63
64
66

STANDARDIZATION OF MINING METHODS

STANDARDIZATION OF MINING METHODS

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A series of important articles
reprinted from Engineering and Mining Journal

FIRST EDITION

Published by
Engineering and Mining Journal

McGRAW-HILL BOOK COMPANY, Inc.
SOLE SELLING AGENTS
239 WEST 39th STREET, NEW YORK
1919

Preface

Great economies in any business of production result from careful and thoughtful attention to details, and mining is no exception to this rule. On the contrary, successful mining is one of the greatest embodiments of the principle. The difference between the careful manager and the careless one is apt to be the difference between profit and loss.

Carefulness in management does not mean merely the prevention of what would be obvious wastes, such as allowing supplies to be slovenly thrown away, or permitting them to deteriorate, which comes to the same thing; but also it means what may be vastly more important, viz., the prevention of the unapparent wastes, especially of labor, by the continuance of uneconomic practices. Even in such an ancient and simple thing as the art of shovelling there may be enormous waste of man-power. The shoveller may be provided with a tool of the wrong design and size. He may handle it in such a way as to consume more of his energy than if he were shovelling more ore in proper posture and with correct movements. The efficiency in shovelling may be greatly increased by arranging for the men to get at the pile in the right way. Finally the work may be designed so as to reduce the shovelling that is necessary or perhaps eliminate it altogether.

This homely illustration may be applied to many varieties of work that have to be done in a mine. It is the duty of the shift-bosses, the foremen, the captain, the superintendent and finally the general manager to study every detail with the view to effecting the maximum of economy. There was never a time when this was more necessary than now, when all industry is wrestling with difficult economic problems. Not only is it necessary now to produce with greater economy than ever, but also working organizations have been impaired by the present unstabilized conditions of the labor market, and much raw material must be converted into skilled miners.

Therefore, I think that there can be no more important educational work and no greater service to the mining industry than what Mr. Mitke has rendered in the preparation of this series of articles, which were published originally in the *Engineering and Mining Journal* and are now republished in book form to meet the gratifying demand that there has been for them. Mr. Mitke, as mining engineer for Phelps Dodge Corporation, had the opportunity to study mining practices in detail as conducted by a great corporation owning and operating many mines. It was his mission to determine the best ways of doing things and promote their general adoption when it was definitely ascertained what was the best. This resulted in a considerable degree of standardization of mining practices and that is what is described and discussed in this book. It was proper that such a noteworthy contribution for the advancement of the art should be issued in this convenient and easily available form.

W. R. INGALLS.

Editorial Comment

Standardization of Mining Methods

(From *Engineering and Mining Journal,* Nov. 9, 1918)

ONE of the great needs of the mining industry at the present time is the working out and adoption of standardized methods, in order to:

1. Lower the cost of prospecting and development work, which, of course, ultimately means lowering the cost per pound of metal produced. If drifts, raises, and winzes can be driven for less money and at greater speed (without a reduction of wages or "speeding up" the men), it will be possible not only to produce more metal with the same expenditure of money, but large bodies of low-grade material, which cannot be mined profitably under present conditions, will become commercial ore.

2. It is essential that attention be paid to prospecting and development work, in order to maintain present production, to say nothing of the great need of increasing the output.

3. As there is now a great shortage of labor, and as in all probability this will continue for some time, it is absolutely necessary to standardize operations and plan the work ahead in order that the efforts of every man may count. This does not necessarily mean "speeding up," or "more work per man per day" (although the latter is highly desirable), but it is important to effect a concentration of labor where it will be productive of the greatest results.

When the war broke out in 1914, prospecting and development work was dropped by practically all companies. Later, when the price of metals went up, labor troubles set in, and the process of "finding ore" was neglected again, while the major efforts were directed toward maintaining production. Some of the larger mines which had good ore reserves in 1914 have made a steady production, but at the expense of their ore reserves, which have been considerably depleted. For instance, to quote an extreme case, in one division of a large mine in southern Arizona, 300 men were employed daily four years ago, producing 10,000 to 14,000 tons of ore each month. This record has now dropped to 165 men per day and 5000 to 7000 tons monthly, the decrease being due largely to the postponement of prospect and development work, which is rapidly shortening the apparent life of the mine. In the future, therefore, it is important that the cost of finding ore be reduced to a minimum, in order that this necessary expenditure shall yield as great an addition to the ore reserves as possible.

In this number we publish the first of a series of seven articles by Charles A. Mitke, dealing with the standardization of mining methods, with a view to economy. Mr. Mitke is an engineer of experience, and has attacked his subject with enthusiasm. Each article deals with a single phase of mining practice.

It is evident that in the growth of the metal-mining industry each individual mine will develop to a greater or less extent a certain degree of standardization in its various operations. Ground-breaking, timbering, raising, shaft-sinking, and other features of mining practice follow in a general way what past experience has shown to be more or less effective.

Formerly managers of mines allowed their foremen to establish much of the detail of mine operation; and intelligent, experienced foremen have done much not only for the individual mine, but for the industry as well. In some cases mining practice has followed, as a mere duplication, the procedure instituted by another mine. No attempt are made in these cases to establish a practice that is peculiarly adapted to the mine in question. The net result has been the growth of practices that are more or less local in character, although the migratory miner has done his share in transplanting the good as well as some of the bad features of mining practice from one locality to another.

The past and present decades have witnessed a steady progress in good engineering. A first-class manager now places upon his staff the duty of studying mine conditions and the working out of methods that are safe, economical, and peculiarly adapted to the mine in his charge. Materials, tools, and appliances are also carefully studied, and only those which stand the test of the mine conditions and meet with the prime requirements of safety and economy are retained.

Standardization implies preliminary experimentation, careful consideration of observations, and selection. It does not imply that the standard practices at one mine are necessarily the best for another, although often some features can well be adapted by another mine. Mr. Mitke presents the results of his thought and his selection in a helpful spirit, rather than with the idea of saying the last word. *We feel that many of our readers will benefit greatly from his articles.* Some may differ with Mr. Mitke, and thus be prompted to contribute suggestions along the lines he has taken, as well as on others. The subject is worthy of the attention of mining engineers at any time, but under present conditions it is extremely important, as large output, safe operation, and economy in labor and materials are vital. We hope that these illuminating and suggestive articles will be studied not only by the operating heads of mines, but also by their foremen and shift bosses, upon whose intelligence and initiative so much depends.

Ventilation of Metal Mines

(From *Engineering and Mining Journal,* Nov. 30, 1918)

AIR is such an invisible substance and is so apparently able to take care of itself, that it is not surprising that the metal miner should undertake its regulation last among the common demands that press upon his attention. The air in a heading or stope must often reach a condition that prevents a candle from burning before steps are taken to better the ventilation. Even under these conditions acetylene lamps have been used because they would operate where candles would not. Only under the most extreme circumstances would ventilating pipe and blowers be installed. Too much reliance has been placed upon the efficacy of ventilation produced by the exhaust from air drills. Happily, this condition is rapidly passing.

Mr. Mitke's article in this issue is a good one. It reviews the field in a way that will be appreciated by mining engineers and operators. We concur in his opinion that a quantity standard is the most practicable. Under coal-mining conditions a quality standard is probably best, but there is little need in the majority of metal mines to undertake the regular analysis of the air in the mine, although abnormal conditions may necessitate this procedure at times.

The "good working atmosphere" that Mr. Mitke defines—a temperature of 78°, a relative humidity of 80%, a velocity of 125 ft. per min. and 350 cu.ft. per minute per man—can usually be readily attained. Mechanical ventilation is necessary for proper control, and this point has been thoroughly discussed. We agree, also, with the necessity for the working out of the ventilation problem for the mine as a whole, both for developing and for stoping. The insistence upon the standardization of small ventilating equipment is a good point. The relative merits of metal and canvas air pipes are discussed.

After all, improvements in underground conditions must find a measure upon the cost accounts. The test of time as well as the operating results secured under a "good working atmosphere" have been applied to Mr. Mitke's work and show in no uncertain manner that attention to ventilation pays. Mine ventilation, held in such casual estimation in many instances, has an important significance in operating economy when subjected to painstaking engineering investigation and followed up by an adequate installation.

Standard Mining Equipment

(From *Engineering and Mining Journal,* Dec. 21, 1918)

SUFFICIENT equipment, well cared for and accessible, is essential in efficient mine management, and the various points regarding standard equipment brought out by Charles A. Mitke in his *article in this issue* are examples of well-conducted operations. Not only is it necessary to supply proper tools, but a place to put them should also be provided, so that each operation may be conducted with speed and dispatch. Considering the old slipshod methods, which, unfortunately, still prevail in some districts, it is not difficult to understand the comparatively high costs, and why a low "tons-per-man" figure was so often to be found. Operators are frequently prone to attribute laziness to their employees, and though this may somtimes be true, not infrequently a close study of underground conditions will show that the men are not to blame, and that the shortcoming is due to lack of system in the transmission and distribution of necessary supplies. The distributive ideas suggested by Mr. Mitke are examples of successful administration, and cover a wide variation of conditions.

The modern machine shop or warehouse furnishes an excellent example of handling tools or supplies. The intricate yet simple manner of "checking out" or "checking in" is merely the outcome of conditions created by the necessity of managing an establishment economically and efficiently, and though this principle cannot be brought to such a fine point in underground mine work, the results that may be achieved by careful supervision of supplies are well worth considering by those who have given the matter little attention. It is not unusual for an examination of old mine workings to disclose a veritable treasure trove in the shape of old shovels, picks, and drill steel, some of which are worthless from the standpoint of further usefulness; but the finding of such tools and material demonstrates the sad lack of a "check" system, which, if enforced, might have saved considerable on the cost sheet.

Too much attention cannot be paid to a frequent use of the Paynter tester, for the practice of assuming that a drill is doing its best work merely because "it sounds that way" leads inevitably to misjudgment of the drilling machines. Any well-working machine must be kept in repair, and it is not to be expected that careless tinkering with a drill is conducive to good results. Both repair work and testing are best done at a well-ordered shop where the right facilities are provided.

Standard equipment for drifting and other operations will, of course, vary somewhat with localities, and can best be determined by the particular conditions encountered, but in the main it may be said that Mr. Mitke's lists are typical. In conclusion, the fundamental ideas are well emphasized and the article merits the attention of mining men. Each step should mesh with the subsequent one, and so build up a smooth-working, well-planned order of operation.

Standardization of Mining Methods

(From *Engineering and Mining Journal,* ec. 28, 1918)

I*N THIS issue we publish the last one* of a series of notable papers on mining practices. Mr. Mitke's papers are good. They cover many important details of mining that do not receive the attention they deserve. Out of many small economies there appears the resultant of a large economy. Mr. Mitke strikes at two important points of a general nature. One is the desirability for the intensive study of the smaller features of mining practice by the engineer. Experimentation is a part of this study. The second, and equally important point, is the training of the miners.

The success of modern quantity production in manufacturing lies in the segregation of processes into sequential steps and the training of each group of workers until they are able to execute their part thoroughly and quickly. Necessarily, the coöperation of the worker must be secured.

In mining operations there are similarities in principle to manufacturing methods, although there is the important difference that the work is distributed and cannot be concentrated, as is done in well-organized factories. The effect of this is to throw a considerable amount of initiative upon the miner or group of miners. Unrestrained or untrained initiative results in waste and therefore uneconomical labor. Efficient supervision and direction by foremen and shift bosses go a long way toward remedying this state of affairs, and together with sufficient training of the workers to enable them to catch the objectives of the system, will produce results exceeding the expectations of the most sanguine.

CONTENTS

Section I

STANDARD RAISES

Section II

STANDARD MACHINE-DRILL ROUNDS

Section III

VENTILATION OF METAL MINES

Section IV

EXPLOSIVES

Section V

FIRE PROTECTION FOR METAL MINES

Section VI

STANDARD EQUIPMENT

Section VII

PROSPECTING AND DEVELOPMENT

Standardization of Mining Methods

I—Standard Raises

THE subject of standardization is now receiving much thought and consideration and the details of application to various lines of industry have proved of inestimable value, resulting in an enormous increase in production. The satisfactory results obtained from the standardization of certain special phases of mining work have led to the belief that the working out and adoption of standard methods of operation, suitable for average mining conditions, will be of economic importance in offsetting the increased costs of production, and will prove equally beneficial both to the management and to the worker.

Expansion of Operations Makes Standardization Increasingly Important

The daily work in the average mine consists of a great variety of operations. For years it was the custom, and in fact was considered absolutely necessary, for the superintendent to give his personal attention to all matters of daily routine, and to decide even the minutest details connected with the working of the mine. Under these circumstances, everything was conducive to specialized tasks, and no particular effort was made toward standardization of either operations or supplies. Such a condition, though possible in small mines, was not practicable in larger properties, and as the mines developed and production increased it became impossible for one man personally to supervise every detail. Responsibility was necessarily divided among a number of departments, the heads of which were directly responsible to the superintendent. This development led to individualism, and it became necessary to formulate standardized rules and regulations for the guidance of all the different departments.

Need for Uniformity Imperative

In the mining department tools and supplies required by the organization had hitherto been purchased according to the individual judgments of the foreman, in consultation with the superintendent. For example, one foreman preferred one type of machine, though another showed a partiality for an entirely different make. He might have his drifts driven larger, or his timbers cut in different lengths, and so on. This necessitated the carrying in stock of a large supply of repair parts for the different machines, steel, and varied miscellaneous supplies and equipment, and extra cutting of timbers both on surface and underground, all of which contributed more or less toward inefficiency and higher costs. It became evident under such circumstances that there was a great need for uniformity, first of all in the supplies and later in the operations.

As a preliminary step, the question of stope timbers was taken up, and suitable dimensions for the average square set were decided upon and adopted. The same principle was applied to timbers used in other stoping methods, drift timbers, tunnel sets, and similar equipment. Finally, the trend toward standardization was developed to such an extent that practically all the timbers used underground were cut to standard sizes. Efforts were made toward standardizing machines and supplies, but the results were not markedly successful. One company which claimed to have made advances in this direction found upon investigation that there were 28 different types of machines in constant use in its mines and about seven kinds of steel.

The standardization of underground operations also presented a difficult problem. The majority of miners, as a rule, move around a great deal, and in every camp men may be found who have gained their experience in mines where conditions are entirely different from those under which they may happen to be working. Consequently, in order to systematize operations it was found necessary to deviate from the accustomed practice of "telling a man what you want done and leaving the rest to his own judgment," and, as an alternative, to create a new precedent by "telling him what you want done, and then showing him the most approved method of doing it." This rule was especially applicable in teaching inexperienced men how to mine.

Development of the Standard Raise

Raises generally contain several compartments, which are used as manways, timber slides, ore and waste chutes, and for ventilation. In a few exceptional cases a raise is put to one use only, in which event it has but one compartment, and may or may not have any timber, according to the character of the ground through which it is driven. The importance of raising is evident when it is considered that between 400 and 500 raises are continually in process of being driven in the Southwest, at costs ranging from $3 to $30 per ft. The extraction of ore and the exploratory work necessary to keep up or increase ore reserves require that approximately this number of raises be kept "running"; and, as a rule, when some are completed others are immediately started.

Character of Earlier Types of Raises

In the past, raises were driven according to the designs of individual shift bosses and foremen, and exhibited wide diversity of construction, not only in the different camps and mines, but in the divisions of a mine itself. The result was that two raises, side by side, were often entirely different in dimensions and construction. This lack of method proved inefficient and wasteful, as every raise was made a special case, and the men were unable to begin work without minute directions from the foremen and bosses. These bosses, in turn, would have two or three types in mind, and would have one type constructed in one place and another type in the next, and so on. In many of these designs the openings in the landings were so small that the men had difficulty in getting through; and, as there were platforms only about every 50 ft., and in some few cases none at all, this presented a dangerous condition, and one likely to be the cause of serious accidents.

Influence of Safety-First Movement

When the Safety-First movement was introduced in the Southwest, about four years ago, some of the first steps toward improving conditions were to cover all chutes and manways, put in more landings, and pass laws determining the distance between platforms in all manways, which reduced the number of accidents, but decreased the workers' efficiency by cutting off the ventilation almost entirely, the chute and manway covers being practically air-tight. In some mines, ventilated by mechanical means and in which the working places had become comparatively cool, the temperature began to increase, and the mines became almost as hot as formerly. It was, therefore, evident that something had to be done in designing chutes, manways, timber compartments and safety guards, to meet conditions which the natural development of the mines had created. This led to the necessity for a standard raise. It was essential that such a raise should combine the utmost safety with the most efficient working conditions, and at the same time admit a maximum of pure air in order to ventilate the mines thoroughly. Inasmuch as safety and ventilation make for efficiency, and efficiency contributes to economy, it was the consensus of opinion that the proposed raise must meet these four important requirements; and that when designed and adopted as the standard the results would be beneficial both to the men and the company.

In the issue of Jan. 18, 1918, of the *Journal* under the caption, "Training a Mining Organization in Efficiency Methods" (Copper Queen Consolidated Mining Co.), an outline was given of the methods adopted by a corporation to encourage members of its operating force to make suggestions and recommendations which might prove of value in the development and operation of its mines. Recognizing the importance and necessity for a standard raise and the possibilities, in the way of suggestions and helpful criticism, that might result from the united efforts of the entire organization, an announcement was made at one of the Copper Queen Company's mining conferences to the effect that every one in the organization was to be given an opportunity of working out a design for a standard raise which would comply with the necessary requirements. It was arranged that all suggestions were to be sent to me, and that I was to aid and assist the men in having their individual designs worked out intelligently, so that these could be presented either in the form of models or drawings, accompanied by descriptive papers. The following specifications were therefore drawn up:

SAFETY

1. Inclined ladders are preferred to straight ladders, as there are cases on record where men who have become unconscious through being gassed have fallen on inclined ladders and remained there until taken to a place of safety, whereas on vertical ladders they would have fallen and suffered severe injuries. Inclined ladders are also easier to climb.

2. A landing in every set. (A set is usually about 8 ft. high.) A man climbing up with tools and supplies is likely to drop something or knock a rock off from the sides of the manway. Should any one be following him, these

landings would prevent his being injured by anything falling from above.

