200 B. C. As time passed, other means of lighting, such as phosphorescence from dead fish, sparks from a "flint and steel mill," oil lamps, candles, and acetylene lamps were devised. Another source sometimes utilized was sunlight reflected into the workings by bright metal reflectors. Acetylene or calcium carbide was developed in 1859, but a method of manufacture was not perfected until 1895. Carbide lamps for use underground appeared about 1905. The portable, electric-type battery lamp was developed largely between 1910 and 1915. Wired, incandescent-lighting installations have been extended from shaft and pump stations to the face workings of some mines, but these installations are not yet fully efficient.

## PRESENT-DAY LIGHTING

### CARBIDE LAMPS

Illumination produced by carbide lamps varies greatly, depending on size and length of the flame, amount of water vapor in the gas, and type of reflector and its brightness. A fairly high level of illumination can be obtained from a carbide lamp with a polished reflector and the flame at full length, but in most instances only a rather low level of illumination is maintained by miners. Measurements of the intensity of individual carbide lights worn by underground employees in mines in different districts throughout the United States were made by the Bureau of Mines to determine the average amount of illumination prevalent during the working shift. Throughout the zone of carbide-lamp illumination, the average candlepower was 4.4; of lamps with bright reflectors, 7.0; at a distance of 2 feet from the lamp, 0.9 foot-candle; at a distance of 4 feet, 0.25 foot-candle. A few efficiently designed carbide lamps with polished reflectors had a mean candlepower as high as 8.0 and an average illumination at 4 feet of 0.6 foot-candle.

[56] Agricola, Georgius (trans. by H. C. Hoover and Lou H. Hoover), De Re Metallica: Dover Publications, Inc., New York, 1912, 640 pp.

#### ELECTRIC CAP LAMPS

Portable, electric hand lamps were used in mines as early as 1890, and electric cap lamps appeared around 1908. The earlier models of electric cap lamps did not give as much light as carbide lamps but provided an even, reliable light that needed no attention or recharging during the working shift. After a few years, electric cap lamps were improved to the point where their performance equaled that of the average carbide light. New and more efficient models have been developed today and provide a light level so much greater than a carbide lamp that they are rapidly replacing flame-type lamps because of convenience and the need for better illumination.

Measurements of light produced by electric cap lamps used during 1954 (figs. 37 and 38) showed them to have an average beam candlepower of 10.5 candles, with a maximum of 175 candlepower at the center of the beam, using a 15:1 ratio matte or spread-type reflector. The present trend in cap-lamp illumination is toward extensive use of the spot (polished-type) reflector, which will provide a beam candlepower of 1,000 candles concentrated in a very small area. The spotlight is contrary to the standards of good lighting because of its inherent glare and limited light area, but present-day mining practices demand a spot-type lamp for increased illumination at greater distances.

It was estimated that by 1954, 90 percent of the underground workers used electric cap lamps because of their convenience and increased-light supply.

Some years ago a large mining company gave the following reasons for adopting electric cap lamps throughout its mines:

> The miner at all times has a light directly on his work, distribution of the light is more uniform and regular than with carbide lights, the miner's hands are free from carrying or handling his lamp, and fire hazards are reduced.

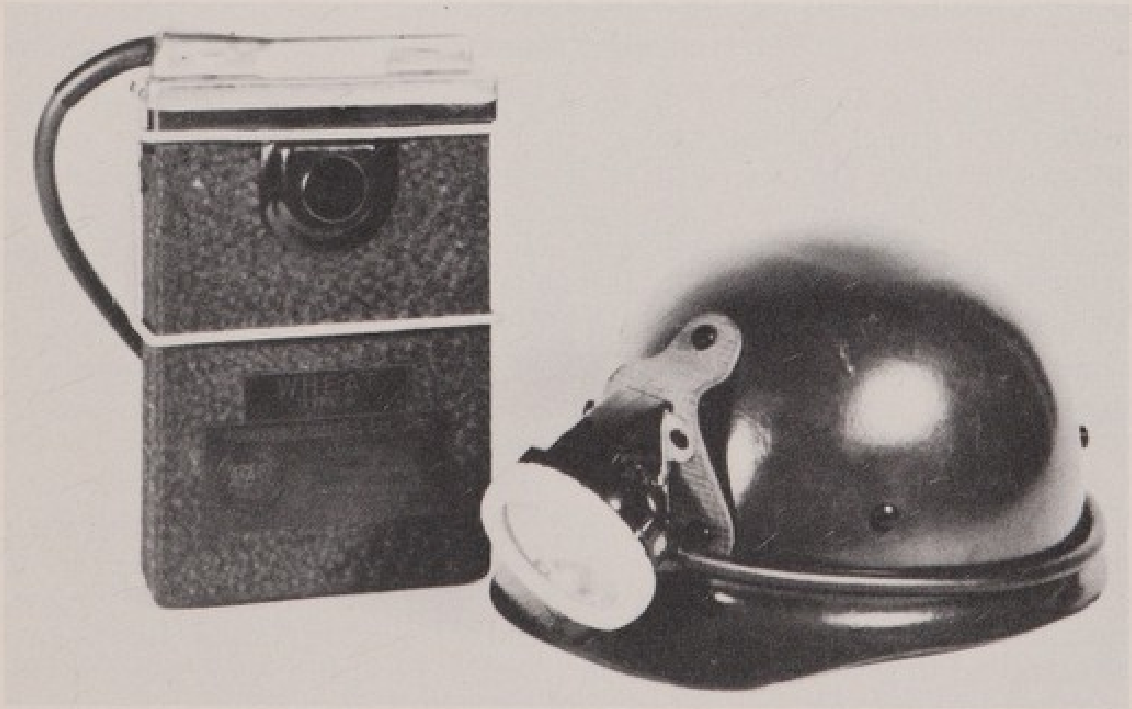

FIGURE 37.—Wheat Electric Cap Lamp.

FIGURE 38.—Edison Electric Cap Lamp.

Electric-cap-lamp batteries are more or less standardized in size and weight, and present efforts toward improvement are directed to greater efficiency (more light per pound of weight). Carbide lamps are no longer desirable for lighting fuses when blasting because they can be extinguished accidentally while lighting the fuse, leaving the miner in the dark. With electric cap lamps providing illumination, the spitter-fuse lighter, the hot-wire lighter, and other special lighters offer safer and more efficient methods and are rapidly replacing the carbide-lamp method of lighting fuses.

## WIRED LIGHTS

Incandescent electric lights on a separate lighting circuit or connected to a direct-current trolley circuit have been installed in metal mines ever since electric lighting has been a reality. Fixed lights on stations and haulageways are common, and in some mines extension lights are provided for working faces and stopes. Approximate, calculated values of the light intensity that may be expected over a 120° angle from 60- and 100-watt bulbs are:

| | *Foot-candles at different distances* | | |
|---|---|---|---|
| Bulb watts: | *5 feet* | *10 feet* | *20 feet* |
| 60 | 1.7 | 0.4 | 0.1 |
| 100 | 3.1 | .8 | .2 |

The values given are for unshaded lights without reflectors and with current supplied to the lamp at the rated voltage. Incandescent lamps burned at less than their normal rated voltage will last longer, but their light output is greatly reduced. Usually, enough lamps can be installed to give relatively good illumination; however, there is the problem of securing, installing, and maintaining wiring and fixtures that will stand the wear and tear of underground service and will not introduce a serious risk of fire and shock.

# SUPERVISION, TRAINING, AND DISCIPLINE

The most ardent supporters of the belief that man failure causes the most accidents are nevertheless firmly convinced that guarding machinery and correcting mechanical and physical hazards are the fundamental and first requirements of a complete safety program. Accepting the figures that 85 to 90 percent of all industrial accidents are caused primarily by the unsafe acts of persons, the relative importance of supervision and training is magnified.