3. Manways should be large enough to allow the passage of a man wearing an oxygen helmet.

4. Timber compartment should be of sufficient size to permit an injured man to be lowered through it in a basket.

5. Safety guards, about 3½ ft. high, should be placed around the chute and manway at the top of the raise to prevent men from falling in. Grizzlies, about 8 in. apart, should be put over chutes. These may be rails or large timbers. Small rails or gratings should be laid over timber compartments.

VENTILATION

The area in the timber compartment and manway should be of a size to allow at least 300 cu.ft. of air per min. to pass through for each man in the stope. If there are a large number of men in the stope it will take a proportionately large number of raises to supply the amount of air required.

EFFICIENCY

1. The ladders and landings should be so arranged that men can climb up and down without inconvenience, even when carrying powder and other supplies.

2. The timber should all be of standard size, so that when an order is sent to the sawmill, all timber for the raise may be cut on the surface and then sent down to the place where it is to be used. This obviates the necessity of any sawing underground.

3. The raise set, with few exceptions, should be the same height as the stope set, that the timbering of the raise may match the timbers of the stope, and allow workings from the raise set to be continued into the stope.

4. The bottom of the chutes should rest on solid ground, not on wooden flooring. The solid ground will not give way when ore is dumped on it from above, and it requires only a chute mouth, whereas a wooden chute bottom would need a great deal of repairing.

5. The timber compartment should be large enough to allow of timbers being hoisted into the stope.

ECONOMY

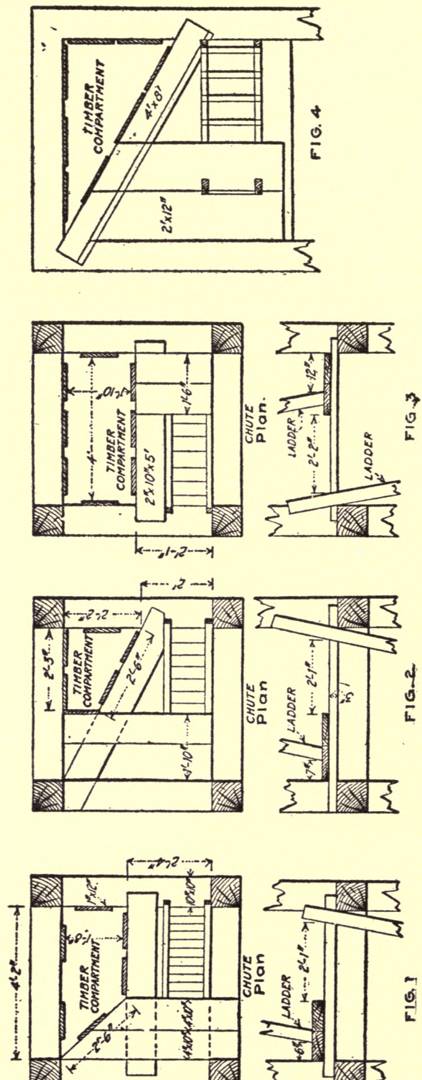
As the cost of raising in general is high, varying from \$3 to \$30 per ft., it is important that expenditures for labor, timber, and other requisites be reduced to a minimum.

The working force evinced much interest and enthusiasm over the specifications outlined, and there was no little friendly rivalry between the bosses of the different divisions. At consecutive meetings of the Copper Queen mining conference, the shift bosses presented outlines of their individual plans, which were discussed, the relative merits and defects being brought out, and several ideas set aside for further consideration. A brief description of some of the more important designs submitted follows:

Fig. 1 represents the first attempt at a new type of raise, showing manway and timber compartment. The manway has incline ladders, arranged as shown in both the plan view and vertical section. This plan was worked out by one of the bosses and is designed for a six-post raise. The area of the chute is equal to that of the manway and timber compartment combined, but the drawing of the chute is omitted. The air space, for ventilating purposes, in the timber compartment is 5.2 sq.ft., and in the manway 3.4 sq.ft., making a total of 8.6 sq.ft. Criticism on this raise was that it was somewhat complicated, as the boards in the landings required extra cutting for each floor. It contained an angular timber compartment, and the manway was situated near the chute, which meant that it would always be dirty from fine ore working out of the chute. This raise failed from the standpoints of efficiency, economy, and ventilation.

Another attempt at a standard six-post raise is shown in Fig. 2, with a much smaller timber compartment. It is also difficult to make, as miners seldom or never have a full set of carpenter's tools. Another objection is that the timber compartment has an area of only 2.8 sq.ft., and the manway, only 3.5 sq.ft., making a total area of but 6.3 sq.ft. Criticism of this raise showed that the design was inefficient, uneconomical, and imperfect as regards ventilation.

In Fig. 3 the manway and timber compartment contains the largest area for ventilating purposes among the designs thus far considered, the total number of square feet of air space being 10.1. It is designed for a six-post raise, is easily built, and there are few objections from an operating standpoint. It has a large timber compartment, permitting an injured man to be lowered through it in a basket. There is also room


TIMBER COMPARTMENT
4"x8"
2"x12"
FIG. 4
TIMBER COMPARTMENT
2"x10"x5'
CHUTE Plan.
LADDER
FIG. 3
TIMBER COMPARTMENT
CHUTE Plan
LADDER
FIG. 2
TIMBER COMPARTMENT
CHUTE Plan
LADDER
FIG. 1

for a helmet man to go up and down the manway after two 1 x 12-in. boards are loosened.

Fig. 4 shows a rather complicated manway for a six-post raise and presents many difficulties from an operating standpoint. The air space in the timber compartment is 4.5 sq.ft., and in the manway 3.6 sq.ft., making a total of 8.1 sq.ft. The helmet men can go up and down the ladders, but the building of this manway would be difficult and expensive. It failed in economy and efficiency.

In Fig. 5 the manway and timber compartment is similar to that shown in Fig. 3, but is designed for a crib raise, whereas Fig. 3 is intended for a six-post raise. The timber compartment contains 5.7 sq.ft. and the manway 5.3 sq.ft., making a total of 11 sq.ft. It is therefore especially advantageous from the standpoint of ventilation, and there is considerable room at the different landings to go from one ladder to another, so that it also fulfills some of the efficiency requirements. Also, most miners are familiar with this type of manway, which is a decided advantage. One criticism was that the ladders were 12 ft. long, which was an objection from the point of view of safety.

Fig. 6 shows another type of manway for a crib raise, with a good-sized compartment for hoisting timber—large enough for a man to be lowered through in a basket. In case of necessity a helmet man with apparatus can climb up and down the ladderway. The timber compartment contains 5.1 sq.ft., the manway 3.3 sq.ft., making a total of 8.4 sq.ft. The ladders are inclined. This raise fulfills the requirements regarding efficiency, as it contains a good traveling manway.

The manway illustrated in Fig. 7 shows all ladders arranged vertically, although they are only one set high. As regards ventilation, there is a total area of 9.6 sq.ft. A novel idea is shown in the chutes, as breakers are placed in each set on opposite sides of the chute (as indicated in drawing on the left in Fig. 7). Any ore which starts from the top will not drop down ver-

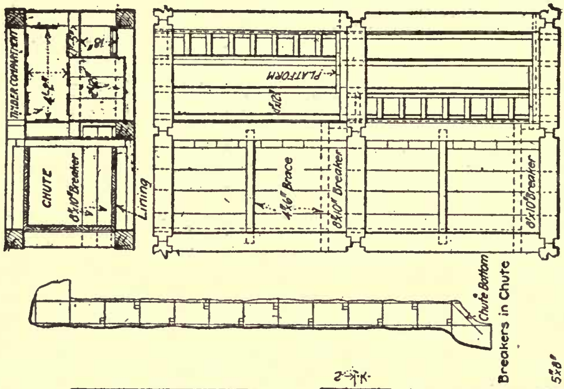


FIG. 7

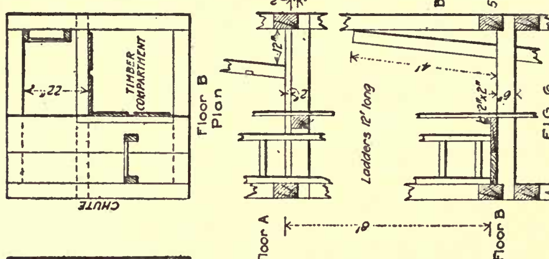


FIG. 6

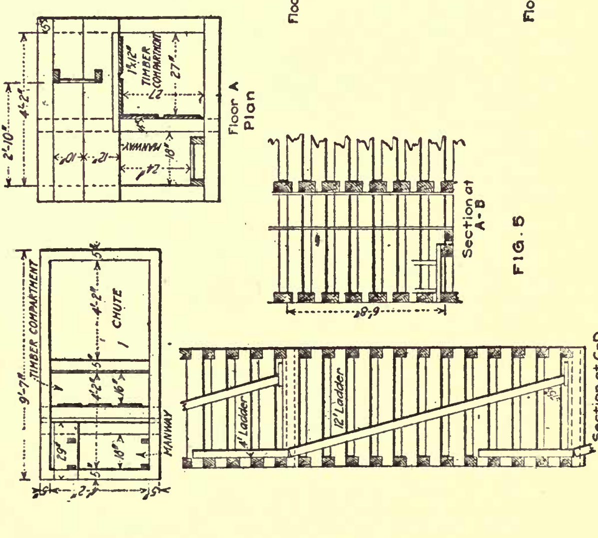


FIG. 5

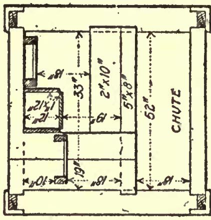


FIG. 10

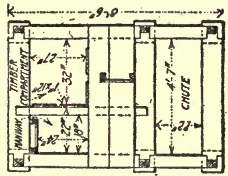


FIG. 12

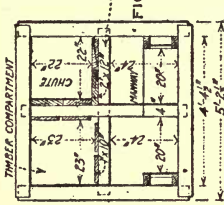


FIG. 9

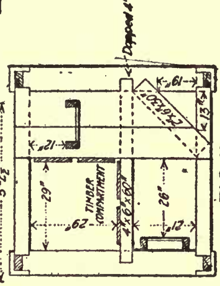


FIG. 11

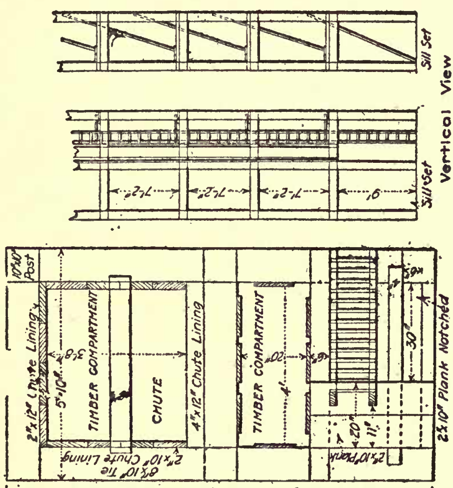


FIG. 8

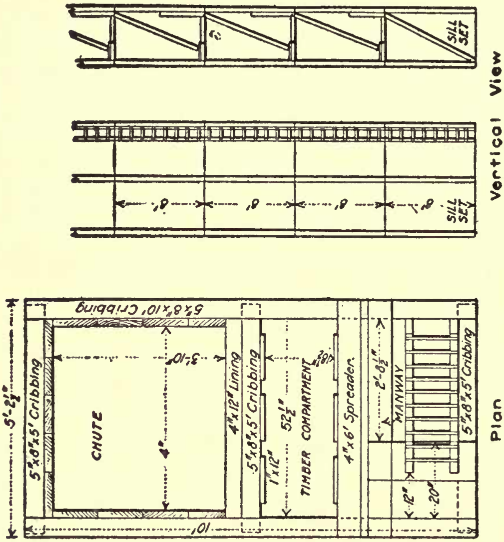

SILL SET
Vertical View
5"x8"x10' Cribbing
5"x8"x5' Cribbing
CHUTE
3'-10"
4'
4"x12" Lining
1"x12"
52½"
TIMBER COMPARTMENT
4"x6' Spreader
2'-8½"
MANWAY
12"
20"
10'
5'-2½"
Plan

FIG. 14

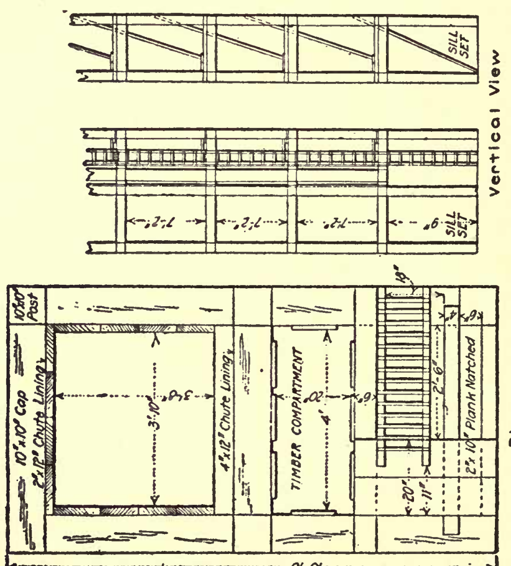

SILL SET
Vertical View
7'-2"
6"
10"x10" Post
10"x10" Cap
2"x12" Chute Lining
3'-10"
3'-6"
4"x12" Chute Lining
TIMBER COMPARTMENT
4'
20"
6"
18"
2'-6"
2"x10" Plank Notched
11"
10'-10"
Plan

FIG. 13

tically and form a solid mass in the bottom of the chute, but will strike these breakers, zigzagging from one to the other until it reaches the bottom. A chute of this sort seldom needs punching, as it rarely "hangs up." The manway is easily made, but did not prove popular with the men, although it is used in several other camps.

The square set raise shown in Fig. 8 contains a total air space of 13 sq.ft. It has two timber compartments, and may have either vertical or inclined ladders. The illustration is interesting in that it represents a smaller chute but larger air space. The chief objections raised were high cost of construction and cost of upkeep, as the chute would have a tendency to break, not only on the manway side but on the opposite side, where it would be difficult to make repairs.

Figs. 9, 10, 11 and 12 are types of small special raises, containing manways, timber compartments, and chutes, designed for use in top slices, small square set stopes, and similar workings. The advantage of small raises of this kind is that they require openings driven through the ground only about half the size of the standard raise, but they also possess a decided disadvantage in the limited capacity of their chutes.

After considering the various designs, Figs. 3, 5, 6, 9, 10, 11 and 12 were selected as representing ideas having considerable merit. Slight alterations and improvements, however, were made to the original plans of Figs. 3 and 5, as may be seen by referring to Figs. 13 and 14. In Fig. 13 it will be noticed that the changes in the manway are such as to allow greater space for traveling, and stronger construction, heavier timbers being used in the manway and timber compartments than were required in the original design (Fig. 3). Fig. 13 also shows a greater area for ventilation. The chief points of difference between Figs. 5 and 14 lie in the fact that in Fig. 14 the ladders have been shortened so as to make it safer for a man going from one ladder to another. According to the design in Fig. 14, he can fall only 8 ft.; whereas in Fig. 5 it would be pos-

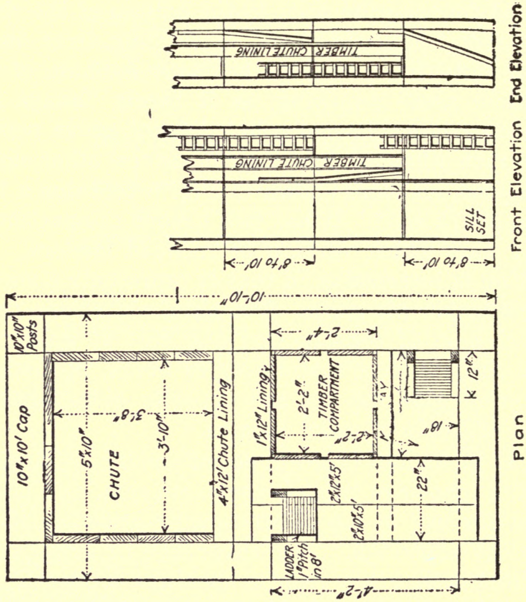


FIG. 15 A

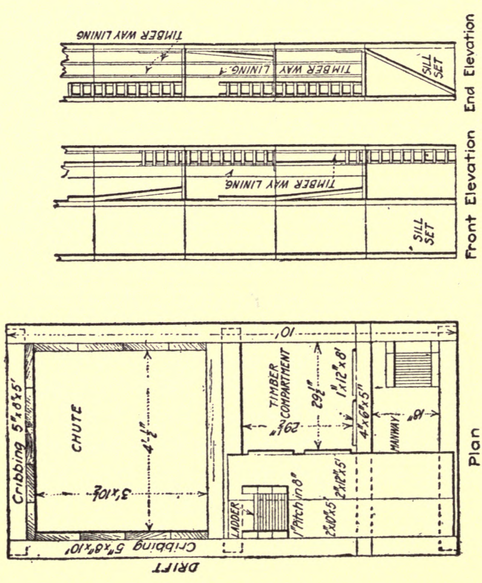


FIG. 15

sible for him to drop 12 ft. Smaller timbers are used between the manway and timber compartment, which improves the ventilation.

Of the designs illustrated in Figs. 6, 9, 10, 11, 12, 13 and 14, Figs. 9, 10, 11 and 12 are intended for use in the special cases mentioned above, and Figs. 13 and 14 are designed to meet conditions when it becomes necessary to construct a manway in a limited space. Fig. 6 was found to have many possibilities, and, after a few minor changes were made, the improved design, Fig. 15, came nearer complying with the requisites for a standard raise than any of the other plans submitted. It was therefore adopted as the standard for the company's mines.

In comparing Fig. 6 with Fig. 15 it will be seen that the changes were slight. Fig. 15 has a larger timber compartment than Fig. 6, and also larger sized openings in the different landings of the manway. Fig. 15A is identical with Fig. 15, with the exception that the latter gives the dimensions of a manway and timber compartment for a crib raise, whereas Fig. 15A is the same design for a six-post square set raise, using 10 x 10-in. timbers. Experience has shown that there are few accidents in a manway of this kind, as it contains all the safety requirements, is satisfactory as regards ventilation and efficiency, and also possesses the following advantages:

1. The ladders are inclined.

2. It is impossible for a man to fall more than one set, which is about eight feet.

3. A man going up the ladder with supplies would not injure any one below, should he drop anything.

4. The timber compartment is large, allowing an injured man to be taken through in a basket.

5. A man wearing an oxygen helmet can get through all the openings.

6. On top of the raise there are guard rails 3½ ft. high around the chute and manway. A grating, illustrated in Figs. 16 and 17, is put over the timber com-

partment, and grizzlies of either timber or rail are laid over the chutes.

7. From the point of view of ventilation, the area is sufficient to allow 942 cu.ft. of air per min. to pass through when the air is moving at a velocity of 100 ft. per min., which is sufficient for three or four men in a stope of ordinary size. If the stope is larger and has more men working in it, additional raises should be put up to increase the quantity of air in proportion to the number of men. The extra raises will also give additional chute capacity to take care of the increased tonnage.

8. All timbers are of standard size; therefore no cutting underground is required.

9. The openings through the landings are large and roomy, so that a man may easily pass through them.

10. Timber can readily be hoisted through the timber compartment into stopes.

11. The solid ground is left at the bottom of the chute, so that the ore, which drops 100 ft., will strike on the solid and not wear out any chute bottoms, which must be replaced from time to time. Only a chute mouth is put in, which requires little repair work.

12. The construction of such a raise is economical on account of its simplicity, standard length of timbers and the fact that most miners are more or less familiar with it. It has proved a success at the Copper Queen Company's mines, and has also achieved considerable popularity in other camps in the Southwest where it has received a fair trial.

Standard Gratings for Timber Compartments

Fig. 16 illustrates the style of grating to be placed over timber compartments of the Figs. 13 and 14 type, and Fig. 17 represents the grating for Figs. 15 and 15A. These gratings should both be of standard size (as indicated in the drawings) and made in the company's shops on the surface. When they are taken underground, the only thing necessary is to fasten the

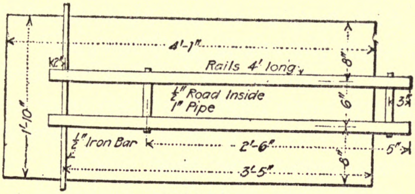


FIG. 16

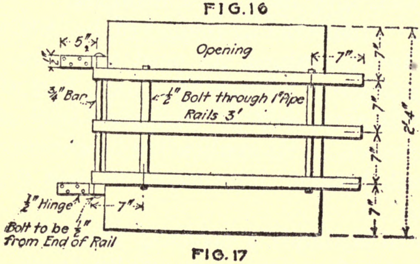


FIG. 17

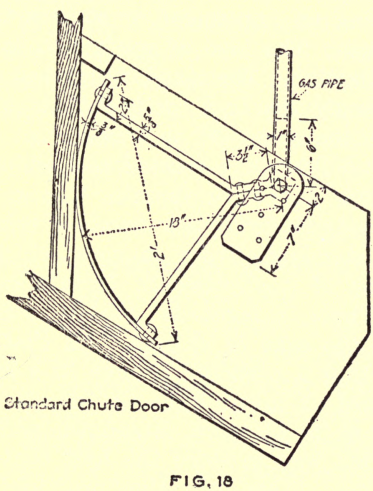


FIG. 18

hinges to the timbers on the sides of the raise.

STANDARD CHUTE DOOR

A circular chute door is shown in Fig. 18 which is to be used in the chute of the standard raise (Figs.

15 and 15A). This door is convenient and is easily operated with a piece of gas pipe, which is used as a lever. Though the raises, gratings, and door described are given as the standards in their particular line, this does not in any sense imply that they may not be changed should a better way be worked out. They merely represent the best-known and most efficient method at the mines in which they have been installed.

The word "standard" is likely to be misleading in that it has two meanings, its most commonly accepted definition indicating something which has attained a state of perfection and is therefore not subject to change. However, in its application to working methods it has a much broader interpretation, and it has been defined thus:

"A standard is simply a carefully thought out method of performing a function, or carefully drawn specifications covering an implement or some article of stores or of product. The idea of perfection is not involved in standardization. The standard method of doing anything is simply the best method that can be devised at the time the standard is drawn. . . . Improvements in standards are wanted and adopted whenever and wherever they are found. There is absolutely nothing in standardization to preclude innovation. But to protect standards from changes which are not in the direction of improvements, certain safeguards are erected. These safeguards protect standards from change for the sake of change. All that is demanded . . . is that a proposed change in a standard must be scrutinized as carefully as the standard was scrutinized prior to its adoption. Standards adopted and protected in this way produce the best that is known at any one time. Standardization practiced in this way is a constant invitation to experimentation and improvement."—Morris L. Cooke, Bulletin No. 5, Carnegie Foundation Series.

Section II

Standard Machine-Drill Rounds

THOUGH different operations connected with the driving of drifts and raises are important, in that they have a bearing on the cost, they are, nevertheless, subordinate to the actual drilling. Success in drilling depends largely on the type of machine-drill round which is used, and involves a number of important questions, such as the "depth of round to be pulled" (advance), "placing of the cut," and "direction and numbers of holes necessary."

Too Little Consideration Given to Cost of Breaking Ground

The character of machine rounds is of the greatest importance as well as being a determining factor in the cost of breaking ground when drifting and raising, but it is, in a great measure, left to the individual judgment of the miner, who follows the old-time method employed in hand drilling and places his round according to the slips, fractures, or crevices which appear in the face of the rock. This he believes to be of the utmost importance, the only other worthy consideration being the number of holes to be drilled. If the ground does not break satisfactorily, more holes are considered necessary, and the prevailing idea, not only among the miners but among many shift bosses and foremen, is that the principal factor governing the breaking of ground is the number of holes drilled, without special regard to the direction in which they are driven, except that their position is determined by the faults and slips occurring in the face. In fact, it is common practice, in cases where a drill round does not break, for the foremen and bosses to order the miner to "put in more holes," without making mention of the direction or depth they should be driven.

An estimate of the average advance per round in ordinary ground would be from 3½ to 4½ ft., with 5 ft. considered good work. At present, practically all rounds are drilled from 6 to 18 in. deeper than the actual advance made. Many miners drill 5 ft. per round, but the total footage made at the end of the month will average only 3 ft. per round. This is due almost entirely to the character of the round.

In rounds where the advance is far less than the ground drilled, the fault in nearly every case lies in the position of the cut holes, as the round will usually break no deeper than the depth of the cut holes, regardless of what depth the other holes are drilled. Consequently, on the position and depth of the cut holes depends the distance of advance of the round.

Earlier Types of Piston Drills Responsible for Lower Position of Cut Holes

The old type of piston drill, with which many miners gained their first experience in machine drilling, is responsible for the placing of the cut holes in the bottom of the drift, as it was necessary to point the holes downward, although this is a difficult position from which to break the ground when the round is blasted. Experience has proved to the miners that it is possible to break the ground with this type of round; therefore it is hard for them to believe that a round having the cut holes placed in some other position may give not only equally good results, but even better, and do more toward removing all the ground drilled than was possible with the old type of round. No round is advanced more than the depth of the holes drilled, but the purpose in working out a standard round is to determine upon the type which, under average conditions, will break all of the ground drilled, in both short and deep rounds. By accomplishing this, the average footage per man per shift would be considerably increased, and this would necessarily result in a decrease in cost.

Standard Round Customary in Tunnel Work

The realization of the advantage of evolving a standard round, though comparatively novel in mining, is not new in tunnel work, in the performance of which rounds are usually driven on contract, and it is to the interest of the contractor to develop a round that will remove the most ground with the least drilling and a minimum amount of powder. Remarkable results have been obtained in tunnel driving, as, for example, in the work at the Mount Royal tunnel, in which a record of 810-ft. per month was established; in operations by the Arizona Copper Co., showing 799 ft. per month, and by the Laramie-Poudre, 653 ft. per month; and at the present time a tunnel is being driven in the Southwest that averages 20 ft. per day, or 10 ft. per shift. Though the advance secured by the use of deep rounds in tunnel work cannot be attained in small mining drifts, nevertheless a type of round may be used which will show a material average increase in the footage over records made with the old type of rounds.

Development of the Standard Round

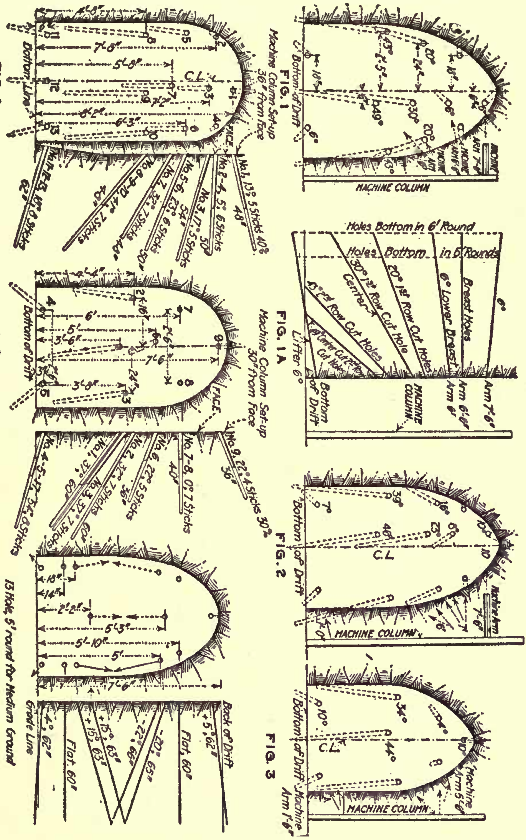
Some time ago, in an effort to secure a type of round which would break practically all of the ground drilled and which might be considered as a standard for average conditions, a number of experiments were made at the Copper Queen mine. These were carried on in all kinds of ground and under varying conditions, so as to establish a basis for a round which could be adopted as standard.

One of the difficulties encountered in conducting these experiments was the opposition of the older men who had been mining from 15 to 25 years. "I have been mining for 20 years, and none of these young fellows 'round here can tell me how to put in a round"; "These blueprint rounds can only be drilled in the office on paper, but not in the mine underground," and similar expressions reflect the opposition that the proposition encountered. However, when it was properly explained to the men that the company would assume all responsibility in regard to breaking the ground, and that if the round failed there would be no discredit to the miner, they did their best with the particular round in question and afterward frequently presented other types of rounds with which they desired to experiment. Another obstacle which had to be overcome was the objection of the men to the use of one type of round in all classes of ground, regardless of fractures, water courses, faults and other irregularities encountered. In their opinion these variable conditions required special types of rounds, the position and number of holes varying according to the situation of the fractures and faults in the face, all of which should be taken into account.

Experimental Types Used in Development of Standard Round

Some of the experimental types of rounds which have been tried out should prove of interest. Fig. 1 represents the old type of 12-hole round, with the cut holes placed at the lower part of the drift face. The machine column and arm, upon which a No. 18 Leyner was mounted, is diagrammed at the right. The height of the arm above the bottom of the drift was 7½ ft. when the back hole was drilled. It was lowered 1 ft. for the three breast holes, then lowered to 6 ft. in height for the next six holes, and finally the machine was lowered as far as possible for the two lifters. This round was drilled in average ground. Fig. 1A is a side view of the same round, and shows where the holes bottomed when the round was drilled 6 ft. in depth. However, when the shots were fired, the actual advance at the drift was only 4 feet.

Another drift was begun in somewhat harder ground, and the round shown in Fig. 2 was tried out. The lay-out is almost identical with that shown in Fig. 1, although the miner who did the drilling claimed he



was using an absolutely new design of round. The results obtained were similar to those secured in the round shown in Fig. 1.

Fig. 3 shows a round used in softer ground, and consequently a fewer number of holes was required. The round was drilled to a depth of 5 ft. The actual advance was only 4¼ feet.

A 13-hole round drilled in hard ground, with the depth to which each hole was drilled, is shown in Fig. 4. In blasting, a 50-lb. box of 40% gelatin was used, and 3½ ft. of ground was broken, leaving the face well squared up.

The nine-hole round shown in Fig. 5 was drilled in uniformly soft porphyry. In one drift 4.4 ft. of advance was made during each of 10 consecutive days, 5¼ ft. being the average depth of each round. Sixty sticks of 30% gelatin per round were used in this instance.

Fig. 6 shows the plan followed in a 13-hole round that was used in a number of drifts driven in good average ground, the arrows in the face showing where the holes bottomed. One drift showed an advance of 5⅓ ft. for 13 consecutive days. This type of round represented something new for the miners, and they first ridiculed it by calling it a "blueprint round." However, when the men discovered the footage which they could make by this arrangement of holes, they did not hesitate to use it in their work.

Fig. 7 shows a 14-hole round, which was used in hard ground. The rounds described in Figs. 2 and 4 were tried in this exceptional ground, but as a rule the advance was equivalent to half what it should have been for the ground drilled. In the rounds shown in Fig. 7 the advance was nearly always equal to the total ground drilled.

Fig. 8 shows a 13-hole round used in a number of drifts in average ground. In one drift 8-ft. steel was used, and the drift was advanced 7½ ft. for a period of 15 consecutive days. The cut holes usually met in the center. On one occasion after the holes were drilled the angles were measured and plotted, as shown in the drawing. When this round was fired it was advanced 7¾ feet.

Standard Machine-Drill Round for Drifts

Figs. 9 and 9A show the types of rounds which were finally adopted as standard, and both represent slight modifications of Fig. 8, with which the best results were obtained. The cut holes are situated in the center, and the burden is properly distributed on the different

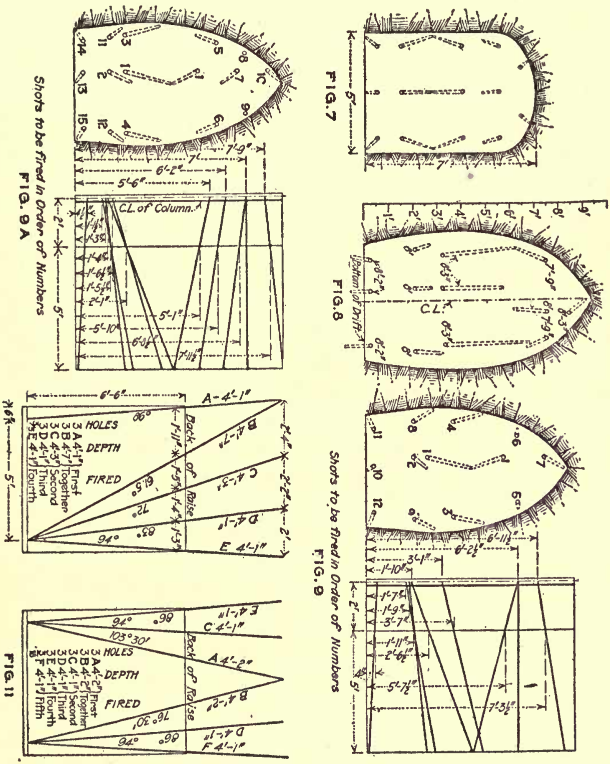


FIG. 9A. Shots to be fired in Order of Numbers

FIG. 7

FIG. 8

FIG. 10

FIG. 11

FIG. 9. Shots to be fired in Order of Numbers

holes. The drift is arched so that it may be used for motor haulage, or, if it is to be timbered, three back holes are used. The numbers at the collars of the holes represent the order in which the shots are to be fired, and the two center holes, numbered "1," are drilled to meet and fired simultaneously. This round was drilled through ground which contained many slips, water-courses and fractures, and compared favorably with another drift in similar ground where the miner used a variable type of round to suit the constant changes in the ground. This latter round advanced only about two-thirds of the footage made by the standard round.

Fig. 9 is a 13-hole round for average ground, and Fig. 9A is a 16-hole round for hard ground, though in softer ground from 5 to 13 holes are frequently found to be sufficient. In these cases the center cut is put in and the same principle carried out as in the harder ground, but the number of holes around the sides and bottom of the drift is reduced.

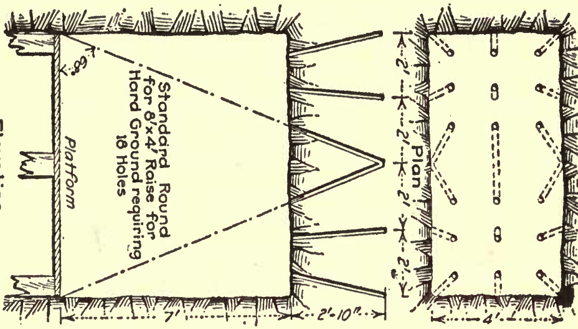
Development of a Standard Round for Raises

The method of procedure followed in the development of a standard round for drifts was also adopted in working out a standard round for raises, and from the many designs presented and tried out those shown in Figs. 10 and 11 were selected as the most efficient. Fig. 10 is an example of the end cut in a 4 x 6-ft. raise and was a popular cut with the miners, although Figs. 11 and 11A represent the standard type of round adopted for raises. Fig. 11 is used in a small raise 4 x 6 ft., whereas Fig. 11A is intended for a 4 x 8 ft. raise. In both cases the center cut is used. In the comparative tests between results of the methods shown in Figs. 10 and 11, it was found that Figs. 11 and 11A showed a better footage per man shift than could be obtained with Fig. 10.

Standard Round for Top-Slice Stopes

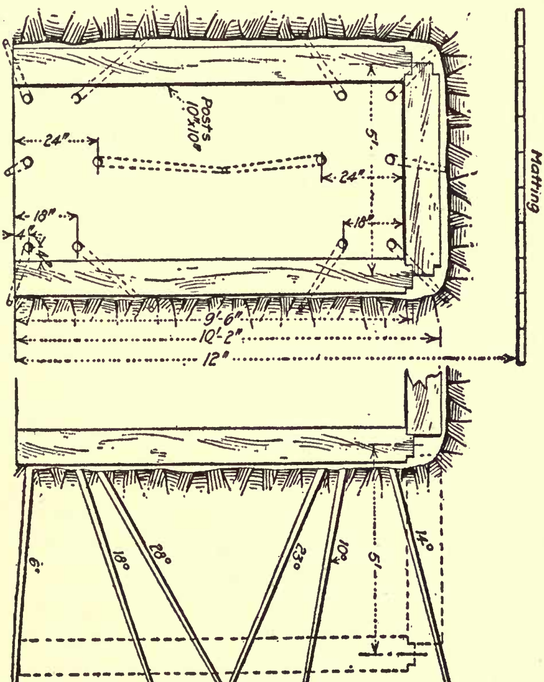
It is impracticable to devise a standard round that will be suitable for all methods of stoping. For example, in cut-and-fill one or two holes properly situated may break as much ore as a round of holes in a square-set stope. However, in horizontal top-slicing there is considerable uniformity in opening up lead sets, so in this special case the same principle which is practised in the standard round in drifts has been applied to this method of stoping, with satisfactory results, and is shown in Fig. 12.