Management must have a sincere and active interest in the safety of its employees; this interest must begin at the top and permeate the entire organization. Safety must be an integral part of day-to-day operation; it must be the chief concern of every supervisor and every employer during all operations at all times. This is best accomplished through a safety program based on engineering and operating experience, consisting of supervision, training, and discipline.[57]

## SUPERVISION

The number of accidents at metal and nonmetallic mines that could have been prevented by practical means has not been determined; however, the low injury rates of those operations making an organized effort to remove the basic causes of accidents prove that the overall injury rate for the industry can be reduced considerably.

The attitude of employees and supervisors toward following safe working practices regularly is a very important factor in accident prevention. A hazardous job can be accomplished with reasonable security by giving proper thought to the hazards involved and providing some measure of protection, whereas heedless and reckless acts at ordinarily safe tasks may cause injuries.

Supervisors, individually and as a group, are more responsible for preventing accidents than anyone else, with the possible exception of management. The supervisor, as management's representative, is in a particularly strategic position so far as safe and efficient production is concerned. He must have the confidence, respect, and enthusiastic cooperation of each employee working under his supervision.

The success of accident-prevention work depends primarily on the interest and example set by the supervisor. If he is indifferent and lacks the necessary enthusiasm to inspire his men with the real purpose and value of accident prevention, the employee will soon become indifferent. If he does not set the proper example, it is only natural that the employee will suffer from his failure. On the other hand, if the supervisor not only believes in safety but practices and insists on it, his men will become so accustomed to doing their work in a safe and efficient manner that it will become a thoughtful habit.

Management must show its sincerity in requiring safe employee practices by making the plant safe and healthful and providing safe methods of operating machinery and equipment.

The supervisor should visit his men frequently; the frequency of his visits, naturally, depends on the location of the men under his supervision and the detailed work that requires his attention.

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[57] Bureau of Mines, Accident Prevention in Nonferrous-Metal Processing Plants. 2. Mills and Concentrators: Handbook, 1954, 380 pp.

The supervisor or foreman plans the work and gives detailed instructions to the employees; it is his duty not only to give, explain, and interpret but to obtain results. To accomplish this, it is essential that every foreman knows his job and his men and understands the importance of the position he occupies in the safety and operating setup of the company. He must be capable of making decisions and exercising his supervisory authority intelligently, tactfully, and impartially.

The supervisor is the contact between management and men; he is the key man in industry, and no safety program can be wholly successful without sympathetic and intelligent support of capable foremen and supervisors.

## TRAINING

Although much of the answer to safe working conditions lies in equipment, guards, warnings, and safe-operating methods for conducting daily tasks, the training of supervisors and workmen in methods of work that are both safe and efficient is a fundamental step in reducing accidents and injuries.

Accidents caused primarily by man failure are often found to have been the fault of an individual who was not properly cautioned or alerted or who was indifferent, preoccupied with personal affairs, or simply prone to take chances. Hundreds of employees at mines and plants realize a work-life span of 40 or more years and never have or cause an accident. This is not because they are not exposed to risks of accidents as much as their coworkers but is attributable, rather, to a faculty for keeping their minds on the job, brought about by early pertinent training or by experience.

Safety training, to be effective, must be much more than an advertising campaign. Promotional programs through such mediums as slogans, stunts, pictures, posters, news sheets, contests, and the like play a vital part in safety, but this type of training must be supplemented intensively by individual contact. Safety training limited to giving employees general caution or safety slogans without telling definitely what to do, what not to do, and why is of indefinite value.

Few individuals, of themselves, will apply general principles or the wisdom contained in a slogan to their own activities, except sporadically and in limited fashion. Detailed guidance and continued persuasion and reminders are needed.

There should be an effective safety-training program for the supervisor. The foreman or other line supervisor is the member of management with the primary responsibility for making the safety program effective. Of equal importance is an effective training program for workers. In the larger mine or plant a competent safety staff is of incalculable value, not only for training but to assist the line organization in making the safety program work. This staff also provides the safety-engineering knowledge, technical assistance, and regular inspections that are essential parts of the program.

Employees should be trained in safety by instruction, demonstration, application, and followup under trained supervision. One of the most important jobs facing management is to discover those men who have not responded properly to the safety-training program, find out why they have not, and either help them to overcome the difficulty or assign them to work at which they are better suited.

Habit plays an important part in causing accidents; the working habits of most older employees were formed when safety instruction or training was limited to that given by the boss for whom they first worked. Habit is difficult to change, and a poor or even difficult way of doing anything seems to become the easy way through constant use; any change appears more difficult and involves extra effort. Through training the new way becomes easier; and, when the advantages of safety, ease, and efficiency are understood, the new way is accepted more readily. There may be conditions, however, under which it is more practical to provide whatever safeguards are needed for an established method of work than to attempt to change to a new system.

Depending on the specific type of training, various methods may be used. Training may be effective in larger groups, such as in first-aid classes of instruction or the discussion of accidents and their prevention in safety meetings; it may be effective in relatively small groups or even individually by a foreman or representative of the safety department, and with the proper incentive, inherent or stimulated, the individual employee may effectively train himself.

Various systems are employed by mining companies for training new men, ranging from the tried but unsuccessful expedient of placing them with another employee to a planned and supervised instruction course, such as depicted in figure 39.

FIGURE 39.—Student Miner Learning to Timber in Instruction Class.

## ANACONDA COPPER MINING CO. TRAINING PLAN

The Anaconda Copper Mining Co. at Butte, Mont., developed a training plan after many years of trial and experience. The outline of this plan follows: [58]

### Introduction

In June 1942 the Anaconda Copper Mining Co. introduced a plan of instruction for inexperienced underground men. The hard-rock mining regions of western United States have had no satisfactory training program for beginning miners for several years. The days of the all-around miner trained by his father to do every task in a mine in a highly satisfactory manner are gone. The breaking-in of green men with the regular miner disrupts the even flow of the work, slows down the job, exasperates the other men, and in places on contract actually causes a money loss to all concerned.

### Preinduction Training

It is recognized, of course, that certain preliminary instructions, as slightly differentiated from training, will be of considerable value to the green hand in his first few shifts underground. With this in view, a suitable safety and mining exhibit has been established in which most of the usual equipment ordinarily encountered underground is not only shown, explained, and demonstrated to the new man but is open to and arranged for his closer inspection should he so desire.

The instructor begins his lecture on the individual miner's personal dress and clothing. From here the group is shifted to the mine model where the general setup of the mine in action is tersely but carefully explained, along with two or three of the most usual systems of mining in this camp. By easy stages and without interruption or confusion the listeners are carried along through the entire exhibition. Everything is animated, everything is action, and everything is modestly dramatized. The result is that the attention and interest of the whole group is closely held throughout the entire period; and it is felt that much good is accomplished toward dispelling strangeness, anxiety, or fear of the new man for his prospective job.

The average time of each lecture is 1½ hours, after which a question and answer period generally consumes from 10 to 15 minutes more. It has been found that periods of 2 or more hours detract rather than add to the effectiveness of the program. Safety is stressed throughout the entire lecture and each listener is presented with a Safety Rule Book. It is our opinion that the instruction given in this mining and safety exhibit represents about the proper proportion of time that can be profitably spent in preproduction training above ground.

The time spent in the safety and mining exhibit precedes actual hiring or employment.

### On-the-Job Training

At this point it is assumed that the green man has attended the preliminary safety and mining demonstration, definitely decided to become a miner, has been directed to a mine having student stopes and desiring student miners, and has there been hired by the hiring foreman. The hiring foreman closely interviews the prospective student and assigns him to that place in the mine for which the student has the keenest desire, and for which he seems to be best fitted. All of this information is noted on the student's personal record sheet which has just now been started and is kept scrupulously from this point on throughout his entire training period.

This on-the-job training is the heart of the entire program and of the utmost importance to both the student and the company. The man has decided to enter a field entirely new to him and one that will definitely affect his entire future and the company has assumed all of the usual safety and other obligations extended to the fully experienced miner. The student is now on the company payroll at standard miner's day's pay, and the company is very definitely and vitally interested in his personal progress and record of proficiency and attainments.

[58] Dingman, O. A., A Working Plan for Training Miners: Proc. Lake Superior Mine Safety Conf., 1944, pp. 15–29.

In general, there are two major or basic divisions of mining operations in an underground mine; that is, crosscutting and drifting, and stoping or mining. It is around these two large basic groups or divisions, therefore, that the student-training program is built.

In considering a training program for small groups in isolated working places that are not easily reached, which is the case in almost any large underground mine, it is apparent that great dependence must be placed in the instructor. He must be sympathetic to the program, highly capable as a miner, have a capacity to teach others, and be physically able to do any of the work found necessary. The number of working places under his direction should be limited to not over two or three so that he may spend a continuous period of 2 or 3 hours with each group every day. Each shift boss handles three or four instructors.

There is only one foreman. It is often desirable or necessary for the foreman to call all of the students on a level or in certain stopes together for instruction that may pertain equally to all of them. This is accomplished by having a suitable place in the mine, generally a little-used station, provided with lights, blackboard, and benches for seating.

Once the student miner reaches the working place, his mining education really begins. Usually the place has been started by a preceding crew and is in first-class condition for continuance of the work. If not, then the group proceeds to do whatever work is necessary to place it in proper condition for the project in hand. Every job, in the progress of the training, is performed at the very time it is first encountered. Nothing is postponed. Nothing is side-tracked. Nothing is left for another crew to do who knows better how to do it. Before the job is begun the instructor sits down with his crew in a safe nearby spot and outlines the program and method of attack. He explains to them the reasons why this particular method has been chosen over others for this particular place and gives them the ultimate objectives to be attained. He details just how the job is to be started and the follow-up steps that will be necessary in its proper prosecution. He then breaks his crew down into the proper working parties, instructs them as to their specific tasks, gives them a final word of caution about being careful, and the work begins.

The significant and very important fact, from a training viewpoint, concerning the work in hand for the next 2 hours or more is that the instructor remains with these men and actually performs with them, each and every part of the work. He demonstrates, individually and collectively, with his own hands and with the aid of the crew, just what to do, how to do it, and what not to do. The instructor takes pride in the work of his crew. He knows from his long experience, his own personal job insructor training, and his study of job breakdown sheets that there is just one correct way to do this particular job in this particular mine or ground and he proceeds to use every intelligent means at his disposal to see that every member of his crew does it precisely that way. He thoroughly explains every part of the work, invites questioning and gladly reexplains everything that is not thoroughly understood. He maneuvers the group in such skillful manner that all have an active part in the job and all are interested in its progress and completion. Without being particularly aware of it, each person has demonstrated to the satisfaction of the instructor that he can do that particular job and that he understands the mechanics of and reasons for doing it. Nowhere in the whole program, thus far, has the instructor hurried or attempted to hasten the work. The whole emphasis has been on explanation, understanding, thoroughness, and safety.

As the training program moves along in the drift or the crosscut, the crew becomes more experienced and is thoroughly familiar with the ordinary work cycle of muck and drill, timber and blast. A careful explanation is made to them of the general haulage and hoisting system of the entire mine and particularly the way it affects their level and the availability of empty cars and supplies for their specific place. It is shown to them that in order for their particular operation to fit into this general pattern it is necessary that they regulate their work cycle to conform.

Although the stope operations are different in detail, the principle is the same.

We assume that the training program has been in operation for several weeks with these men in this same stope. The stope cycle has been in complete and highly successful operation on both shifts for several days, thus changing each member of the crew from one part of the work one day, such as drilling, to another part of the work the following day, such as timbering. All of the ordinary things in stoping have occurred and some of the unusual happenings such as loose ground, small caves, blasted-out timber, and blocked chutes have been discussed and taken care of. The foreman and shift boss have informed the men some time ago that stope production records have been kept from the start and that much improvement is being shown by the stope both in tonnage and reduction of ore dilution. The foreman attributes this to more experience, better mining, and consistent effort on the part of the crew. He explains to them the engineers' measurements and the cubic footage calculations for their breaking, timbering, and handling of broken ore and calculates for them the amount they would have earned if they had been paid for their work at the going rate for similar work to regular miners in other parts of the mine. This generally proves most interesting to the trainees, and they usually are surprised to find that their stope production is considerably below that which warrants day's pay. The fact that they have been receiving full miner's pay from the company since the very first day of their training, without actually having earned it according to the regular standards, appeals very much to their idea of fair play.

The foreman and shift boss voice the opinion that those men of the crew who think they now know enough about this particular type of stope mining to swing a regular job should probably be given a trial. They suggest, however, that before this is done the attempt should be made to bring this stope's production up to the day's pay level in order to show what will be expected of them as experienced miners. Usually the response is such that the goal is reached. Those men who still wish to assume the responsibilities of a full miner's job and whom the shift bosses agree are skilled enough, are given the first opportunity that presents itself. Where possible, they are placed in similar stopes in favorable places in the same mine and under shift bosses who will encourage and assist them in every legitimate way.

It goes without saying that not by any stretch of the imagination can these men, at this stage of their training, be considered full-fledged miners. They have probably spent from 6 weeks to 3 months in this special training course. Things just simply do not happen within such a short period of time in any mine in the world that would come even remotely close to furnishing a totally green man with a fully qualified miner's experience. No attempt is being made in this training program to produce the all-around fully qualified miner in 3 months. This is not the aim because it is not felt that this is necessary. As stated before, the different branches of actual underground mining, namely, drifting and crosscutting, stope raising and sinking—have become so highly specialized that they require specialized miners. This is particularly true with the larger companies where these different types of work constantly require the labor of several hundred miners.

The instruction given in this training program is thought to represent the very best that is possible to devise. It includes the remnant best of many trials over a long period of time and is taught by a group of thoroughly experienced miners especially coached and trained for the purpose. Full miner's pay incentive for the trainee has been provided by the company. Every usual job and detail of the work has been encountered and successfully solved several times. Many unusual jobs or situations have been created so that they might be studied, explained, discussed, and subsequently solved.

Under these conditions, it is believed that fully 1 year of the normal training and experience of the average green miner has been condensed or crowded into this 3-month period. Furthermore, the student has been informed of and has discussed many of the important allied services about the mine that many miners never notice or understand.

If the need for miners increases, there is always a tendency to shorten the training period. This is admitted to be one of the weak points of the entire program and cannot be allowed to go too far or the purpose of the entire program would be defeated.

### Supplemental or Related Training

There are many avenues for the continuation of the training period for both the stope and drift or crosscut miners after they have reached their minimum requirement. Each may receive the training the other has just finished, or the stope miner may be placed in a stope having an entirely different type of mining. How far such a system of diversified or pyramided training should be carried is a debatable question. Where the company guarantees day's pay for the entire training period, there certainly is a limit, and it would seem to be at two or three changes for each individual.

### Follow-Up

There is little doubt that lack of proper follow-up is the chief reason for the failure and ultimate collapse of many seemingly suitable and easily workable programs attempted underground. Large mining operations are particularly susceptible to such practices. Much time, effort, and money are spent in studying, organizing, and putting into operation certain laudable practices which later die a natural death because no one in particular is interested. The plan has failed and is roundly condemned. It never had a chance to succeed. It failed not because it was a poor plan but because it was never properly followed up.

As an aid and basis for follow-up, incorporated in this student training plan is a system of records regarding the student; his work, personal experience, and progress as the program advances. It is of the utmost importance both to the trainee and the company.

Strictly speaking, the first real follow-up for the unified training program for beginning miners comes after the student has graduated. The placement of the graduate trainee in a favorable working place as a regular miner is undoubtedly the most important single step in the whole setup both from the viewpoint of the young miner and the company. Under these conditions it would be most unfortunate for the company and disastrous for the young miner to be assigned to some shift boss who may be unsympathetic with the training program. It is absolutely imperative, therefore, that the follow-up part of the program definitely places each of the graduate miners in a stope or drift similar to the one he served in; preferably in the mine he has worked in but at least in one of similar conditions of ground and temperature under an even-tempered shift boss wholly sympathetic to the training program and one well-known for his capable handling of new miners. The performance record of each student is kept for 1 year after graduation.

### Training of Instructors

As is usual in picking men for important positions of responsibility, we set the ideal as a goal and strive to gain that ideal. The perfect training instructor or training shift boss does not exist, for if he did he would be immediately promoted to higher positions of further responsibility.