When standard rounds were adopted, orders were given to the foremen to have blueprints made and posted in all the mine offices, so that the bosses might become familiar with them, and instructions were issued to



Elevation

FIG. 11A



Round for Lead Set in Top Slicing

FIG. 12

use the standard rounds in all prospect and development work. Wooden models with wires showing the drill holes were then made and placed in the mine offices and later transferred to the miners' change room, so as to give the men an opportunity to familiarize themselves with the standard round. Drill instructors were appointed from among the miners who had made the best footage with the standard rounds, and they were sent to train all the machine men.

It is advisable that the drill instructor should be a man who has had experience in drilling different types of machine rounds in other camps for different classes of ground. Unless he has had a wide experience of this nature, the men whom he is supposed to instruct, and who have been in other camps themselves, are in a position to argue with him and tell him of the success of certain other rounds in these camps. If he is not in a position to prove to them that such a round is not efficient in the class of ground in which they are at present working, his efforts as an instructor will be unsuccessful. It is therefore necessary for him to have drilled other types of rounds beside the standard, so that he may be able to draw comparisons and prove its worth to the individual miners.

The instructor starts with one miner at a time, instructing him how to drill the new type of round, and stays with him until the miner becomes proficient and is convinced that he can secure further advance with the standard than he could with the other types. After one miner has mastered the standard, the instructor spends several days with another, and so on until all the machine men have become accustomed to the new methods.

In some cases the duty of instructing the men may be performed by a development boss, who acts both as instructor and supervisor of all development work. In others a machine foreman has been employed for this purpose, and his duties are similar to those of the drill instructors and development bosses. The question as to whether instructions should be given by a drill instructor, development boss or machine foreman should be decided according to conditions at the particular mine.

Results Attending Adoption of Standard Round Have Justified Experimentation

Adoption of the standard round has led to a material increase in the footage per man shift. The amount of ground drilled is usually removed in the blast, as the holes bottom in a vertical plane which leaves a square face for the next set-up. Since the introduction of the standard round, the size and shape of drifts are more uniform, and the men are careful not to drill wild holes and break a lot of unnecessary ground in the back or sides, as they formerly did.

It has been satisfactorily proved that a machine-drill round need not necessarily be drilled according to the slips and breaks in the ground, as the footage advanced by the standard round has far surpassed that obtained with a variable round put down according to the fractures and faults in the face.

In drifts where the bonus system has been instituted, the miners have repeatedly tried and failed to make the bonus when using the old type of round, and have found that it is possible to make the required footage only when the standard round is used.

Abnormal labor conditions and the loss to the mines of large numbers of trained miners who have joined the Army, have, during the last year, detracted from the results formerly obtained from the use of the standard type of round. However, when normal conditions are restored, results as good as if not better than those formerly achieved may be confidently expected.

Section III

Ventilation of Metal Mines

IN THE early stages of the development of metal mines, all prospect work is necessarily directed toward finding ore, and little or no consideration is given to the subject of ventilation until the orebodies are discovered. In prosecuting this work, natural ventilation is utilized to its fullest extent until all its possibilities are exhausted. It is then generally supplemented by the installation of a few small blowers. These answer the purpose temporarily, until the prospect develops into a mine, when, in the course of time, the natural ventilation frequently proves insufficient, and a scheme of mechanical ventilation must be worked out.

Much has been accomplished in solving the ventilation problems in coal mines, but it is only recently that this subject has received serious consideration by metal miners. In the past, practically all mines were ventilated by natural means, and the miners were expected to do their best under the varying conditions, which are always poorest during the summer, as is evidenced by the decreased labor efficiency in the summer months.

It became increasingly apparent in recent years that conditions of natural ventilation were inadequate to meet the needs of the metal mines of the Southwest, and the question arose as to what extent improvements could be made in ventilation by mechanical means in order to bring about the desired change in the temperature, humidity, velocity and volume, and as to what should constitute a "good working atmosphere." No readings had been made to determine the volume of air entering or leaving a mine; the necessary quantity of air per man per minute; to what extent the humidity would be increased from the time the air entered the mine until it reached the different outlets; the amount of air needed to clear away the smoke during ordinary blasting in the average mine workings; or the total friction losses, due to the extreme irregularities of the workings, which may be termed "the mine resistance."

In some states standard requirements for ventilation in mines are prescribed by law, but, in general, this is left to the discretion of the operators. The Arizona mining law says that "the total quantity of carbon dioxide present in the air shall not exceed 0.25% by volume, except that at any place where firing of explosives has been done a higher percentage of carbon dioxide shall be permissible for a reasonable length of time after the last explosion. . . ." The Anthracite Mine Law of Pennsylvania specifies a minimum quantity of 200 cu.ft. of air per man per min., and the law further stipulates that the amount of air in circulation shall be sufficient "to dilute, render harmless, and sweep away smoke and noxious or dangerous gases," proving that even in coal mines, where the problems of ventilation have not the intricacies found in metal mines, no fixed standard has been adopted upon which to base figures for a "good working atmosphere." This, then, was the problem that confronted the ventilating engineer.

There are two methods by which the degree of ventilation may be determined: (a) According to the quantity of pure air per man per min. entering the mine; (b) by determining the amount of impurity present by making a chemical analysis of the air. The quantity standard is less expensive and more practicable, and is the method most generally used. The quality standard is expensive, and its application is necessary only in exceptional cases. It has only a remote bearing on the efficiency of the men, but occasionally it is found advisable to have accurate determinations made on several samples of mine air.

Humidity Causes Many Mines to Seem Hot

After a large number of readings had been taken, it was found that in many mines, though the temperature was not high, the humidity was excessive, the velocity low and the volume small. A stope having a temperature of 80° F. and a humidity of 99% seemed excessively hot, though another stope with the same temperature and a humidity of 75% was comparatively cool. This was affected somewhat by the velocity and volume of the air in the working places. The greater the velocity and volume (provided the temperature and humidity were constant), the cooler the stope appeared to be. For example, the following readings were taken in a stope that was evidently in need of better ventilation: Velocity, 10 ft. per min. (approximately); volume, 50 cu.ft. per min. (approximately); temperature, 84° F., and humidity, 96 per cent.

A small 5-hp. blower was forcing air into this stope. The miners were uncomfortable and complained of the excessive heat. Five months later, after a new ventilating system had been installed, the following readings were made in the same stope: Velocity, 100 ft. per min.; volume, 500 cu.ft. per min.; temperature, 84° F., and humidity, 90%. The miners mentioned happened to be working in this stope on that date, and one miner remarked, "The stope is not nearly as hot as it used to be, and we can work much better." The men did not sweat excessively in this atmosphere, and the greater comfort that they experienced was due to the increase in velocity, which also means an increase in volume, with lower humidity, and not to the temperature, as it was the same in both cases.

After a number of experiments had been made, the following specifications were decided upon as constituting a "good working atmosphere": Temperature, 78° F.; humidity, 80%; velocity, 125 ft. per min., and volume, 350 cu.ft. per man per min. Though there were some places in the mines where the velocity and volume were much higher than this, there were others in which they were lower; consequently, this was taken as an average of all the velocities and volumes in working places in the mines in which the tests were made. It was found that in an atmosphere of this character men could be expected to perform a fair day's work, and that smoke and gases from the mine were diluted and finally carried off. This working atmosphere has been found to be particularly suitable for mines in the Southwest.

Careful Study Must Precede Installation of Mechanical Ventilation Equipment

In mines where mechanical ventilation is required painstaking consideration should be given as to the kind of atmosphere which it is advisable to establish. When this has been determined, a thorough study of the mine and workings should be made in order to obtain definite information concerning underground conditions. In order, therefore, to estimate the amount of air which will be necessary for the desired working atmosphere, the following factors should be taken into account: Number of men and animals in each district, the production of CO_2 or other gases, relative humidity, temperature, amount of explosives used, the distance from currents of good air, the number of lights, air leakage, friction of the air currents, number of splits of the air current, and method of distribution.

In mines where there is considerable square-setting in ores containing much sulphur, and where a large amount of timber is used for doubling up, bulkheading and similar work, a greater volume of air will be required to maintain the same good working atmosphere than in mines where the cut-and-fill system is used, with its usual limited amount of timber. The same may be said of top-slice stopes. In top-slicing, there is a large timbered mat directly over the men, which usually cuts off any outlet to surface. Stopes of this character are more difficult to ventilate, and take more air, than shrinkage stopes, which have practically no timber and where the ground is so firm that connections above the usual workings are easily maintained as outlets for the air. In caving methods using the incline-raise system and extensive grizzly levels, it is necessary to do a large amount of blasting, first in drawing the ore down to the grizzly level, and, second, in breaking boulders on the grizzly. This naturally results in a large amount of powder smoke, and it is consequently necessary to provide for an unusual quantity of air in order to maintain a good working atmosphere.

Ventilating Systems May Aid Fire Fighting

Ventilating systems have been planned in a few mines and installed primarily as safety measures to permit immediate attack being made on possible mine fires, and only secondarily as aids to ventilation, the natural air currents having proved fairly satisfactory. In most cases, however, the direct object for which a mechanical ventilating system is installed is to improve the atmosphere, and its use in fire-fighting is given only secondary consideration.

By far the most economical method of installing a ventilating system is to work out a comprehensive scheme of mechanical ventilation (using the natural air currents wherever possible), in connection with the development of new orebodies, so that, when the orebodies have reached the producing stage the necessary air connections will have been made. Ventilation should go hand in hand with stoping, both being planned simultaneously, so that, when the latter is begun, the ventilating system will also be in operation, making it possible for the men to perform their duties in good air.

One of the objections to installing a ventilating system as the orebody is developed is that, if the installation is delayed, it may be found possible to get along with the natural ventilation. However, in the majority of cases this can easily be foreseen, and in practically all deep mines mechanical ventilation is a necessity.

It always costs more to put in such a system afterward, when many new connections must be driven, than it does if planned right in the first place with the development of the workings.

Separate System for Development Work

Frequently, after a ventilating system has been installed, the necessity for its expansion, coincident with the stoping, is overlooked, and, while the stoping continues, nothing is done toward the ventilation, so that in course of time, as the workings increase, it loses its effect and fails to serve the purpose for which it was designed. It is therefore highly important that the ventilating system be expanded to meet the constant changes and progress in stoping.

There are two systems of mine ventilation, the exhaust and pressure. In the exhaust system, the fan is usually on the surface, and exhausts the vitiated air from the mine while the fresh air enters through the working shafts and flows in to take its place. The pressure system usually has the fan placed underground, near the main downcast shafts, which should also be the working shafts, and forces the air through the workings by putting the entire mine under pressure, the air finding its way out through shafts, raises, or ground caved and broken to the surface. Most installations in the Southwest are of this latter type, because shafts at many of the largest mines are all operating shafts and cannot be spared for ventilation purposes only. It is, therefore, impracticable to put a suction fan on the surface at an operating shaft. The placing of fans underground has given satisfaction, nevertheless, as owing to the use of double doors, there has been practically no short-circuiting of the air.

Correct Distribution of Air Principal Object

The mere installation of mine fans, however, does not constitute a complete system of mechanical ventilation. The proper coursing and distribution of air through the workings is the only effective test of the efficiency of a ventilating system. In a few mines large fans have been installed without much attention being given to this important consideration, and a thorough study of the workings would show that better ventilation in general could be obtained with half the number of fans, provided the mining features that are involved received proper attention. This would not only improve the ventilation but would materially reduce the cost of the ventilating system.

The capacity of fans which have been installed varies from about 10,000 to 200,000 cu.ft. of air per min., the pressure or suction being from 1 in. to 5 in. The large-capacity fans of from 250,000 to 400,000 cu.ft. of air per min., which are found in coal mines, are impracticable in metal mines, except in a few instances, because the total intake or outlet areas of shafts in metal mines are not nearly equal to those in coal mines.

Some mining companies have installed reversible fans, the idea being to reverse the fan in case of fire in a downcast shaft. However, after consideration of the 35 mine fires which have occurred in the Southwest during the last seven years, I find that in no case was it necessary to reverse the fan. In fact, in nearly every instance the danger would have been increased, because the men expect the air to keep moving in a certain direction, and, if the air currents should be changed without their knowledge, there would be danger of the miners being caught in gas.

Simplest System Uses One Central Installation

The most inexpensive ventilating system, using pressure, consists of one central installation (either on surface or underground) with large intake and a discharge into diverging drifts, from which the air is further discharged into still larger areas. In the suction system, the blower is usually on the surface, and all drifts from the workings should converge to the central intake at the fan, through which the air is drawn to the surface and discharged. One central installation, however, using either pressure or suction, ordinarily could not supply adequately the scattered workings, which require in most mines from one to four additional installations to be satisfactorily ventilated. Occasionally, "booster" fans are used as an aid to the general ventilating system. Two or three mines are sometimes so intimately connected that, in order to work out a ventilating system for one, it is necessary to work it out for all. In some instances a combination of both the pressure and exhaust systems is adopted.

The installation of the mine fans is the smallest part of the cost of putting in a ventilating system. By far the greater expense is incurred in the necessary changes in the mine, such as cutting a blower station for mine fans (in case they are underground); driving drifts and raises to allow sufficient air to pass to ventilate the stopes; erecting doors in suitable drifts and crosscuts and putting in stoppings to cut off old workings and leaks which would impair the efficiency of the ventilating system, and making other similar and necessary alterations.

Development and Other Workings Must Also Be Ventilated

The systems described above are for the purpose of ventilating the major portion of the workings, which comprise about 80% of the mine; the remaining 20% must be taken care of in some other way. This 20% generally consists of the prospect and development work, such as drifts, raises and winzes, and must be done in advance of the usual stoping operations. For this work it is necessary to use an auxiliary ventilating system, which should be standardized wherever possible.

When the headings are being driven in such work the exhaust air from machine drills is used to furnish the necessary ventilation. No compressed air is required when machines are running. The exhaust of the average machine gives approximately 100 cu.ft. of ventilating air per minute. However, it is well known that this is not the purest air, as it is vitiated somewhat by the oil which vaporizes in the machine and comes out with the exhaust. After blasting, the full head of compressed air is usually turned on to clear out the heading.

After drifts, raises, or winzes have been driven a certain distance, a point is reached at which the compressed air is insufficient, and it then becomes necessary to install artificial ventilation. An air jet, for example the Koerting-nozzle type, which uses a small amount

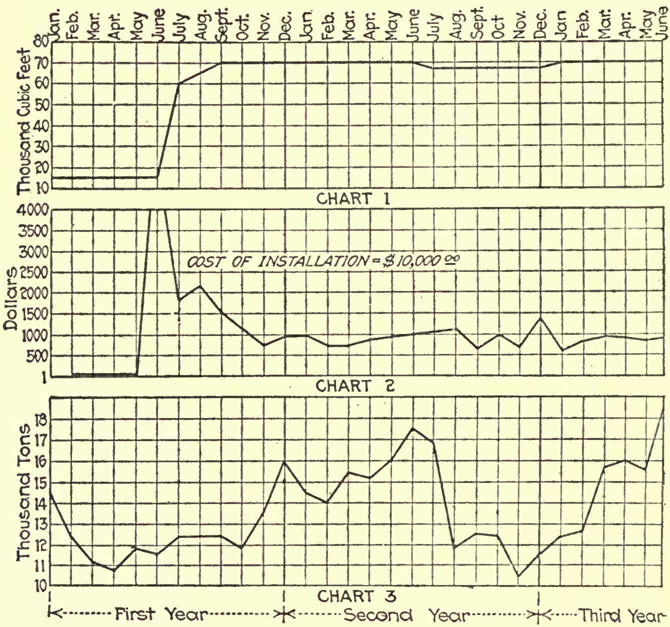


FIG. 1. CHART 1 ILLUSTRATES TOTAL VOLUME OF AIR MOVED PER MINUTE. CHART 2, TOTAL COST OF VENTILATION. CHART 3, TONNAGE PRODUCED

of compressed air, at the same time having a strong suction so as to draw a large amount of fresh air around the nozzle and force it through the ventilating pipe, is generally found sufficient. (One cu.ft. of compressed air will furnish approximately 18 cu.ft. of ventilating air.) As raises and occasional winzes are driven only about 100 ft., an air jet supplying air for 10-in. pipe should provide ample ventilation under average conditions. Drifts are usually driven longer distances, and should be provided with electric blowers. In general, a 10-in. blower, designed by standard manufacturers, using a 2½-hp. motor (both blower and motor mounted on one base) is suitable.

Jets and Blowers Must Be Properly Placed

The position of air jets and blowers is important. If they are placed within the drift or raise to be ventilated, air will merely circulate between the blower and the end of the pipe. They should be situated outside or have the intake outside of the drifts and raises. The pipe should reach to the working face, so that it will not be necessary to use compressed air. Before blasting, the sections near the face should be taken down and put where they will not be injured.

After the drift has progressed about 3000 ft., the blower should be provided with a reversing attachment in order that it may be reversed to clear the smoke away, and after that be run as a pressure fan, to furnish good air at the heading. In exceptional cases, principally in tunnel work, where speed is important, two blowers should be used, one for pressure and the other for suction. This permits almost continuous work at the heading.

Ventilation May Be Standardized

With the introduction of mechanical ventilation, it has been found that the atmosphere in mines can be standardized instead of having shifting and uncertain currents of natural ventilation. It has also been demonstrated that this standard atmosphere is well within the economic limit and that it pays to ventilate a mine by increasing the amount of air until such standard conditions are reached.