There are, however, certain characteristics or basic requirements that all training personnel must have to a fair degree. *The first fundamental* requisite is that the instructor must be thoroughly grounded and well experienced in all branches of the art of mining as exemplified in his particular camp or district. *Second*, he must be able to impart his knowledge to others, for without this accomplishment his own personal knowledge does others no particular good. *Third*, he must be sympathetic toward and believe in the training program and its ability and capacity for developing able miners. *Fourth*, he must have the viewpoint of both the young man and the new man learning a trade so varied and difficult as mining and the vast patience and tolerance that is so necessary for successfully teaching such men. He must never lose his temper. *Fifth*, he should have a certain capacity in sizing up men and that elusive but strictly human quality which allows him to get under men's hides, get things done, and make them like it. *Sixth*, he should have the physical stamina to personally perform any and all of the many fatiguing tasks in mining.

In the initial stages of the training-staff set-up those men are selected as instructors and shift bosses who most nearly possess all of the above qualifications. The next logical step, of course, is to set up the organization necessary to instruct, train, and educate the instructor and shift-boss personnel in the requirements in which they are deficient. This is accomplished through job-instruction training and other allied courses.

We are training bosses right along. Shift bosses attend special schools for 3 days with wages paid. They have all kinds of appropriate material to study and even examinations to fill out. The classes take trips underground, mentally criticize everything, and upon their return to the classroom, discuss and recommend changes. We take all of the bosses in rotation and send them to each of these schools. By the time all of them have completed one school we have another type of school started and put them all through that school.

The courses for bosses and other staff employees provide instruction in safety, methods of supervision and coordination of work, mining methods, job relations, and fire prevention. Classes include lectures, discussions, motion pictures, and first-hand investigations of practices under discussion. Accident-prevention duties of bosses are explained and discussed, and safe and unsafe practices relating to all phases of the operations are studied; safety is found to be a vital consideration in all operations.

Methods of training similar to those at Butte were adopted at Canadian mines, where it was found impracticable to attempt to train men in a short time to do more than one part of the work. It was also found that with a heavy percentage of new men on the job they could not be given workable instruction by miners or shift bosses until they had some preliminary schooling.[59] These instruction courses for new, inexperienced miners will possibly do much in time to overcome the drag that is placed on changes in mining practices by the old established father-to-son teaching of sometimes obsolete ways.

### PHELPS DODGE CORP. TRAINING PLAN

A plan for training men who had worked in the mines for years, as well as the new men, was put into effect at the Phelps Dodge Corp. mines in Arizona many years ago. As described by an official of the company, the plan was as follows: [60]

Our experience during the past 5 years indicates that the safety educational program is probably the most important and yet the most difficult phase of accident-prevention work. In final analysis, the object of an educational program should be to develop such a spirit of safety consciousness in the organization that every employee is looking for conditions and practices that may lead to an accident, and yet at a first glance appear to be safe.

All accidents that occur are first investigated, then analyzed and discussed with the various safety committees. This policy has proven invaluable in educating the organization as to where, how, and why accidents occur and the procedure necessary to prevent the occurrence of a similar accident. By means of this analysis of accidents numerous cases were noted where employees were injured while doing their work in an unsafe or wrong manner. Usually, we learned after the accident occurred that the work was being performed in the wrong manner and that no one had ever instructed the workman in the right way to do it.

After realizing that unsafe practices, on which the workman had never been properly trained or instructed, were a major source of accidents a job analysis of the different operations was made. This standardization of practice was accomplished by having committees, composed of the departmental superintendent, foremen, and bosses, study the movements connected with a certain job or operation and agree on which was the most efficient and safest method of performing the work. When a standard method was decided upon, the method outlined was placed into effect and the workmen were instructed in this method of performing their work. By having the foremen and bosses make the job analysis and agree on what should be the accepted method of doing each operation, they automatically put their stamp of approval on the method, with the result that the training program is entirely in harmony with their point of view.

Contrary to the opinion expressed by many to the effect that a standard method of procedure cannot be applied to mining operations, the various companies of the corporation have been able to work out such a standardization

[59] Hicks, H. B., Safety and Training the Recruit: Canadian Min. Jour., vol. 66, No. 5, May 1945, pp. 325–328.

[60] Henric, H. C., Accident-Prevention Work at the Phelps Dodge Corp.: Min. Cong. Jour., July 1931, pp. 345–350.

covering many of the more common operations, and this standardization work is being constantly extended.

The responsibility for seeing that proper instruction was given to the workmen was placed squarely on the shoulders of the foremen and bosses.

In addition to instructing the workmen how to perform their work in a safe and efficient manner, every employee was required to pass an oral examination covering the safety and operating rules of the company.

Mine foremen, assisted by the safety engineer, make a practice of talking to small groups of workmen during the lunch hour. These discussions generally center around conditions, unsafe practices, and methods of performing the work in the particular section of the mine represented by the group in question. This practice has also been followed in the various mechanical shops.

The natural sequence after having recognized the hazard, then standardizing practice along safe and efficient lines, and properly instructing the workman, is to have ample and proper supervision in order to see that the correct methods are properly understood and carried out. Foremen and bosses must not only be trained to accept their safety responsibility but must be held responsible for unsafe conditions and unsafe methods of doing work by the workmen under their supervision.

## DISCIPLINE

A safe mine or plant is one where there is respect for discipline, which in its positive sense is continuous in every phase of the operation and applies to supervisors and workers alike. Discipline is essential for plant efficiency, good employee relations, and in all phases of plant relationship. It is not confined to safety. You will not find good safety discipline in a plant that has poor discipline otherwise. There should be little difficulty in bringing about compliance with basic safety and operating regulations. The educational approach will suffice to bring this about in the very large majority of cases. There will be only a few instances where individuals insist on violating good safety practices. In those instances management must be prepared to handle the situation.

In most cases of safe-practice violation, corrective discipline can be applied in the form of a personal reprimand; however, if it is found that supervisory and training methods fail to impress an individual or he is incapable of understanding the standards of safety and efficiency necessary to a certain job, transferring him to different work where he will not bring harm to himself or men working around him often will solve the problem. In the extremely rare cases where an individual is determined to do things his own way, is found to be indifferent by nature, or deliberately disregards established rules and practices, as a last resort he should be discharged under suitable procedures designed to prevent injustice.

## MINE-SAFETY ORGANIZATION

From the foregoing discussions of the duties of the supervisors of a mining operation in respect to safety, it is apparent that the major part of the safety work in any establishment must be done by the regular organization, although a safety department or a safety engineer should be a part of that organization.

A common form of safety organization is one in which a safety department is made up of a chief safety engineer, assistant safety engineers, and safety inspectors. Such a department might function from a central mine office or a general office for a group of mines operated by one company. The duties of the safety department are largely of a consulting capacity—studying safety problems of the mines and surface plants; advising executives and supervisors of hazards and measures to correct them; cooperating with supervisors in conducting their safety work; and keeping executives and supervisors informed on accident trends, causes and consequences of accidents, and measures for preventing accidents.

To avoid division of control with resultant confusion and irresponsibility, the operating department must take control of the safety of men, equipment, and conditions of work. The plant manager, having laid down the accident-prevention policy, must see that it is carried out and, when there is a failure, must take up the matter with the appropriate operating man. He is the nominal leader in safety work and is accountable for the results to the heads of the company. The safety engineer is the adviser and in some respects the agent of the manager or superintendent in administering the safety program; he serves as technical leader and adviser of all operating officials in accident prevention.

A safety department that is overorganized and out of proportion to its function of suggesting safety improvements, counseling the operating staff, and inspecting and reporting on safety conditions is likely to defeat its own purposes by consciously or unconsciously stealing responsibility and incentive for improvements in safety from the operating staff.

Although the foregoing principles apply more directly to mining organizations large enough to have a safety branch or department, they will apply almost equally to any mine or plant having a "safety man" who is not at the same time a high-ranking operating official. Thus, the burden of the safety program at a small mine must be carried by the active head of the operating staff, with the help of his subordinates to whom he can delegate specific details.

There are certain aids from outside the organization, both to large and small mines; this assistance comes from State mine inspectors, safety engineers of casualty and insurance companies, and safety engineers of the Federal Bureau of Mines. In many ways the representatives of these agencies cooperate with company safety men or supply the need where the mine has no one to look after such work. Safety associations, comprising groups of mines in particular districts, have also been potent in preventing accidents and increasing efficiency in the mines and plants of the member operators.

E. H. Denny, from his experience with the Bureau's mine safety work, has stated the fundamentals upon which safety programs must be based: [61]

Reduction of mine accidents appears to depend upon essentially the same fundamentals, whether considered from the viewpoint of the mine operator, miner, State mine inspector, or safety engineer. Conditions of mine operation with respect to safety are governed in most States by a mining law, usually somewhat general in its provisions but more specific than laws dealing with other industries. Methods of mining development and practice evolved through experience have been handed down from generation to generation; many of these are intended to avoid injury to men and also loss of property. To carry out the intent of these bases of law and experience relating to safety, supplemental measures and conditions are necessary. Among these may be: (1) Planned

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[61] Denny, E. H., Suggested Methods for Reduction of Mine Accidents From the Viewpoint of the Safety Engineer: Bureau of Mines Inf. Circ. 6925, 1936, 6 pp.

safety rules adapted to the mine and compliance by both officials and miners with such of these rules as pertain to their work; (2) a supervisory force adequate and competent to administer the mining laws and safety rules; (3) discipline adequate to secure compliance with safety measures; (4) safeguards against mechanical, electrical, falling, and other hazards; (5) mining operations planned with respect to safety of workers; (6) an active safety organization of officials and employees; (7) education of officials and employees in safety practices; and (8) an active sustained interest in safety by management and employees.

State mining laws or regulations relating to safety form the background for most mine-safety rules, and sometimes they are the sole compilation of safety rules for mines without a safety program. Usually, the initial step toward such a program is assembly of safety rules adapted to the particular mining operation and selection of measures to insure that they are carried out by mine officials and miners. Such rules supplement the State law. They may be few or many, depending upon the size and complexity of the mining operation. Assistance from the employees in the discussion and preparation of proposed rules is likely to promote better compliance. In any case, safety rules need frequent study as to applicability; they have no value unless understood and carried out.

Safeguards against mechanical and electrical hazards, falls, and other similar dangers may play a more important part in accident reduction than figures indicate; a good system of guards about all machinery exposed to man contact impresses miners with the company's interest in their safety and tends to make them think of safety also. Safety engineers must consider the problems introduced by the constantly increasing use of electricity underground and on the surface with workers in proximity to power lines having a potential of 220 to 500 volts or more.

Safety engineers are able to suggest changes in methods of operation that will increase safety. In some cases generally accepted practices may not be the safest. For example, a trip rider was killed by returning too soon to a "pop" shot in a boulder on top of a car, which suggests that there should have been no rocks coming through the chute into the car big enough to have to be shot and that a smaller screen or grizzly, with better breaking on an upper level, would have made such an accident impossible on a haulage tunnel where speed in moving ore is considered essential.

Attention must be given to proper transportation, distribution, temporary underground storage, and use of explosives, with the thought in mind that allowing only the required number of men to handle the explosive or be near it lessens the hazard. Much mechanical mining involves frequent blasting during the shift, and a definite tendency to let down on underground storage and transportation practices follows. Blasting during the shift necessitates properly guarded shots to avoid injury to men and requires a means of ventilating to remove fumes so that the men will not remain exposed to them.

Safety engineers will insist on suitable pipe connections underground with hose available, fireproofing underground electrical equipment stations, suitable fire extinguishers near danger points, electric miners' lamps, concrete drift portals and shafts, and protecting all wiring with insulators or conduits. They will have ample supplies of portable firefighting equipment on the surface and men strategically located on the surface and underground who have studied what to do if spontaneous or unexpected fires occur.

Safety engineers freely study and use accident statistics of their own company and other companies to reduce accidents. They first classify accidents as to the standard direct causes and compute the accident frequency and severity rates; they study the records of mine sections and mine bosses and consider the natural conditions of the various mines or sections; they obtain reports of all accidents and treatment given; they secure proper medical treatment for the injured and try to get them back to work as soon as they are fit, but only if they are fit. They charge permanent partial disabilities, permanent total disabilities, and fatalities on a definite time-lost basis intelligible to all and do not make a "joke" of the record by putting an injured man back at some light job and calling him well on the accident-report sheet. From time to time they total the compensation and medical cost of accidents and compute how much they really cost the company and the injured men. They investigate all serious accidents and consider whether the ascribed causes of the accidents were the real ones, what other causes enter into the picture, and what measures should be taken to avoid repetition.

Plainly, these and other methods of reducing accidents are not carried out by safety engineers themselves. They act as agents of all supervising officials to observe, suggest, and check on matters pertaining to safety. To effect safety programs, they work in many and various ways with management, underground officials, and men. Safety engineers reduce accidents by getting the other fellow to do the work. The interest of management is held by a report that points out results achieved, including life and money saved, dangerous conditions corrected, accidents investigated, and cooperation. Mine officials are told at meetings and by individual contact of comparative accident records

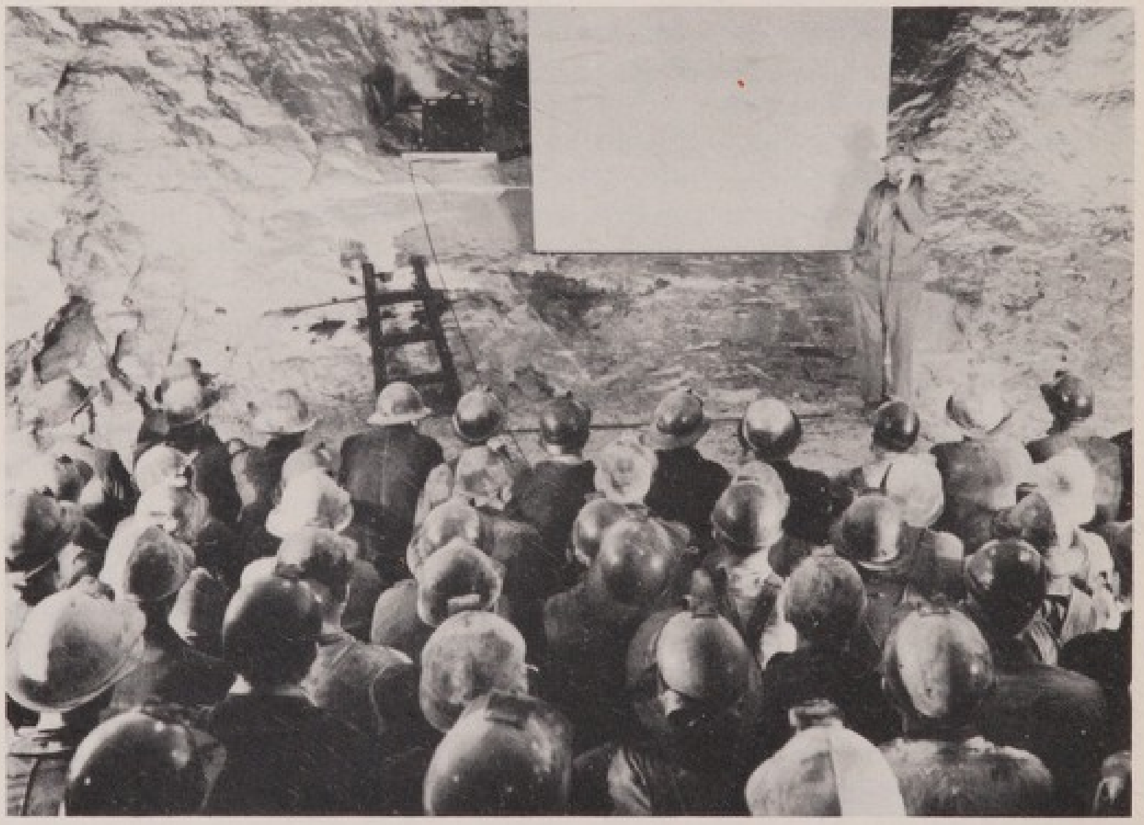

Figure 40.—Safety Meeting Underground.