The velocity of air currents in working drifts has been brought up to 1200 cu.ft. per min., and in exceptional cases to 2000 cu.ft. The former figure approaches the economic limit at most mines where power cost is a large item, and the latter should be set as a maximum for safety. The "good working atmosphere" mentioned previously has been tried out in a number of mines in the Southwest for a period of over five years and has proved entirely satisfactory as a standard for conditions existing in this part of the country.

Cost Sheets Prove Value of Good Air

Actual figures showing a reduction in costs and a decrease in consumption of compressed air prove the value of such an installation, and point to the results that

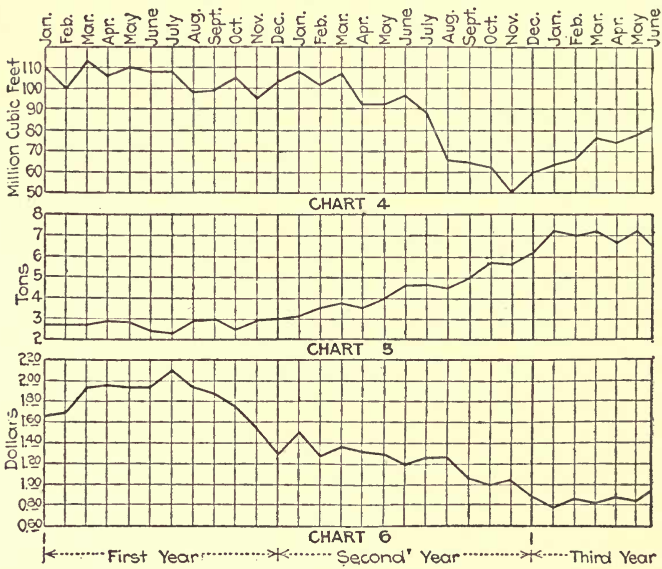


FIG. 2. Chart 4 Illustrates Decrease in Compressed Air Used After Installation of Ventilation System. Chart 5, Increase in Tons per Man per Shift. Chart 6, Decrease in Cost of Mining

might possibly be obtained were the standard made still higher by securing a lower humidity, lower temperature and greater volume of air per man per minute. The accompanying charts show the results obtained by installing a well-planned mechanical ventilating system, and cover a period of two and a half years.

Chart No. 1 shows the total volume of air moved per minute, and Chart No. 2 the total cost of ventilation. In Chart No. 3 it will be seen that after the date of the installation of the mechanical ventilating system there was a marked increase in tonnage until the latter part of the second year, when, owing to unusual conditions, production was much curtailed. However, in the early part of the third year the tonnage again increased, and in June there was an increase of 4000 tons over that in January of the first year.

Chart No. 4 illustrates the decrease in the quantity of compressed air used, owing to the installation of the ventilating system. The curve shows the total amount of compressed air needed both for ventilation and machine drills. This accounts for the rise in the curve from November of the second year to June following, as the tonnage increased from 10,500 per month to 18,500 tons. Consequently more machines were used to break the ore represented in this added tonnage.

Chart No. 5 shows the increase in tons per man per shift. This is obtained by dividing the daily tonnage by the total number of men employed in the mine. The mining method used in this particular mine was practically all square setting, and all the ore had to be sorted. Only one stope in the entire mine was worked by the cut-and-fill method. The increase after the new ventilating system was installed was from about 2½ tons to 7 tons, or approximately 180 per cent.

Chart No. 6 illustrates the decrease in the cost of mining the ore, and an average for the first seven months of the first year, compared with an average of the seven months preceding June of the third year, shows a drop of from \$1.57 to \$0.85, or a decrease of \$1.02 per ton.

Large fans are designed for the capacity, pressure or suction, as well as for the elevation where they are to be operated. Regarding small blowers, however, a standard size and design of electric motor, blower and ventilating pipe should be decided upon. A 2½-hp. motor, connected to a 10-in. blower and 10-in. ventilating pipe, is usually sufficient. It is important that a standard be selected, as, for example, the one mentioned above, as there are many mines where 8-in., 10-in. and 12-in. ventilating pipe, with different types of blowers and complementary apparatus, may be found in use at the same time. This is likely to cause confusion and delay because of attempts to attach pipe of the wrong size to blowers, and in other ways.

Either metal pipe or canvas tubing may be used for ventilating purposes. Metal pipe has been found satisfactory and is in general use in mines throughout the Southwest. When properly put up, with joints that are carefully sealed with burlap and tar, it requires no further attention, as joints of this character prevent leakage, and the angle at which the pipe is hung prevents water lodging in it. It stands up well under mining conditions, and when the usual precautions are taken to remove the lengths near the face before blasting, the pipe is usually not materially damaged by the small rocks which occasionally strike it.

Canvas tubing has the advantage of being more easily handled, as it can be taken down the shaft and hung in less time and at less expense than iron piping, and it is also more flexible in rounding curves, as iron pipe needs an elbow at every turn. There is, however, a question as to how its durability will compare with that of iron tubing under ordinary mining conditions. The difficulty arising through water gathering in it is also generally experienced, making frequent attention necessary. In some of my experiments underground, when the miners were ready to blast they would take down the canvas tubing, coil it up along the drift, and move it back a reasonable distance. At times some of the smaller pieces from the blast flew back and cut holes in the canvas, which damaged it considerably, and in addition, the tubing was subjected to the ordinary wear and tear of rolling it along the drift and coiling it up in places where there was frequently mud and water.

Some time ago experiments with small blowers and different kinds and sizes of ventilating pipe in 100 and 200-ft. lengths were made under my supervision. It was found that the velocity and volume delivered at the end of 200 ft. of 10-in. canvas tubing were considerably less than when delivered, under similar conditions, at the end of 200 ft. of 10-in. iron pipe. This made it evident that in order to deliver the same volume of air at the working face through canvas tubing that it is possible to deliver through the iron pipe, it is necessary to have a much larger size of canvas tubing, or else, if

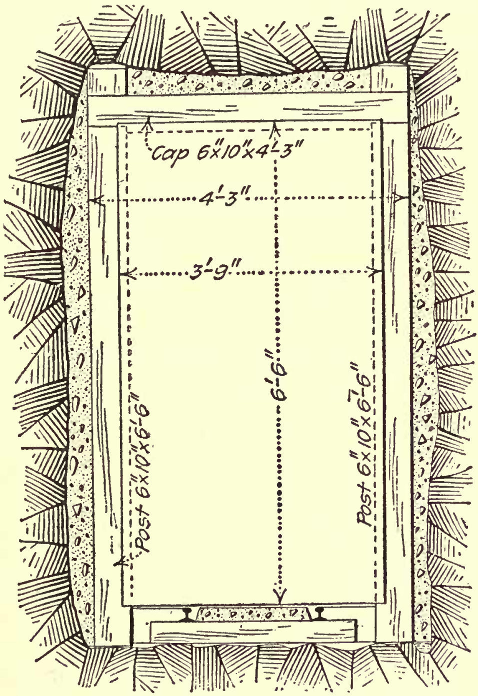


FIG. 3. DOOR FOR BOTH HAND AND MULE TEAM

the same size tubing be used, the blower must be speeded up or a larger blower be installed. In places where the cost of power must be considered, the extra expense is important. Metal rings inserted in the canvas tubing at frequent intervals restore more nearly the condition effected through the use of the iron pipe, as they help to support the canvas, which otherwise would have only the air pressure as support. However, all these improvements add to the cost of the tubing, and there

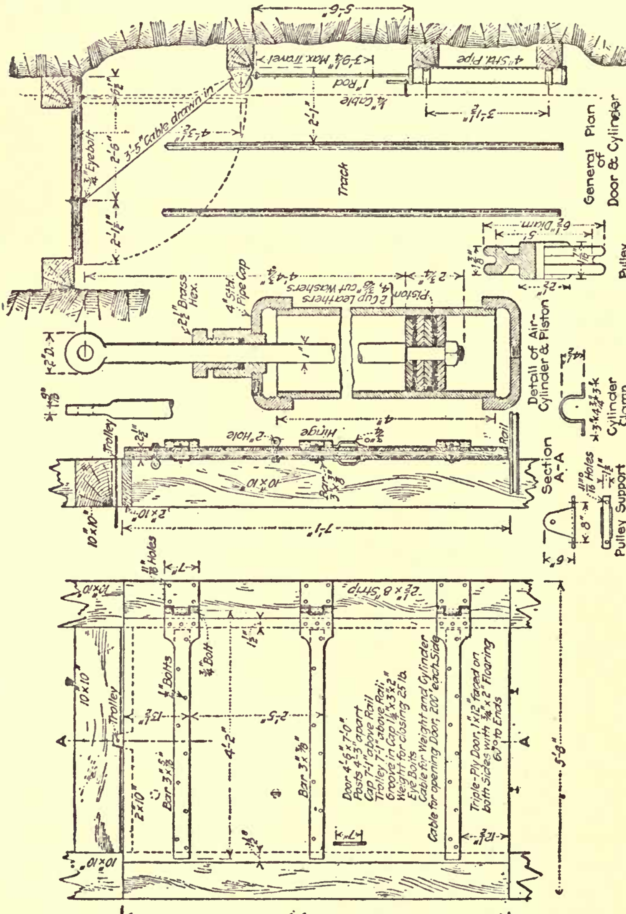


FIG. 4. A DOOR FOR USE IN MOTOR-HAULAGE DRIFTS

is some question, when all is considered, whether, even under these circumstances, it would prove as efficient as iron piping.

In the mines in some districts stoppings are called bulkheads. These are used to seal off dead workings, air leaks, or drifts and raises leading to stopes which are not in operation. A stopping which may be adopted as standard should be constructed as follows: Suppose a drift is to be bulkheaded. The ground is first cut out around the drift where the stopping is to be placed. After that, 4 x 6-in. posts are set up, three feet apart, across the drift. Then 1 x 12-in. boards are nailed to the posts, making a partition. Metal lath is tacked on to the boards. In case metal lath is not available, double wire netting with small-diameter openings may be used. A fine coating of cement, $\frac{3}{8}$-in. thick, put on either by hand or with the cement gun, is then applied. If only old workings are to be sealed off, and it is desired that some air should be allowed to pass through them, the cement and boards in the stopping, near the center, should be omitted. For example, a space 2 x 2 ft. should be left, but the wire netting should cover the entire surface. Should it be found desirable to seal up this space later, a cement coating may be put over the wire netting.

Standardized Doors Should Be Used

All doors should be of standard size. In general, two standards are necessary. They are illustrated in Fig. 3 and Fig. 4. In Fig. 3 is shown the design of a door for both hand and mule tram. Fig. 4 shows a door for use in motor-haulage drifts. In the latter sketch details such as handles, hinges, weights, cable, pulleys and canvas are given. Fig. 4 also illustrates an air-controlled arrangement to be attached to the same door, so that motor trains may pass throughout without stopping.

The Canton automatic door has been installed in many mines and has given satisfaction when used against low pressures. Double doors should be placed in all important drifts where it is necessary to keep up either a high pressure or suction in order to force the air from the drift into more distant mine workings.

Regulator doors are constructed as are the doors, already mentioned, except that openings are cut in them and slides built in to regulate the flow of air. In this manner the volume of air to any area can be regulated so that all workings may receive their proportion of the air supply.

The necessary equipment in a mechanical ventilating system, such as doors, frames, hinges, weights, automatic arrangements, small motors, small blowers, and ventilating pipe, should all be standardized. Standardized manways, timber compartments and chutes in raises should also be designed as an aid to the ventilating system.

In order to maintain the maximum production, with a corresponding high standard in the quality of the work, it is absolutely necessary that every working place should have a good working atmosphere, and that the ventilation should be so kept up with the progress of the work that the men may continue to perform their duties in health and comfort. Mechanical ventilating systems which have been designed with careful study and are now in operation have fully justified the cost of their installation, as evidenced by the increase in tons per man per shift and the decrease in cost. In mines where such a system has been carefully worked out and conditions have been standardized as much as possible, there has always been a great saving in the amount of compressed air used. In fact, in some cases the economy in this item alone has more than balanced the cost of installation.

Conditions can be made standard in mines only where a complete mechanical ventilating system is in operation. Fewer men will be gassed in headings when standard equipments are available and installed before the atmosphere becomes dangerous. There will also be less decay of mine timber. Further experimental work may suggest the advisability of raising the standard of mine atmosphere.

Section IV

Explosives

THE dangers incidental to the storage and handling of explosives are the cause of much concern to members of mining organizations. Apart from unavoidable hazards and fatal and serious accidents due to carelessness, the injurious effects produced by large quantities of noxious gases resulting from the explosion of dynamite must be considered. Many serious injuries have been sustained by men who are gassed.

All operations connected with the handling and use of explosives should be standardized. This would be of considerable help in eliminating many of the regrettable accidents which are constantly occurring, and would tend to reduce the quantity of noxious gases, produced by the explosives, to a minimum.

When a carload of powder is received at the mines, it is necessary to have it unloaded and stored on the surface. Great care should, of course, be exercised in its transportation to the magazine, and provision made for the different kinds of powder stored in one place, so that there may be no confusion between low- and high-strength explosives. To prevent this, the magazine should be divided into a number of compartments, each being properly labeled for the different kind and strength of powder which is to be stored in it. The magazine should be well ventilated, to avoid the powder being kept in an atmosphere where the humidity is high, and should preferably be constructed as a chamber driven into the hillside, where it will be free from shock and where there will be no possibility of a chance rifle bullet entering it. In exceptional cases, where it is not practicable to drive into the hillside, an adobe, cement, stone, or brick magazine is usually constructed in which to store the powder. Adobe is preferable to cement, stone or brick, because, in case of an explosion, it will probably crumble and there is less danger of the material used in its construction being broken up into missiles.

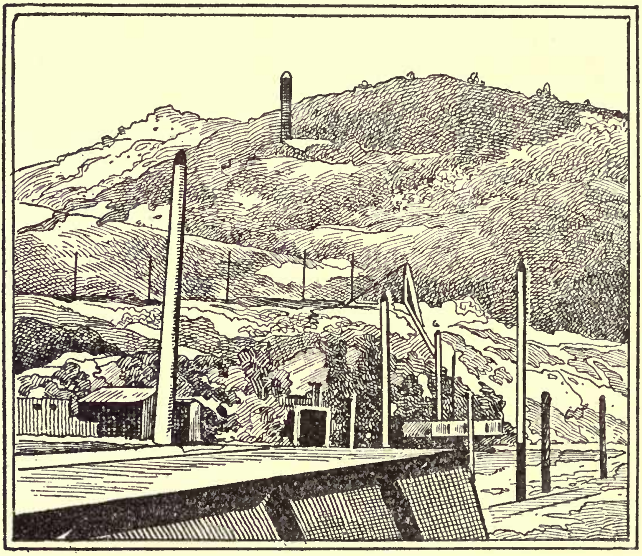


Fig. 1. Explosives Magazine in Hillside

The powder house should have double doors, with openings large enough to admit a man's hand, so that they may be locked from the inside. This is effectual in preventing any one working at the lock in an endeavor to pick or strike it with a hammer. Fig. 1 is an illustration of such a magazine. In this case there is one main adit leading into the hillside, closed by double doors, locked from the inside. In Fig. 2 a plan view is given of the parallel drifts leading from the main tunnel, showing the placing of chimney and the different compartments in the magazine.

When the powder is transported from the surface magazine to the different mine shafts, it should not be left at the collar of the shaft longer than is abso-

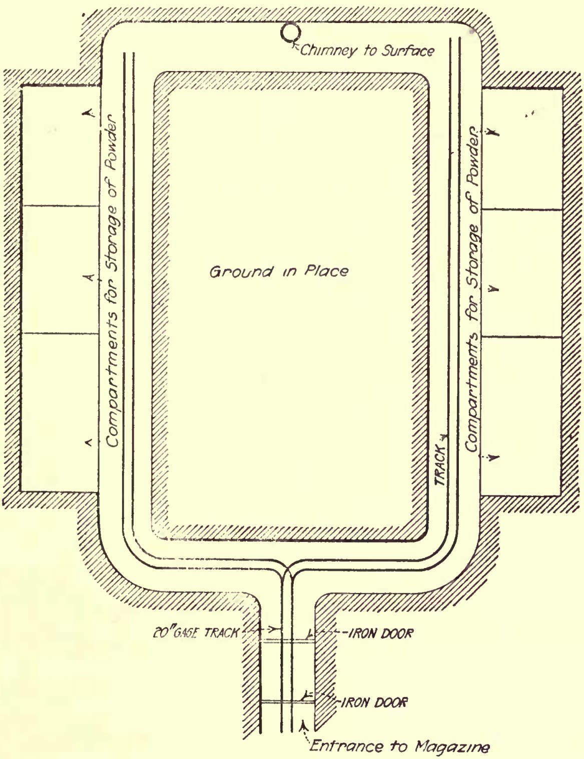
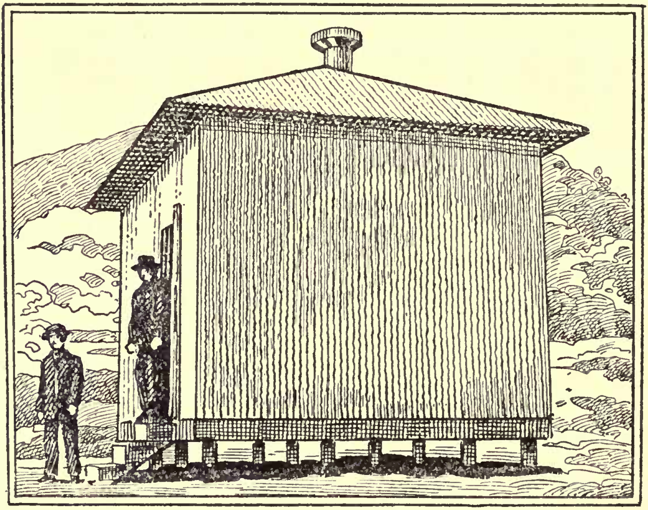


FIG. 2. PLAN OF POWDER MAGAZINE

lutely necessary, as many accidents have occurred through the explosion of powder there, before being taken underground. This is of the utmost importance.