FIGURE 41.—Safety Bulletins Describe Accidents.

of both good and bad conditions noted in their sections, changes needed, and work planned. The interest of employees in their own safety is maintained through safety meetings and a company safety organization in which they have a definite voice, through workers' safety committees, safety ratings with awards to miners and officials, numerous personal contacts, company publications, bulletins, posters, and letters, and through the thought that on the individual lies a large responsibility for safety. An underground-miners' safety meeting and a surface bulletin board for describing the causes of accidents as they occur, shown in figures 40 and 41, are examples of the use of the foregoing method in metal and nonmetallic mines.

## EXAMPLE OF MINE-SAFETY PROGRAM

This outline of a mine-safety program has been drafted from the viewpoint of a safety engineer; the safety program of a large mining corporation is described in a Bureau of Mines information circular.[62] Some pertinent excerpts show major points of the program that has been evolved:

The prevention of accidents is considered a necessity at all branches of the operation, and since there is a continual exchange of data on safety accomplishments between the various units, their safety programs are fundamentally similar. The safety of new employees receives a large part of the attention devoted to operation. In keeping with this policy the actual accomplishment of accident prevention is left largely to the local management.

The accident-prevention program at the smelter has passed through several stages of evolution, and the process is not necessarily completed. It embodies the following features: Safety committee, accident investigations, codes of safe practice, systematic plant inspection, foremanship conferences, physical

[62] Anundsen, E. A., Accident Prevention at a Copper Smelter: Bureau of Mines Inf. Circ. 7061, 1939, 26 pp.

examination, dust investigations, first-aid training, and miscellaneous safety elements.

### Safety Committees

Safety committees are essential to the planning and execution of a successful accident-prevention program. Every plant employee at the smelter is included in one or more safety committees.

*General Safety Committee.*—The General Safety Committee is divided into two sections: The Foremen's General Safety Committee, for all foremen and department heads, which meets once a month, the smelter superintendent presiding; and the Departmental General Safety Committee, including all employees below the rank of foreman, which meets monthly in groups, each foreman conducting the meeting of his group. The objectives of the two sections are parallel. They criticize existing practices and conditions relative to safety, furnish safety suggestions, discuss accident-prevention methods, and consider pertinent items from minutes of other safety committee meetings.

*Departmental Committeemen's General Safety Committee.*—Each individual group in the Departmental General Safety Committee elects a representative to serve for 3 months on the Departmental Committeemen's General Safety Committee. An elected committeeman has the following duties:

1. He conducts monthly safety inspections of his department and prepares a report on unsafe practices, faulty equipment, and miscellaneous hazards observed.
2. He keeps department bulletin boards up to date.
3. He assists in investigating and classifying accidents.
4. He observes and corrects any violations of rules and codes.
5. He checks the application of codes and suggests desirable revisions.

*Smelter Investigation Committee.*—The Smelter Investigation Committee is composed of five members, including one permanent representative from the safety department. Three members are selected from the ranks of foremen or department heads and one from the workingmen's group; all serve a 3-month term. Appointment of the last member must receive the approval of the Employees' Representative Committee.

The Smelter Investigation Committee investigates all reported accidents, whether or not there is personal injury. No injury is too slight to warrant investigation, and it is believed that nearly all injuries are reported. This committee meets weekly and prepares detailed reports on the accidents investigated, classifies the accidents according to cause, determines responsibility, and recommends steps for the prevention of similar accidents.

*Branch Safety Committee.*—Smelter division members of the Branch Safety Committee include the superintendent, chief engineer, master mechanic, chief surgeon, heads of construction and preparation departments, and representatives of the Safety and Employment Department. Similar employees of the mine division represent it on this committee, and the branch manager acts as chairman. Upon the Branch Safety Committee falls the responsibility of outlining the safety program.

*Safety and Employment Department.*—Although the Safety and Employment Department is not a committee, it is represented on all committees. Members of this department edit and distribute copies of reports of meetings, inspections, accidents, and codes of safe practice. They investigate accidents, check action taken on safety suggestions, and generally coordinate safety committee work.

The Safety and Employment Department keeps informed on safety activities of other companies and has been instrumental in introducing many desirable features into the smelter program. Upon the Safety and Employment Department also falls the responsibility of selecting and instructing new employees.

*Accident Investigations.*—Recognizing their value, the management at the smelter has carried investigation of accidents beyond the usual limits. Accident investigations are based on the realization that:

1. A detailed story of the accident must be obtained to determine the cause of injury, which may indicate the cause or causes of the accident.
2. The cause or causes of the accident must be pursued to the point where positive correction can be applied successfully.

3. Responsibility for the accident must be determined.

4. A means of preventing occurrence of similar accidents must be shown.

A thorough analysis of each accident is believed to have a far-reaching effect, and the management feels that the results obtained more than compensate for the time and expense of investigation. The principal accomplishments are:

1. Determination of the true cause of the accident and *description of the essential preventive measures place the responsibility for prevention of similar accidents on a certain individual or group of individuals.*

2. The investigation forcefully instills safety consciousness into the individuals directly affected—the witness, the victim, the immediate supervisor of the latter, and the committee members.

3. Publicity of a reasonable type given to findings has a similar, if less forceful, effect on the entire personnel.

4. Unbiased placing of responsibility for accidents and accident prevention encourages employees to adopt a more cooperative attitude toward the latter. There can be no feeling of persecutiton where committeemen render impartial judgment phrased in temperate language, and the responsibility falls as readily on supervisors as elsewhere.

5. Thorough and determined investigative work presents to all a most convincing argument that safety is of first consideration.

### Codes of Safe Practice

It became obvious that if the foreman was to discharge his end of the accident-prevention program successfully, he and his men must be provided with something more than general safety rules, that is, a specific and detailed guide describing the correct method for each operation they performed. Accordingly, selected officials were given the task of studying operations with a view to making "job analyses" and preparing the necessary guide. An outline was developed, and "code of safe practice" drawn up covering each separate operation. The time and work required on these codes proved great; however, the benefits derived were substantial.

After the problem of code preparation has been largely solved, the difficulties of familiarizing the employees with the objectives, hazards, duties, responsibilities, equipment, tools, apparel, safeguards, etc., that attach to his job still exist. Although the codes have been made as brief as is practicable for complete coverage, they still are too long and detailed for rapid assimilation. To familiarize the employees with the codes, combined study, verbal instruction, and practical training are employed, with a definite follow-up schedule of examination.

### Systematic Plant Inspection

Codes of safe practice include one for general plant inspection, which describes the minimum safety requirements to be considered in such an inspection.

Each departmental committeeman is provided with a general inspection sheet (revised), covering the same items in outline form for making monthly departmental safety inspections.

Inspection codes of more specific application have been prepared on such subjects as wire rope, bridge cranes, powerhouse switchboards, and related equipment.

Not the least important of the safe practice codes pertaining to plant conditions and equipment is that prepared for the engineering department.

Serious hazards are apt to be created through the neglect of safety in design and choice of new equipment.

It is impracticable to draw up a detailed code specifying standard safe practices in respect to all designs and equipment within the scope of engineering department operations. Much detailed material has already been published covering this field and is readily available.

Therefore, the "Index of Standard Practices and Equipment" lists the item on which safety information is desired, together with the authority or reference containing such information.

The "Check List for Structure and Plant Design" has been drawn up to assist in checking over general drawings and layouts for hazards.

The "Check List for Equipment" has been drawn up to assist in checking all new equipment to guard against the introduction of new hazards into the plant.

### Foremanship Conferences

Foremanship conferences over the United States are a rather general means of developing the desired essential characteristics of individuals holding such positions. Those conducted at the smelter differ from the usual training in two respects: They are both self-starting and self-operating. A foremen's club organized by the smelter supervisors conducts the conferences, furnishing its own conference leaders. Subjects for discussion are partly suggested by a published course of training.

Foremanship conferences represent one phase of safety education blending with the safety-education program as a whole.

### Physical Examinations

A complete physical examination is required for employment. Defects that do not prohibit employment may still influence the selection of the kind of work to which a new employee can be assigned.

### Safety Suggestions

The value of a safety suggestion depends chiefly upon the consideration, acknowledgment, and application of the suggestion.

Main sources of safety suggestions are departmental safety inspections, departmental safety meetings, and accident investigations. However, many suggestions are offered directly to supervisors or to the Safety and Employment Department. Virtually all plant physical improvements in the interest of safety and efficiency are direct results of safety suggestions. Many improvements in working practice also can be credited to this feature of the safety program.

### Relative Value of Elements in the Smelter Accident-Prevention Program

90-Percent Factor

*Increased safety consciousness, i. e., convincing everyone that safety is first*

| Method | Relative value, percent |
|---|---|
| A. Study of practice and elimination of unsafe methods | 35–40 |
| 1. Written codes. | |
| 2. Good foremanship. | |
| a. Advance planning of work. | |
| B. Better shop and departmental safety meetings | 20–25 |
| C. Systematic plant inspection by workmen committeemen, which has been productive of visible results [1] | 15 |
| D. Analytical investigation of *all* mishaps | 15 |
| 1. Classification. | |
| 2. Publicity on findings. | |
| E. Foremanship conferences | 5 |
| F. First-aid training | 5 |

[1] In time this factor is likely to be increased, as committeemen assignments are progressive.

10-Percent Factor

*Better physical conditions, safeguarding, and dust control*

| Method | Relative value, percent |
|---|---|
| A. Systematic plant inspection, carefully noted and followed up | 40 |
| B. Suggestions in shop and department meetings | 20 |
| C. Personal apparel, etc | 20 |
| D. Alertness of foremen and department heads | 10 |
| E. Analytical investigation of *all* mishaps | 10 |

The above conclusions apply only to the smelter program and the period covered. A similar analysis of another safety program is likely to produce substantially different values. For example, at the operations of some companies, first-aid training as a means of increasing safety consciousness may supplant some factors in the preceding outline and may even carry a 40-percent valuation.

Programs applicable to large mines or plants have almost no relation to the problems of safety at small operations where the relationship of individual workers to the operator is much more personal.

Methods that will promote safety at a small mine will function at any mine, for it is particularly important that the human element in such mines be taken into account, and personal contact is essential for a successful safety program. To be successful, safety engineers must be patient but firm, rather than attempt to introduce an overly ambitious program. Overzealousness about policy and procedure and getting things done immediately in safety work must not be too evident lest it be construed as arrogance and develop antagonism.[63]

Safety technique at large modern mines owes much of its success to the psychological advantages offered in such organizations. Logic and statistics carry much weight in safety work through management efforts at large plants, but logic and statistics only fall flat at a small mine and, alone, have never aroused popular support in any group. To be successful at a small mine, safety engineers must know, through training, experience, and personal contact, the safe and unsafe practices of the field. They must develop a plan and have the personality to carry it through by persuasiveness. Once improvements have been successfully adopted at one or two mines, they are likely to be taken up by neighboring properties. Example is an effective method of promoting accident prevention. Improvements in safety at small mines must come mainly through education of operators and workers in better and safer methods and practices.

## SAFETY-ORGANIZATION CHARTS

A carefully planned and operated safety organization is an asset to the efficient mine or plant; it designates the responsibilities of management, safety department, supervisors, and employees; it gives a concise picture of the activities and limitations of various individuals in the organization; and, last but not least, it coordinates the efforts of safety and production into an efficient operation.

Figure 42 shows the organization adopted at a large underground metal mine in Northeastern United States. The following are its essential factors:

1. The district manager, assistant district manager, and mine superintendent must maintain active safety attitudes. The district manager insists on complete cooperation. The safety department is an integral part of the operating department.
2. The safety engineer must be thoroughly experienced in every phase of underground mining and be well versed in mining safety. He is responsible for planning and directing the overall safety program.
3. The mine safety inspectors at this operation have had years of mining experience. Each was selected for his job because of his intimate knowledge of mining practices and the characteristics of formations encountered, his interest

[63] Ash, S. H., What a Safety Engineer Can Do to Teach Safe Practices to the Employers and Employees at a Small Mine: Southern California Safety Soc. Conf., Los Angeles, Calif., May 12, 1938, 6 pp.

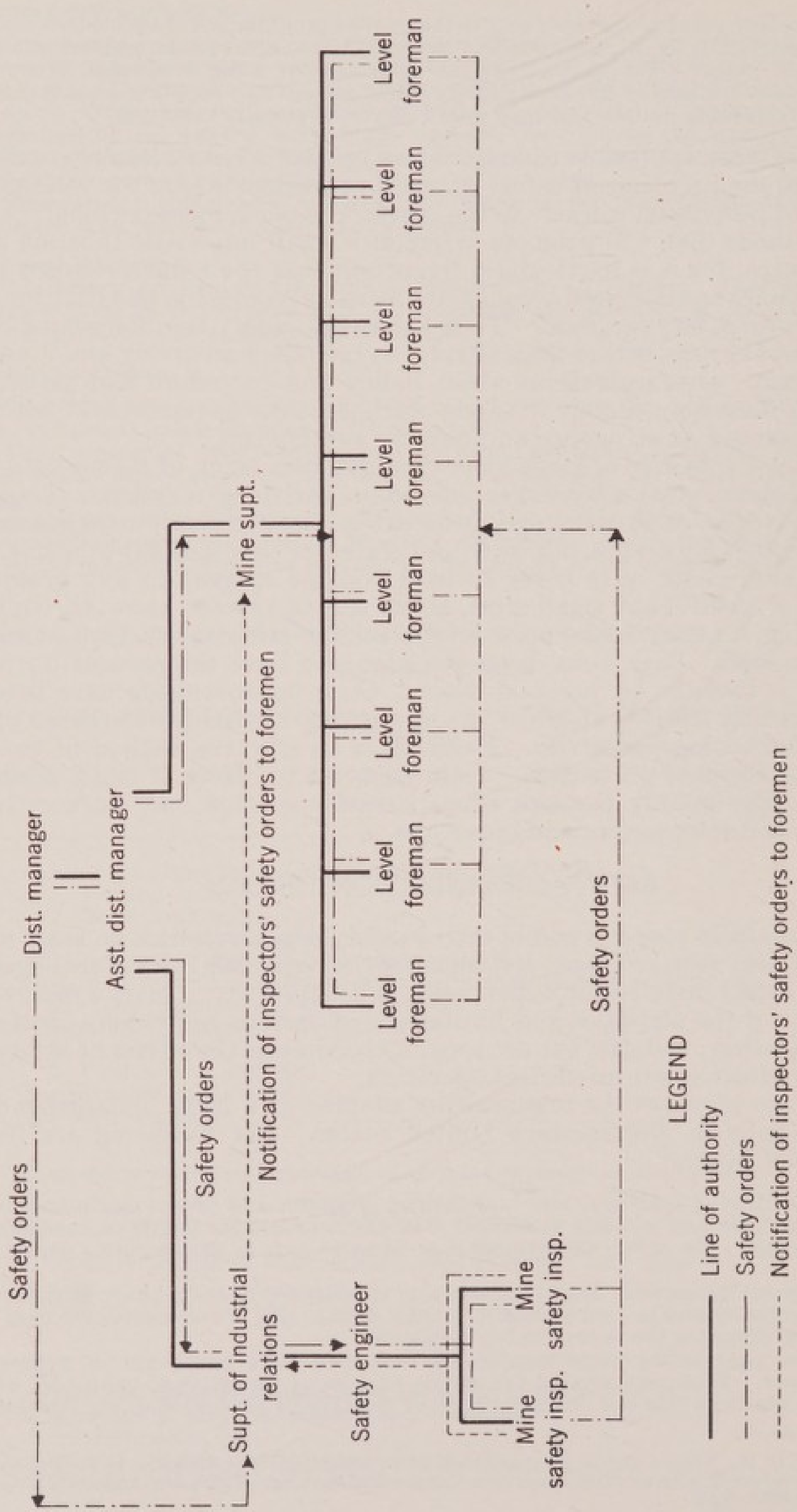


FIGURE 42.—Organization at Large Northeastern Underground Metal Mine.

in safety, his physical capabilities, and his ability to tactfully execute and/or initiate safety orders.