I have recently noted cases where the powder is taken to the collar and left there for an hour in the morning during the time when the shift is going to work.

Not more than one day's supply of powder should, of course, be taken underground. Powder should never be lowered with tools or supplies of any kind, as that will establish a practice which will lead to the lowering of powder with steel and similar material. At the different shaft stations it should be a rule that the powder men must remove the powder from the stations



HOUSE WHERE FUSES ARE CUT AND CAPPED

immediately after it is brought down. A boulder falling down the shaft might accidentally strike the explosive.

From the shaft stations the powder is taken to the underground magazines, of which there should be one on each level. These magazines should be situated conveniently for all the men on the level, and at the same time far enough removed from the blasting to minimize the danger from shock. The magazines should be well ventilated, and not placed where the humidity rises to more than 80% and the temperature is high. They should be used for the storage of powder only and not as combination magazines for powder, tools, and supplies, as is the practice in some mines. Each magazine should be in charge of a powder man, usually called the "powder monkey." His duties are to give out the powder to the drillers as they call for it, and to keep an accurate check on the amount and the place where it is to be used, and this work is usually combined with other duties, such as checking up tools and other supplies in the tool house, which should be situated some distance from the magazine. The same man also attends to another magazine which contains the caps and fuse.

Though it is advisable to have the powder and capped fuses taken to the heading separately, it is impracticable in most cases, and all miners coming to the powder magazine should have powder and fuse sacks in which to carry their powder, fuse, caps, and stemming. The fuse, caps, and stemming should be placed in one sack and the powder in the other. These sacks should have suitable handles, so that a man can put one on each shoulder when climbing up a raise. Instances have been known of men tying fuse around sticks of powder, and carrying it up ladders in this manner. Should the fuse become loose and a stick of powder drop, the results are likely to be serious. The caps and fuse should be kept in separate houses on the surface. In mines where the humidity is high, the fuse should not be capped underground. The cutting and capping should be done by men who devote their entire time to the work, and these operations can readily be standardized.

Mechanical Fuse Cutter

A fuse cutter is preferable to a knife or ax, as it is necessary that the fuse be cut square across and to exact measurements. Fig. 3 is an example of a suitable arrangement. This consists of a table 3½ ft.

high, 3 ft. wide, and 10 ft. long, with a blade of steel, foot pedal, and spring attached. The table is marked into feet and inches, so that the fuse may be cut any length up to 10 ft. At one end is a movable block, set at right angles to the table. This regulates the length of the fuse. The fuse spools are set on pegs, just above the table at the opposite end to the movable block. In cutting, the movable block is placed at the length desired, and the fuses, of which the table accommodates any number up to about 25, are drawn along the table until the ends touch the movable block. The operator then steps on the foot pedal, which pulls the steel blade, set at zero, down to cut the lengths of fuse. On releasing the pedal the spring raises the steel; the operator again pulls the freshly cut ends to the movable block, steps on the pedal, and repeats the operation. The use of this machine obviates all danger arising from the fuses not being cut square. After being cut, the lengths of fuse are drawn along the table a little further, where they are capped.

Capping of Fuses

In capping, the fuse should be placed in the cap so that it barely touches the charge, and the cap not too tightly crimped on. If the fuses are to be used in damp or wet places, a further precaution should be taken by using P. & B. paint, heavy grease, or some other material which is water-tight, to keep all moisture from penetrating the cap through the junction between the cap and fuse. Whenever a sufficient quantity of fuses are capped and ready for use, they are put into special fuse cans. These may be made by taking carbide cans, cutting them down about 9 in., fitting them with special lids which are water-proof, and lining the inside with felt ½ in. thick. The lids should be lined as well as the cans. The fuses are coiled and placed inside these cans and transported in this manner to the shafts, from which they are transferred to the different underground fuse houses. The fuse cans should be sent back to the fuse house on surface to be refilled as the supply underground runs low.

From the standpoint of efficiency, the capping of fuses by men specially employed for that purpose has proved to be a success at a number of mines. In one instance, two men do all the cutting and capping on the surface for the entire mine, averaging 3000 caps a day. This

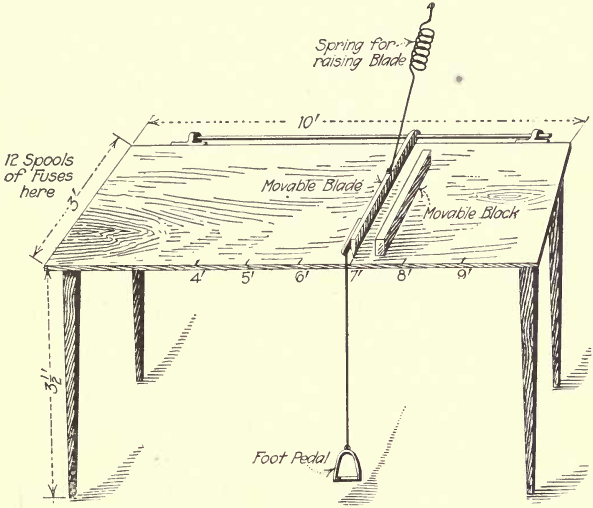


FIG. 3. ADJUSTABLE FUSE CUTTER

work was formerly part of the duties of sixteen powder men, who cut and capped fuse for their individual levels, and who are now required to do repair work and cleaning tracks in the time formerly spent in crimping caps. At another mine, one man is employed in a well-ventilated fuse house underground, and cuts and caps from 1100 to 1400 fuses a day.

STEMMING OR TAMPING

Stemming, or tamping, as it is called, is extensively used in practically all mines except metal mines. Its use has been in practice in coal and iron mines and in mines in England and on the Continent for many years, but it is not extensively used in the metal mines in this country. In Michigan, where many of the miners originally came from England, stemming is used, for the reason that the men have been trained in that country to the idea that stemming goes with the powder, but its use has never been enforced by the

FIG. 4. FUSE CANS

operators in the West; and the miner has come to know that by filling the hole with powder and using the explosive instead of stemming he can satisfactorily pull the ground, and, inasmuch as the company furnished the powder, there is no need for him to be economical.

It naturally became the practice for miners in this country to load a hole with powder and then use an extra amount for stemming, thus establishing a custom for the use of an excessive amount. In this connection

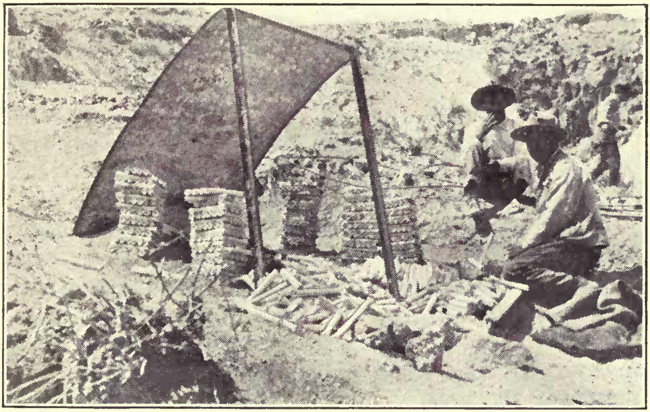


FIG. 5. MAKING STEMMING AT A MEXICAN MINE

it may be noted that contractors in the Southwest who furnish their own powder generally use stemming. The miners working on day's pay, on the other hand, never do so, as they well know that holes loaded with an excessive amount of powder without stemming will satisfactorily break the ground, and that the use of stemming entails extra work and is contrary to custom. In justification of the miners' attitude it should be taken into account that not enough has been done in eliminating missed holes, as it is dangerous to clear out the stemming in a missed hole in order to blast it over again. It is therefore absolutely essential that the number of missed holes be reduced to a minimum before making the use of stemming compulsory.

STEMMING INCREASES EFFICIENCY

It is an established fact that stemming increases the efficiency of the charge, and Technical Paper No. 17 ("The Effect of Stemming on the Efficiency of Explosives") of the U. S. Bureau of Mines, describes experiments showing that the gain in work accomplished when dynamite is tamped varies from about 35% with the quick-acting to over 90% with the slow-acting explosives. De Kalb says that in no case is detonation absolutely perfect under ordinary conditions, but this perfection is approached more closely according to the concentration of the explosive impulse, due to good confinement.

Experiments made by the Western Australian Government Commission, and described in the "Blue Book" of 1905, showed that the tamping of charges has a marked effect on the proper detonation of the explosive used. When bore holes are tamped carelessly, or when no tamping is used, the lack of confinement apparently causes a small part of the explosive to be detonated incompletely, and consequently more offensive fumes are given off than when the charge is tamped properly.

Some of the arguments advanced against the use of stemming are as follows:

1. It takes longer to load a round of holes when stemming is used.

2. In the case of missed holes, the stemming must either be cleaned out or another hole drilled alongside; and if the miner is careless there is danger of drilling into the unexploded charge.

3. It is contrary to custom, especially in the Western States.

The advantages of stemming are:

1. Greater efficiency of the explosive.

2. Complete detonation, and, therefore, a minimum amount of noxious gases.

3. A saving in powder and, incidentally, in cost.

Classes of Stemming Used

Different kinds of stemming are used on a small scale in some of the metal mines in the West. In one mine, for example, the powder man collects several boxes of clay, which he brings to the powder magazine. The clay is rolled into balls about the size of the ordinary baseball, and he hands these to the miners when they come for the powder. About half this stemming is scattered along the way to the working places. When ready to load, the miner is often so rushed for time that he is unable to take these large balls of clay and roll them down by hand to fit the holes, so the remainder of the stemming is usually lost. In cases where the miners actually do use it, the quantity is so small that the effect is negligible.

Another method which is being tried in some places is the use of paper forms made the same size as the powder. These forms are filled in some instances with wet and in others with dry sand (see Fig. 5). So far, this has been tried out only occasionally in certain mines, and therefore has not produced the results for which it was intended. Mill tailings are sometimes used, the fine dust in drill holes has been collected and used in others, and dust from the ores has been tried in a few mines, but this has not as yet passed beyond the experimental stage.

Value of Clay for Stemming

It has been proved by experiments that plastic clay which has been properly tempered is most suitable for stemming. Consequently, when an attempt is made to introduce the practice in a mine, it is advisable to use the best material available. At the property of the Mogollon Mines Co. a machine was devised and has been in use for some time to mold clay in the desired form, and a system also has been adopted by which the stemming is properly distributed.

In the larger mines 3000 or more shots are fired every day. This requires a large amount of stemming and necessitates manufacture on a large scale. After a careful study of this matter and after taking up the question with authorities on brick-making at different plants, I came to the conclusion that a brick-and-tile machine, with a die made to suit the measurements of stemming, would be practical for such a purpose. Fig. 6 shows a machine of this kind, capable of turning out stemming in quantity greater than required at the average mine. For this reason a smaller machine should be designed to meet requirements.

Use of American Auger Machine

The clay from which the stemming is to be made should first be thoroughly mixed and tempered in a pug mill, boulders broken and sufficient water added to make it plastic. After being thoroughly mixed, the clay is run through the stemming machine and forced out through a cluster die, containing six to ten orifices each approximately one inch in diameter, cut into about ten-inch lengths, and wrapped in paper. This paper should be of different color to that used for the powder. The product should be sent to the various shafts, lowered, and taken to the powder magazines

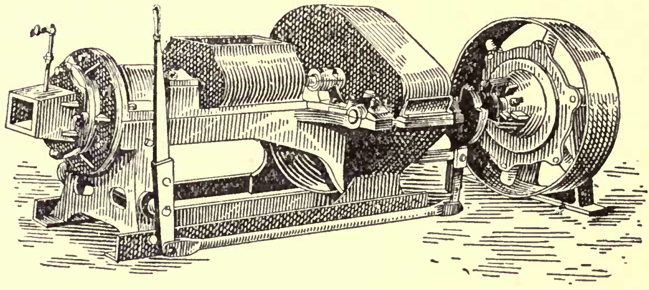


Fig. 6. American Auger Machine for Making Stemming

together with the powder. When the miner goes for his powder and caps he should receive the stemming at the same time.

A plant such as is suggested could be designed and constructed at a reasonable cost. The pug mill and stemming machine can be operated by electricity at small expense, and the clay obtained from waste dumps, and the quantity of water used would be negligible. When it is considered that the machine shown in the illustration is capable of turning out from 1000 to 2000 building bricks per hour, it is obvious that with a smaller machine, designed to meet the requirements of the average mine, two men could turn out sufficient stemming within a few hours to supply the daily needs, and for the remainder of the shift they could be put to other work.

Loading and Blasting Practice

Great care should be exercised in slitting the powder and putting it in the holes. Except in the case of very wet holes, every stick of powder should be slit. A wooden tamping stick should be used, and the powder carefully tamped so that it will fill all the air spaces in the drill holes.

In placing the primer, there is considerable difference of opinion as to where it will have the greatest effect. It is best to decide on one particular place, let that be the common practice, and adopt it as standard. Though it is possible, with the uninflammable ammonia dynamite and the gelatins so extensively used in mining, to place the primer anywhere with small danger of ignition, (providing a high quality of fuse is used), the tamping can be done more effectively if the primer is placed near the top of the charge. On the other hand, the explosive is more generally detonated by having the cap in the center of the charge. In the Southwest, the general practice seems to be to place the primer near the bottom of the hole; and although there is a possibility of the powder being set on fire by the fuse before it reaches the detonator, the use of the best quality of fuse seems to have, so far, avoided this danger.

In making up the primer many methods have been practiced, of which Fig. 7 shows one of the most popular. In the practice illustrated misfires are of frequent occurrence. In those instances where the fuse was cold it was doubled up by the miner so as to break, which was also the cause of misfires. The wrong way and the right way, shown in Figs. 7 and 8, respectively, should be illustrated by blueprints, which should be placed in front of the mine office for the benefit of the men. Orders should also be given to the men regarding the standard practice which has been adopted.

After loading and placing the primer (in case stemming has been introduced and become a regular practice), the remainder of the hole, to within about six inches of the collar, should now be filled with stemming. By leaving this distance unfilled it will then be possible, in the case of a misfire, to ascertain the exact direction of the missed hole, so that another may be drilled with safety.

The fuses are now spit about ½ in. so that they can easily be ignited. The old method of using a piece of fuse about a foot long and cutting it about every inch is the most practical fuse spitter in use at present. At this moment caution should be exercised to spit the cut holes first, as many rounds are lost on account of miners neglecting this important point, and hastily spitting the fuses, regardless of the order in which they should be fired.

Danger From Missed Holes

As previously mentioned, before stemming is used, the number of missed holes must be reduced to a minimum. The causes have frequently been enumerated and are well known. A thorough investigation of conditions should be made at mines where a large percentage of missed holes occur, and the causes eliminated. Frequently, the use of a stronger detonator will have a marked effect on the reduction of missed holes. If, therefore, proper attention is given to the handling and care of powder, caps, and fuse, as outlined above, and only the best quality is used, there should be few misfires. In some mines the number has already been reduced to less than 1%, and at one in particular, where a strong detonator is used, the monthly average is about

0.25%. In headings where a great deal of water is encountered, or when sinking in wet ground, it is generally advisable to blast by electricity in order to eliminate missed holes.

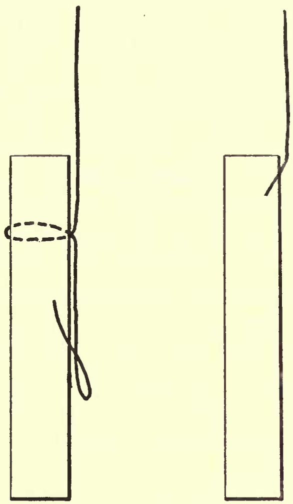


FIG. 7 FIG. 8

WRONG AND RIGHT WAYS OF MAKING UP THE PRIMER

GASES FROM EXPLOSIVES

Some conception may be formed of the effects of gases produced by explosives from the fact that, in one mine, 37 men were gassed during a year, of whom 11 (29.72%) were gassed in stopes, 12 (32.43%) in drifts, 12 (32.43%) in raises, and 2 (5.42%) in winzes. The total time lost was 84¼ shifts, with individual losses up to 10 shifts per man. At another mine 21 men were gassed in a single night as the result of excessive powder smoke and gas from blasting.

When it is considered that one stick of 1⅛-in. 40% gelatin dynamite will produce approximately 1.54 cu.ft. of carbon dioxide and 0.09 cu.ft. of carbon monoxide (calculated for atmospheric pressure at sea level), and that in a drift or raise averaging 10 to 20 holes, with six sticks of powder to a hole, there would be about 90 times this amount, or 157 cu.ft. of gas, some idea can be formed of the effect. It takes approximately 650 cu.ft. of fresh air to dilute the gas from one stick of such powder and improve the atmosphere until the carbon dioxide present is 0.25%. For the drift mentioned, a relatively larger amount, about 58,500 cu.ft., of good air would be necessary.

Stopes worked by undercutting systems, where boulders must be plugged during the shift; caving systems where ore is simply drawn off and where it is necessary to put in more holes with the stoper from the chute in order to cave the ground above; horizontal or incline cut-and-fill stopes, necessitating the breaking of boulders for the chutes; top slices, in order to break the ore in case the previous shift did not blast—all require blasting to be done during the shift. This results in an excess of gas over and above that formed from the regular blasting at the end of the shift. The greater the atmosphere is vitiated, the more good air must be produced. This requires more power and closer supervision of the ventilating system in order to have the place ventilated as thoroughly as possible; and this naturally adds to general cost.

The large amount of gas produced is due partly to the excessive use of powder on the part of the miners and partly to incomplete detonation. The former naturally multiplies the volume of gas, and it is a well-known fact that when a charge of dynamite burns instead of exploding, a much greater amount of carbon monoxide is formed, and other harmful gases are produced. Incomplete detonation, due to the use of caps of insufficient strength, or the presence of moisture in the cap, adds to the seriousness of the situation by increasing the percentage of dangerous gases present. The efficiency of the explosive is also reduced when the charge burns instead of exploding; in fact some authorities estimate its efficiency to be only about 50%.

"In practice, the fact that an explosive has not been properly detonated is made manifest principally by the production of considerable quantities of disagreeable and poisonous fumes, the presence of unexploded powder, the small amount of work done by the powder, and often, with high explosives, a section of the bore-hole in which the powder has burned is unaffected. . . . The bad fumes in incompletely detonated powder are due to the fact that its decomposition was effected at a temperature below that which corresponds to the most violent chemical action. The result is that instead of producing nitrogen and carbon dioxide in the gases from the explosion, both the poisonous nitric oxide and carbon monoxide are formed. . . . The weaker effect from imperfectly detonated powder is due largely to two causes—lesser heat of formation of carbonic oxide gas and the heat absorbed in the formation of nitric oxide. Thus, when carbon monoxide and nitric oxide are present in the gases from an explosion, poorer results are obtained than when carbon dioxide and nitrogen are liberated. Further investigation during late years has shown the presence of volatilized nitroglycerin in the fumes from burning or incompletely detonated dynamite. Nitroglycerin is very volatile, and a small quantity may easily be evaporated by the heat from burning powder. This is made manifest by the action of these fumes on human beings. It is a common fact that men breathing the fumes from nitroglycerin explosives, particularly when improperly detonated, get violent headaches, similar to those due to slight nitroglycerin poisoning. This great similarity, and the fact that the same treatment effects a cure in both cases, are accepted by a number of authorities as satisfactory evidence that nitroglycerin vapor is present in the fumes from poorly detonated or burning dynamite."

Formulating of Blasting Rules Difficult

Though it is difficult to formulate rules regarding blasting in mines where the method employed necessitates the use of explosives during shifts, something can still be done to systematize the work as much as possible. If men are working over a grizzly and find it necessary to blast frequently, then instead of blasting each boulder separately as they come to it, they may be able to keep the ore running until they have five or six of these boulders together. In place of the customary one, two, or three sticks of powder on each boulder, they should put a small hole in each with a Jackhamer, insert about half a stick of powder, a strong detonator, and a little stemming on the top. This will generally break the rock just as effectively and reduce the total quantity of powder from 10 or 12 sticks to about 2½ or 3. This would result in a marked effect on the ventilation in general, as it would decrease the quantity of poisonous or noxious gases which are generated in the first place, and thereby require less air to dilute the products of combustion. It would also effect a considerable saving in powder. The organization can insist on these different operations until they become habitual with the men and finally become standard.

Section V

Fire Protection of Metal Mines

FIRES are the greatest hazards encountered in the development and operation of mines. The loss of life, damage to property, and utter disorganization of regular routine which frequently accompany them make them occurrences to be dreaded by mining organizations. The period of confusion immediately following their discovery and preceding the time when an organized method of attack shall have been planned is generally the most critical, due to the lack of definite working plans; men frequently expose themselves unnecessarily and often incur serious injuries, which at times prove fatal.

During recent years there have been approximately 35 active mine fires in the Southwest. Twelve of these were shaft fires, but the majority occurred in stopes, or in drifts and raises directly connected with stopes.

Causes of Mine Fires Varied

Fires result from many causes, among which are defective electric wiring, use of candles, spontaneous combustion in pyritic orebodies, and, I regret to say, incendiarism. In this connection it might be stated that 40% of the fires mentioned above were due to this latter cause.

Fires in surface buildings were formerly the cause of many disasters underground. The fire was communicated from the building to the shaft and thence to the mine workings. In recent years, however, steel headframes and other fireproof construction have come into general use, and timber connections between buildings and shaft collars have been avoided. A convenient water supply is always available, and the possibility of a mine fire from this source has practically been eliminated.

Friction, due to moving ground, intensified by caves and extreme pressure, is often the cause of fire in ores containing considerable pyrite, chalcocite or chalcopyrite, and recently it was demonstrated that a fire can exist in sulphide ores the sulphur content of which is approximately 3%. Fires in metal mines have become so frequent that almost every district has its history of them, and most companies are now taking precautions to meet such emergencies when they arise.

Various methods of fighting fires have been employed at the different mines with more or less success. The plan most generally resorted to in the past has been that of sealing up the fire or fire district, and allowing it to remain for a considerable length of time, extending in some cases over a period of years, while this portion of the workings was temporarily abandoned. This has proved fairly successful in mines containing large areas of low-grade ore, but where the mine is a high-grade producer, the removal of a large portion of the orebody from active stoping, even if only temporarily, would seriously curtail production.

At one mine, a complete mine-fan equipment has been installed on the lowest level, which may be started in case of fire by entering the workings through an adjoining mine. This, in addition to a fire-fighting equipment, consisting of portable blowers, ventilating pipe, bratticing, helmets, etc., together with a set of rules prescribing duties for the organization, makes up the fire-protection system.

Another company places entire reliance on teams of trained helmet men. It is expected that these will be able to cope successfully with any emergency which may arise.

A third mine has a system of bulkheading and patrol in force. Bulkheads are put in as seals at all stopes which are not in operation. Though the seals are not airtight, they could easily be made so in case of fire. The patrol has the specific duty of visiting every working place shortly after the men go off shift. Gates are put in at tunnel entrances to the mines and are kept locked both day and night. When the shift is going on, a watchman opens the gates and checks the men, allowing only those who have time cards to enter. When the shift goes off, the watchman again takes charge. If motors are to take timber and other supplies into the mine through the gates during the shift, it is necessary for the motorman to have a key to the gates in order to pass through. Screen gates, such as shown in Fig. 1, are also put in front of important shafts, so that it is impossible for any one to get near these shafts except when the foremen and bosses go through, or when the shift is coming on or going off. In the district in which this mine is situated there have been a number of incendiary fires which have necessitated these extreme measures.

Each Man's Duty Specified in Case of Fire

At a fourth mine a set of rules is in force which governs the actions of practically every man employed, from the one who discovers the fire right up through the organization to the operating department. For example: A miner discovers fire. He reports to the cagers, who in turn report to the hoisting engineer. The hoisting engineer telephones central and also the power plant, which flashes a general alarm and shuts off the mechanical ventilation. Central notifies the electrical, mechanical, safety, supply, and operating departments. Having notified the hoisting engineer, the cagers proceed to close all fire doors and turn water into the compressed-air lines while on surface. They then visit the different levels to see that the doors are shut, while the men who have received the alarm are coming to the shaft stations, there to be checked off by the shift boss. By this time, the men of the operating department arrive and take charge of the situation. Aside from these definite instructions to individuals, there is a complete supply of fire-fighting equipment always on hand in the mechanical department, and oxygen helmets and pulmotor are kept in stock, ready to be transported immediately.

At another large mine, signals are given on the lights, calling the men to the shaft stations, there to await orders. Refuge chambers are provided by means of drifts in dead ends on certain levels, where men may enter, close the door and turn on the compressed air and thus remain until the rescue party calls for them, if they are unable to leave the mine.

At practically all mines there are hoses and connections at the collar of the shaft so that a stream of water may be turned into the shaft in a short time. In some places a water line is run around the collar of the shaft so as to distribute the water properly. There is a possibility, in case of a fire, of the water not reaching it immediately by this method.

Methods Used Questionable in Some Ways

Some of the features of these fire-protection systems which are in use at the present time are commendable, while others are open to criticism. Merely turning a water line into the collar may not necessarily extinguish a shaft fire, as the water may not come in direct contact with that part of the shaft which is burning. On the other hand, a series of sprays placed at regular intervals in the shaft distributes the water in such a manner that every portion of the shaft becomes soaked in a few minutes.

Automatic sprinklers, which have been used to much advantage in buildings, are not suitable for use in shafts. These sprinklers operate when the heat of the fire becomes great enough to melt a plug, the removal of which allows the water to flow. They are extremely dangerous in shafts where there are no fire doors, for if a fire breaks out in the shaft, all the sprays begin to operate at a certain temperature and are not subject to control. This changes the draft and forces the smoke and gas into the workings, thereby endangering all the men in the mine. Consequently, if sprays of this character are to be used, they should be controlled by a valve on the surface and should be connected to a separate water line installed for this purpose.

Refuge chambers have been used to advantage in coal mines in case of explosion, but their value in metal mines is questionable, as the men have to depend on the compressed air which is piped into the chamber. Should a small cave occur near or over the compressed-air line, the pipe may be damaged and the supply of air cut off. In fact, it becomes necessary at times to turn water into the compressed-air line in order to put water on the fire, which, of course, necessitates turning off the compressed air entirely.

Chemical engines have been suggested for employment at mine fires. However, their use is accompanied by serious danger, which is apparent when one considers the large volume of gas—at least 100 cu.ft.—which is released with one charge. On the surface this would be diluted without danger to any one, but underground, it is merely another menace added to that of the gas produced by the fire.

Helmet Work Requires Careful Planning

Though helmet men are relied upon entirely at some camps, their work should always be mapped out with great caution. They should be sent into smoke or gas but a short distance. Only a limited amount of work can be expected of them, as a man wearing an oxygen helmet does only about 20% of the amount of work that he would do when working in good air without the apparatus.

Various forms of fire alarms have been suggested, such as turning off the compressed air, flashing an alarm over the electric wires, etc. The disadvantages of these are that the compressed air frequently goes off during the shift, due to other causes such as minor troubles at the power plant, and that in many cases electric wires do not extend into distant workings.

Many working shafts are now being fireproofed by means of concrete or gunite. This is most effective but quite expensive and is not justified where the life of the shaft is comparatively short.

Standard Method Outlined for Protecting Shaft and Stations

All timbered shafts should have spraying systems installed. These act not only as a means of fire protection but may also be used to preserve the timber in dry shafts. Spraying systems should be placed in the shafts and shaft stations. They consist of a main water line, extending from the surface to the lowest level, with lines of spray on the dividers between the shaft compartments and above the timbers in the stations. The number of lines of sprays will be determined by the number of compartments in the shaft, a two-compartment shaft requiring only one line, and a three-compartment shaft two lines. The sprays, of the lawn-sprinkler type, should be placed about 25 ft. apart in the shaft and 10 ft. apart in the stations. Branch water lines, 1 in. in diameter, should connect the main line with the sprays. Small valves should be placed between the sprays and the main water line to permit regulation of the water at will. The system as a whole should be connected with the main fire-water line by a valve on the surface, from which it may also be controlled.

In case of fire in a shaft, should water be turned in, the smoke and gases are apt to be carried into the workings, as stated before, thus endangering the lives of the men. To avoid this contingency, wooden fire doors should be placed a reasonable distance from the stations, so that the draft can be controlled. Such doors

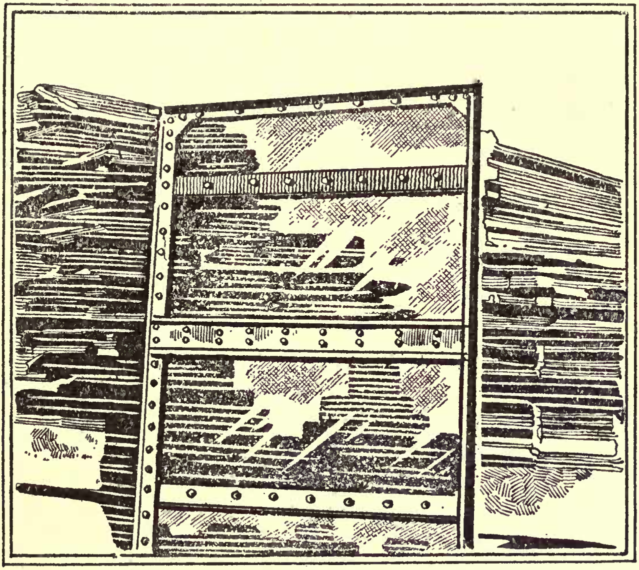


FIG. 1. TYPE OF SCREEN GATE USED IN FRONT OF IMPORTANT SHAFTS

serve to separate the shaft from the rest of the mine workings and should always be closed in the event of fire in the shaft.

PURPOSE OF FIRE DOORS TO CHECK THE DRAFT

Iron fire doors have been in use at many mines for a number of years, but the wooden door has proved equally satisfactory and much more economical. The purpose of all fire doors is primarily to check the draft and not to stop the progress of the fire. Should an iron door be subjected to intense heat it would warp and the draft pass through unchecked, thereby exposing the men to dangerous gases. Wooden doors should be

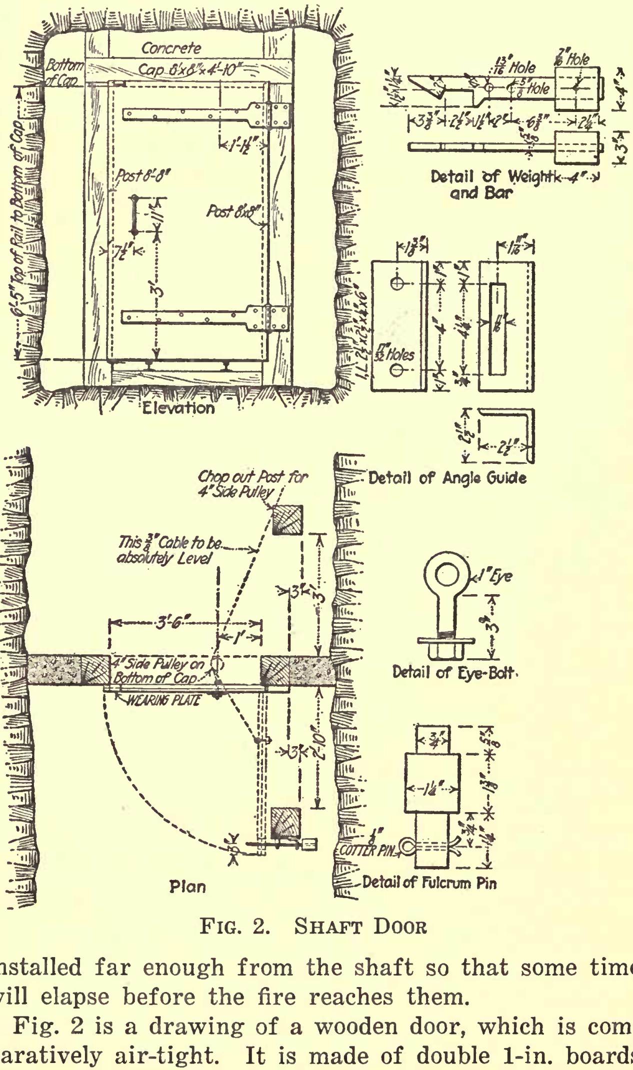


FIG. 2. SHAFT DOOR

installed far enough from the shaft so that some time will elapse before the fire reaches them.

Fig. 2 is a drawing of a wooden door, which is comparatively air-tight. It is made of double 1-in. boards with roofing paper in between, and is designed to fit against a set of timber and not into a frame. Otherwise any sag in the door or the frame or any swelling of the wood would prevent the door from closing properly. It is important that all doors should be hung in this fashion and merely overlap the timbers a distance of

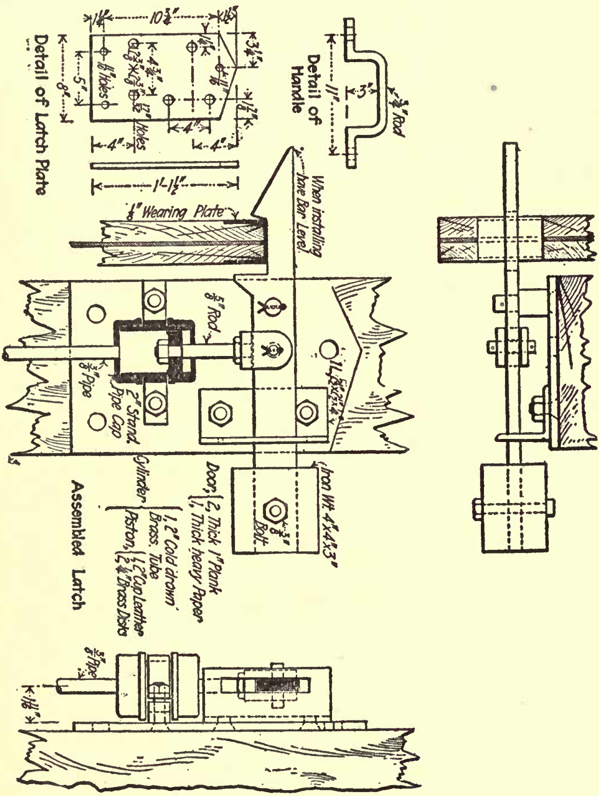


FIG. 2*a*. DETAILS OF SHAFT DOOR

about 2 in. A 2-in. strip of canvas should be nailed on the timbers to make an air-tight joint.

Around the set on the sides and the back should be built a concrete stopping 8 in. thick. In the bottom of the drift no concrete should be used, but it should be built up with timber to about 2 in. above the rail, grooves being cut for the car wheels to pass. Standard iron handles should be made and heavy strap hinges

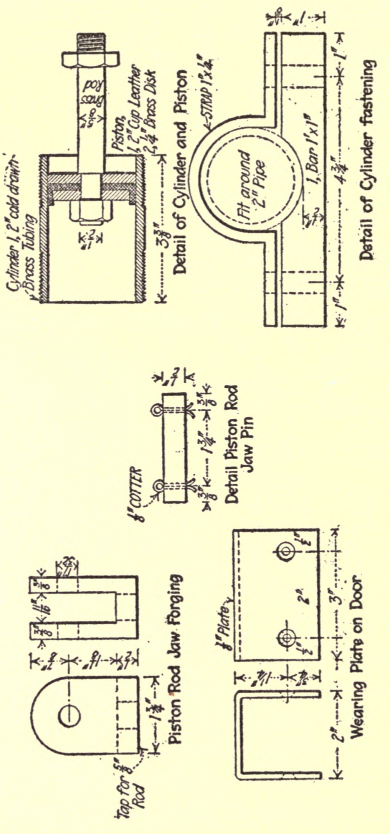


FIG. 2*b*. DETAILS OF AIR CONTROL FOR SHAFT DOOR

used; also pulleys with 15-lb. weights to pull and hold the door tightly shut when closed.

An air control, as shown in Fig. 2*b*, should accompany each door. This is a simple and inexpensive device and affords accurate control. A 1-in. air line should be put in each shaft and connections made from it to each fire door of that particular shaft. If it be desired to close the doors on each level, a valve is shut on the surface, cutting off the compressed air, and a release valve opened, which automatically closes all the doors. These valves should be placed near the collar of the shaft, so that no time may be lost when an alarm is given.