4. Level foremen understand that an unsafe operation is not to proceed until recommended corrective measures have been adopted. They are responsible for safety and are held accountable for unsafe practices and conditions. The cooperation required between them and the mine safety inspectors has removed an objectionable feature and resulted in a vastly improved safety program.

The normal flow of safety orders is from the district manager to the mine superintendent and the superintendent of industrial relations; the superintendent of industrial relations conveys them to the safety engineer, who in turn gives them to the safety inspectors. If for any reason the district manager wants immediate action on some safety measure, his orders are given directly to the superintendent of industrial relations, thence to the safety engineer and mine inspectors.

Because the mine inspectors are assigned daily to underground safety duties in their respective sections of the mine, the district manager has deemed it expedient that these men, with the approval of the safety engineer, issue safety orders in his behalf to the mine foremen. When conditions warrant, safety orders may be given to the men actually doing the particular job on which a hazard is considered to be apparent. The safety engineer is advised of any orders of this nature. He in turn conveys them to the superintendent of industrial relations who sees that the mine superintendent is informed.

Line safety orders received by the mine superintendent are given the level foremen for execution. One function of the inspectors is to see that these same orders are fulfilled; they also receive the orders through line channels.

Figure 43 shows the organization adopted by a company in the Southwest operating a mine, mill, and smelter; figure 44 shows the organization used in the West by companies operating quarries and cement plants.

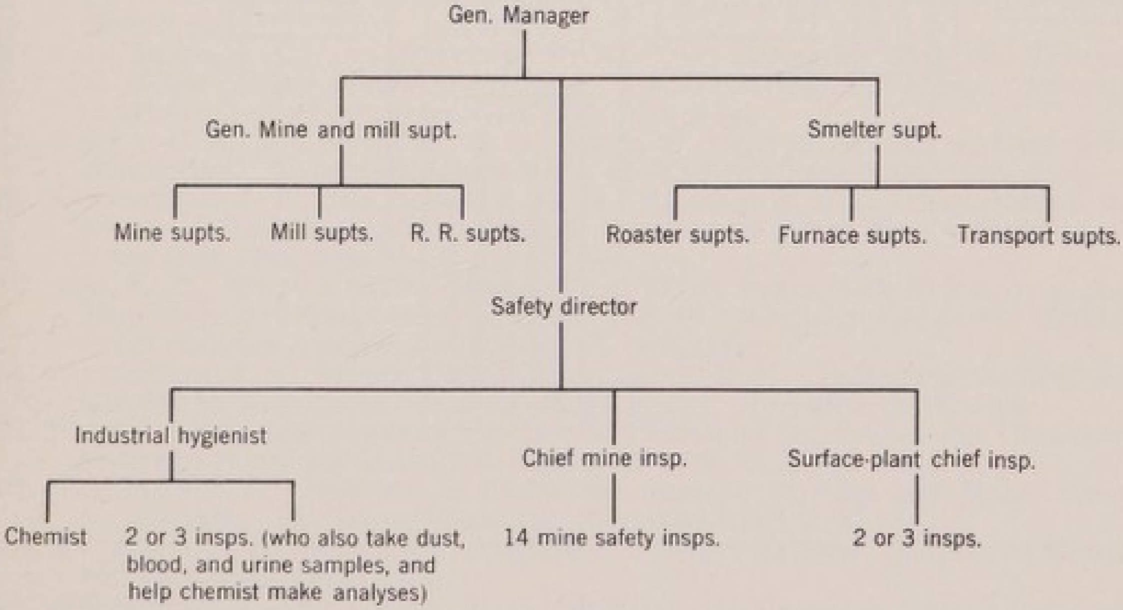


FIGURE 43.—Organization at Mine, Mill, and Smelter in the Southwest.

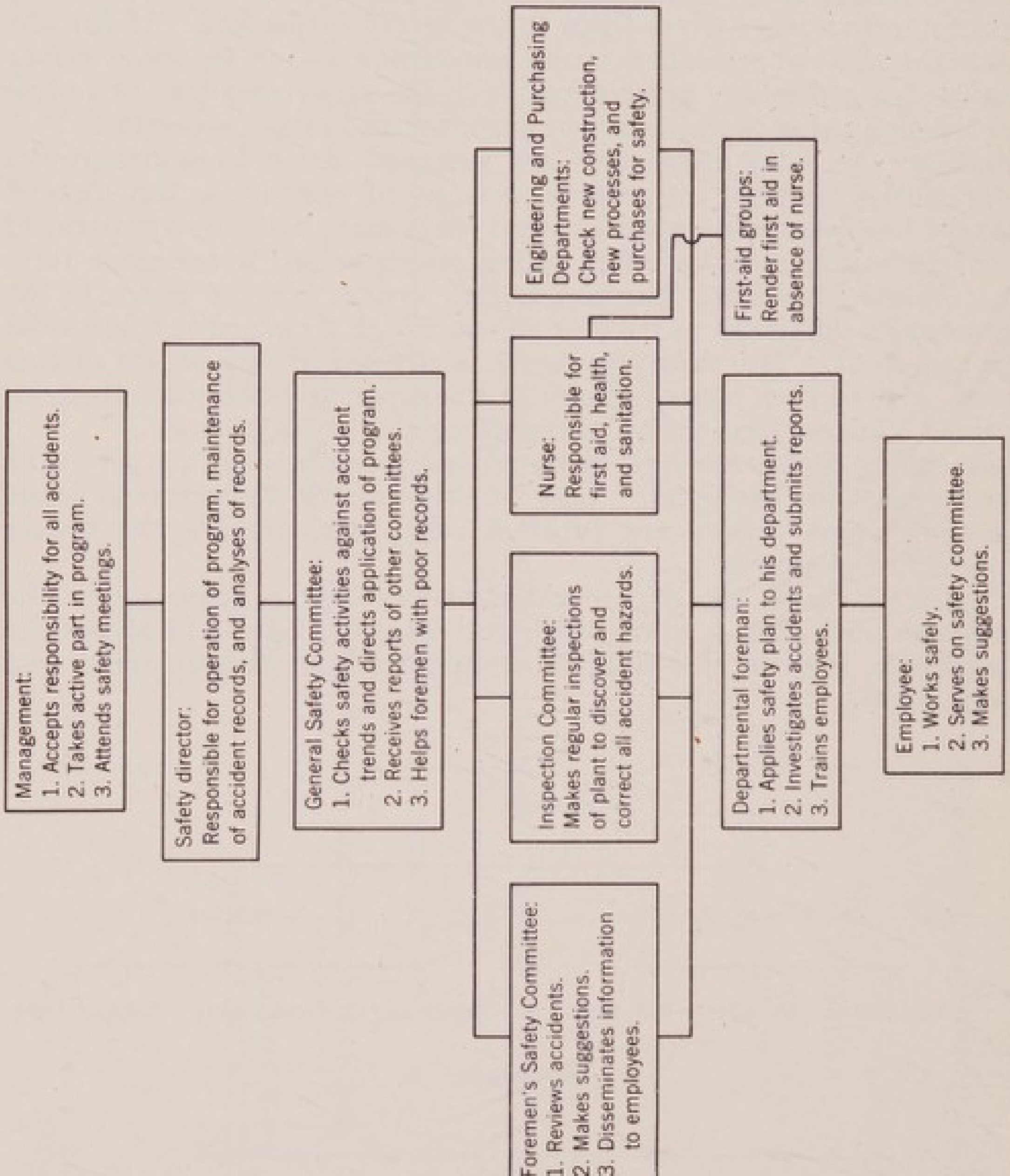


FIGURE 44.—Organization at Cement Plants and Quarries in the West.

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