It is important to keep the automatic closing device in good repair, as otherwise, in the event of fire, it would be necessary to send a man down to make sure that all doors had shut when the release valve was opened. An electric control of the doors would answer the same purpose admirably, but would cost more. Once closed, either by air or electricity, the doors can be reopened only by hand.

Fire extinguishers should be kept in the stations for immediate use in case of an outbreak of fire in the station or adjacent heavily timbered drifts.

Fire Rules Should Be Posted Near Collar

A set of rules, similar to the following, should be posted on the surface near the valves which control the fire doors and spraying system, governing the actions of the men and the steps to be taken in case of a fire in the shaft:

First—Notify all men in the mine to go to a place of safety at once.

Second—Close the valve in the air line and open the release valve. This will close all fire doors.

Third—Open the water valve connected with all the sprays.

Mine telephones should be installed at important points, as they facilitate getting the men to a place of safety in the shortest time, though it is better to get all men out of the mine in case of a shaft fire. The prompt closing of the fire doors will prevent smoke and gas from entering the workings and allow an immediate attack to be made on the fire. The men will have sufficient time to make their exit through another outlet before the small amount of gas which may leak through the doors overtakes them.

Fighting Fires in Workings More Complicated

In the event of a fire in the mine workings, one of the most serious difficulties is that of removing all the men before the workings become filled with smoke and gas. For this reason it is necessary to provide means of giving a general alarm, so that all men underground may be warned as quickly as possible. Instructions should be given that upon the discovery of a fire the different sections of the mine should be telephoned and the alarm spread, and that the foreman and shift bosses be notified immediately. The men, upon warning, should go at once to the shaft station, where the shift bosses should check them and see that all have arrived.

As soon as the foreman is notified, he should take charge of the situation, instruct one man to telephone the mine office, have another put in the emergency call for the cager, and send others to the different working places to make sure that all the miners have been called to the shaft stations. He should then investigate the nature of the outbreak to decide how many men he will need to fight the fire and how many should be sent to the surface.

The mine office, as soon as informed, should notify all departments—supply, mechanical, electrical, pipe, safety, and operating departments. The cager should go to the level where the foreman is collecting his men and hoist them as fast as possible if it is found necessary to leave the mine. His duties should be to obey the foreman. It should also be understood in the organization that in case of fire, and until the arrival of the superintendent, the mine foreman should take charge of the situation, and, in his absence, the assistant mine foreman, and should he be away for any reason, then the senior shift boss. If it is found necessary to leave the mine, the men should follow the regular routine and report to their timekeeper, who will check up the shift and advise the foreman if any are missing.

The compressed air should not be turned off and water turned in unless it is thought advisable by the foreman or superintendent. The same rule should apply to the ventilation. No change should be made in this except in case of fire in the shaft. Great care should be exercised in mines ventilated by mechanical means. It is seldom necessary to close down the mine fans; in fact, it is usually dangerous to do so, as the men are all accustomed to the general direction of the air currents, and, if these are changed, they are likely to go into dangerous places which were perfectly safe while the fans were running.

Fire-fighting equipment should be kept on hand at all times and ready for immediate use. As soon as it arrives, an effort should be made to extinguish the fire by putting the fire district under pressure, building brattices, etc. If the fire proves too big for these emergency measures, then a definite system of attack should be worked out under the direction of some one experienced in this line of work.

Equipment Should Include Fans and Blowers

Fire-fighting equipment should consist of one or more three-foot disk fans, and several 10-in. blowers, connected to 2½-hp. motors (fan and motor mounted on one base). These are necessary for providing mechanical ventilation in fighting the fire. All fans may be mounted on trucks so that they can easily be transported to the place where they are to be used and electric connections made. A roll of canvas or roofing paper should be kept on hand for bratticing; also about 300 ft. of 10-in. ventilating pipe for the blowers; 200 ft. of hose; 100 sacks of cement and sand; about 100 ft. of metal lath, 6-ft. wide, which is to be used for bulkheads and a supply of 1-in. boards, 10-penny nails, long 10-ft. nozzles, helmets, and a pulmotor.

The storage-battery blower has not proved successful as an aid to fire fighting. In the first place, the volume of air produced by the small blowers is of little consequence when attacking a large mine fire. The storage battery with blower complete is very cumbersome, especially when it is necessary to move it from one level to another. It has been found that small electric blowers, which can be transported from level to level within a few minutes, may be attached to the wires by electricians and put in operation in far less time than the storage battery kind. Moreover they can be kept in operation continuously, whereas the life of the storage-battery blower is limited.

Mechanical Ventilation Useful in Fires

The advantages of mechanical ventilation as a means of preventing mine fires is apparent on noting that the cost of fighting fires in mines where it is employed is about 20% of that in mines using only natural ventilation, as has been proved in all the recent large mine fires in the Southwest. Furthermore, in mines where mechanical ventilation is used, a large number of smaller fires have been extinguished before they had an opportunity to develop into big fires. This would have been practically impossible in mines where the ventilation is not controlled by mechanical means.

During recent years, when exploratory work is to be done at long distances through smoke and gas, mechanical ventilation is used to clear the atmosphere as far back as the fire district. This enables the helmet crew to maintain a station in the proximity of the fire, so that attacks can be made by going only a short distance, as, for example, 50 to 75 ft., thus ensuring safety, as it is then possible for the men to come out, even though one of the sets of apparatus should get out of order. This method also permits the largest part of the work around a mine fire to be done by men without the oxygen apparatus, so that a far more rapid attack can be made. When using mechanical ventilation to fight mine fires, fewer men have been knocked out with smoke and gas than in mines having natural ventilation.

Natural Ventilation Gives Unstable Currents

Another consideration of great importance is the continuity of air currents in a certain direction when mechanically controlled, as contrasted with those in mines where no mechanical system has been installed, and where the miners are subjected to the continual change of atmospheric conditions. In all cases of natural ventilation, such changes result in reversals of air currents, depending upon the season of the year, time of day, etc.

With the mechanical system, a mine in which a fire exists may be kept in continuous operation by putting the fire district under pressure and thus obviating long delays, large expenditures and curtailment of production, frequently incurred by the use of more expensive means of extinguishing the fire.

In case of fire in the mine workings, there should be no stopping of the air circulation, save in exceptional cases, when it is absolutely certain that all the men are in a place of safety and that the fire-fighting crew will not be endangered. It is the continuous circulation which makes possible the rapid attack on a mine fire, and therefore it should not be disturbed.

Gob Fires Require Special Handling

A fire in a gob generally gives warning before it actually breaks out. Gases are given off which can be recognized as a sign of incipient or actual fire. A suspected district should be patrolled at least once each day, and if necessary, once each shift. When it appears likely that a fire may exist or may develop, the drifts and air courses should be opened to a separate exit, through which the smoke and gas may pass to the surface. Great care should be taken not to turn water into such a district intermittently. While this method has proved successful in leaching the heated ores, it has the disadvantage of generating a large amount of additional heat, which may prove dangerous to the surrounding district.

In dealing with such a problem, large volumes of air should be used continuously to cool the heated district before it actually takes fire. This is the most economical way of lowering the temperature of a sulphide fire district. If, however, the gases coming from the district indicate that fire actually exists, it is then necessary to keep a constant stream of water flowing over the hot area, while steps are being taken to mine out this material and send it to the surface. The waters naturally become charged with copper, and their acidity frequently damages the pumps and water lines as the water is pumped to the surface. In such cases, large quantities of iron and lime have been used to remove the copper from the water and neutralize the acid. However, the returns from the salvaged copper are usually far less than the damage done by such acid waters.

Doors should separate adjoining mines, so that a fire in one will do no damage in another. Old workings should be sealed off with screens instead of airtight bulkheads. This will allow free circulation and prevent rapid decay of timber, which results in caves.

In general, at least 10 ft. of ore or waste should be kept in all chutes. In case of fire from the stope above dropping into the chute, it can thus be checked before it burns out the bottom of the chute and caves in the entire drift beneath.

Arrows, marked "This Way Out," should be placed in all important drifts, pointing to another exit which is to be used in case the main shaft may not be used, owing to fire. This presupposes the existence of certain drifts and manways which are to be kept in good repair so that the men can climb to the surface in an emergency.

From time to time there should be conferences between the mine superintendent and his foremen and bosses, at which the question of fires in the different parts of the mine should be discussed, so that in case of emergency there will be no confusion, but each foreman and boss will know exactly what to do.

Section VI

Standard Equipment

THE handling of tools and supplies underground has not received the attention that the subject deserves, although it is one of the important links in the chain of standardized operations in prospecting and development. Good work is impossible unless good tools are provided and a sufficient supply is kept on hand to meet all emergencies. A miner was once heard to remark: "Give me the tools, and I will do the work." This statement followed the boss's reprimand at the end of a shift for not doing a satisfactory day's work; but the miner had been forced to spend several hours seeking an ax and pick before setting up to begin his round. The fact that a great part of the miner's time has to be spent in collecting tools and supplies is not always understood by bosses.

When hand drilling was the practice, the careful handling of the steel and supplies was simple compared to the complications that are inseparable from machine drilling. The hand miner, on receiving his hammer and several pieces of steel, is prepared to do a day's work, whereas the machine miner must assemble a far greater variety of tools and supplies before he is ready for drilling. To start without a complete outfit means stoppage of the work and a series of delays until the necessary parts are found.

Distribution of Tools and Supplies Underground

A distinct system for the distribution of tools underground is employed in almost every mine. In one case a number of locked tool boxes may be found, to which only the shift bosses and repair men have keys. The difficulty with this system is that the repair men may lose their keys or the shifters forget theirs, causing serious delays. Cupboards are used in other mines. These are always open, and anybody may help himself. As a general rule, there are seldom any tools there, as the men forget to return what they take out; and it is hardly possible, with such a lax system, to keep an accurate check on the contents of the cupboards. Another plan is to have the tool house and powder magazine in the same drift, which, of course, is extremely dangerous. In still another instance, tool houses, with all tools and supplies, arranged in their proper place, may be situated so near to the powder magazine, though in a separate drift, that the powderman can attend to both. He checks out all the tools at the beginning, and receives them at the end of the shift. This is a good system, inasmuch as an accurate record can be kept of all tools, but it is practicable only in small mines where the distances between the working faces and the tool house are short. In large mines, in which the workings are scattered and the drifts and raises a considerable distance from the central tool house, it is not practicable to return the tools at the end of the shift. An improvement over this method would be to leave the tools in the different working places in the mine, and have the tool "nippers" check them over, replacing them when necessary with others from the central tool house. When going off shift the boys should leave a report of all tools and supplies taken from the central tool house, and of the situation of the working places in the mine where they were distributed. A record should also be kept of all machines taken from the working places and sent to the repair shop.

CARE OF ROCK-DRILLING MACHINES

Marked progress has been made in drilling-machine design in the last few years, and new models are constantly put on the market. It has, therefore, been impossible to standardize on one particular machine. In some camps it was considered good business to scrap the old machines and purchase new ones at once, though other organizations continued to use their old machines and added new ones when they were brought out. This led to an accumulation of many different types. A number of good machines are now available, and it is possible to select a few which are best adapted to the kind of ground that is being worked, and to standardize on them. At several properties where many different machines were in use, a Paynter tester was installed, and the drills were tested for efficiency. It was found that many machines which apparently seemed to be working well struck a blow only one-third of their rated strength. Machines in this condition involve a constant loss, and the tester provided a rapid and satisfactory method of determining how many drills among those which had been in stock for a considerable time were fit for further use. Those found to be worn out were immediately scrapped.

REPAIRS TO ROCK DRILLS

A machine which is out of order is frequently put aside on the ground. The next miner who comes along may not know of its condition, and, quite possibly, may pick it up and put it on the bar. After he has made his complete set-up he discovers that the machine is entirely out of order. Examples of such a mistake are frequent, and time studies have shown that in one mine, within a single shift, as many as three machines have been put up on the bar, each in turn found to be in defective condition.

When the drill does not work well, the miner underground often opens the valve chest and tries to take the machine apart. Often this is done where there is a considerable amount of loose dirt and by a miner whose hands are not clean and who has no cotton waste. Many particles of dirt and rock are dropped into the mechanism, and by the time the miner thinks he is through with the repair work the machine is in a far worse condition than it was before he opened it. In all cases where there is anything seriously wrong with a machine it should be sent to the proper repair shop, which may be either underground or on the surface. Often, owing to low air pressure, the drill appears to be out of order, and the machine man is tempted to take it apart and try to find out what is the matter.

Frequently, the miner forgets to blow out the hose with compressed air before connecting the machine, and any rock and dirt accumulated there is sent directly into the machine and causes much trouble and delay. Every miner should have a standard oil can to take the place of the variety now in use, which includes tomato cans, tobacco cans, and various kinds of bottles. These receptacles usually contain dirt, which finds its way into the machine.

Sound of Machine No Indication of Work Done

Many miners believe that, when a machine is operating in a drift, they can judge it by the sound. The remark is frequently made: "Listen to the hammer of that machine. There is a good machine. You can tell by the sound that it is surely cutting the rock." In most cases judgment made on such evidence is based on error. The sound of a machine is no indication of its actual cutting power. Machines often sound as if doing excellent work when, in reality, operating at only 50% efficiency. This can be proved by the Paynter testing machine.

Sufficient rock drills should be kept in stock underground. Accidents will happen occasionally, and machines get out of order, and there should be a number on hand to provide against such an emergency. In this event any man who starts a round, even if he has serious machine trouble, will be able to finish it in the shift.

Small Machines Often Suitable

Wherever possible, the small machines should be used, except in drifting in extremely hard ground, where the larger machine still holds it own. Recent competitive tests have been made with several drifting machines weighing about 150 lb., and the results compared with those obtained from small machines, weighing about 45 lb., and the drilling speed was found to be the same in both cases. This is possible because the smaller machine puts in a smaller hole, and consequently less ground is taken out. The tests were made in fairly hard ground. In medium ground, however, more satisfactory results were obtained with the small machine than with the larger one; and this indicates a wider field for it than has been thought possible.

In some mines the small machine has already replaced the large machine in all development work, as well as in hard ground in stopes, and is giving equal if not better satisfaction. Moreover, it has the added advantage of requiring only one man, either to operate or set up, which naturally reduces the expense. Under present conditions of high cost of production and scarcity of competent mine labor the small machine should be more generally adopted, and the large machine and larger steel held merely in reserve for use in exceptional and unusual cases.

With the small machine, and correspondingly smaller-size steel, the holes drilled will naturally be much smaller than those drilled with the heavy Leyner type of machine. Consequently, in hard ground, higher-strength powders should be used. This was formerly impracticable, on acount of poor ventilation, but recently so much attention has been devoted to an improvement in the methods of maintaining healthful atmospheric conditions, that it is now possible to use the higher-strength powders in the smaller holes without detriment to the working atmosphere.

Handling Steel Underground

Before it is possible to standardize on steel, it will be necessary to standardize on machines. Usually, in most mines, four to six different kinds of steel are in use. Experiments are being conducted in one mine having an output capacity of 2000 tons a day, and an effort is being made to standardize on one kind of steel only, which is to be used for drifting machines, pluggers, and stopers. However, it has not been demonstrated that this will be practicable; but it is reasonable to believe that the entire drilling in the average mine can be done with two kinds of steel—the large, round, hollow steel ($1\frac{1}{8}$-in. diam.) for large machines working in exceptional ground, and the hollow quarter octagon ($\frac{7}{8}$-in. diam.) for the Jackhamer type and stoping machines. This is being done successfully in several mines, and when put into general use will facilitate the standardization of steel and do away with the expense of carrying in stock a number of different kinds. The inefficiency resulting and the confusion caused underground should thus be materially reduced.

Necessity for Underground Steel Racks

Another important consideration is the character of the steel and drill bit. A great deal has been written on this subject, and much has been done to improve the design. The drill bit should be made with great care, with the temper which the ground requires, and with the exact gage, cutting edge, and reaming surfaces. Four pieces of steel (the 1st, 2d, 3d and 4th) should be fastened with an iron ring into one bundle, to facilitate handling. This bundle contains all the steel required for the drilling of one hole to its proper depth, and can be used over again until the steel becomes dulled.

Another problem is to keep the steel moving. For example, after it passes through the drill-sharpening shop, it is transported to the shaft, lowered in steel cars to the various stations, and taken thence to the steel racks. Frequently, it is merely stood up on the ground, and becomes plugged before it is put in the machine. This may be avoided by the use of steel racks, where it is sorted into different lengths and kinds. These racks (see Fig. 1) should be on all levels underground, at convenient distances from working places. The steel is taken to the racks from the shaft stations on

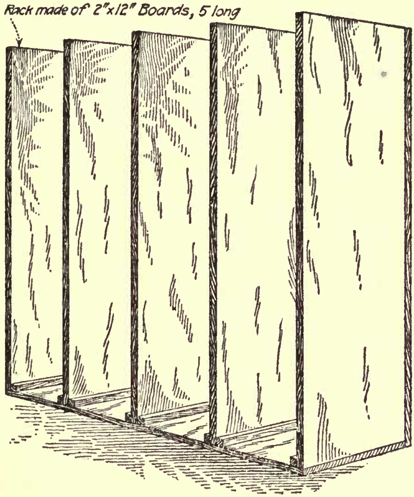


Fig. 1. Underground Steel Rack

trucks, and distributed to the different tool cars by the tool "nippers," who, in turn, take the dull steel back on small trucks to the shaft stations. Here it is put into the steel cars in which the sharp steel has been brought down, and sent to the surface. A surplus of sharp steel should always be kept in the central steel racks, so that a man who has not enough steel to finish his round can obtain more.

The central steel rack should be near the tool house and also close to the powder magazine, so that the powderman who gives out the powder, caps, and fuse can also attend to giving out the tools, supplies, and steel. He should also check all that comes out, in order that a record may be kept of the machines and other equipment.

Standard Equipment for Drifting Work

To have a complete outfit, so that the machine man will not find it necessary to seek additional tools or

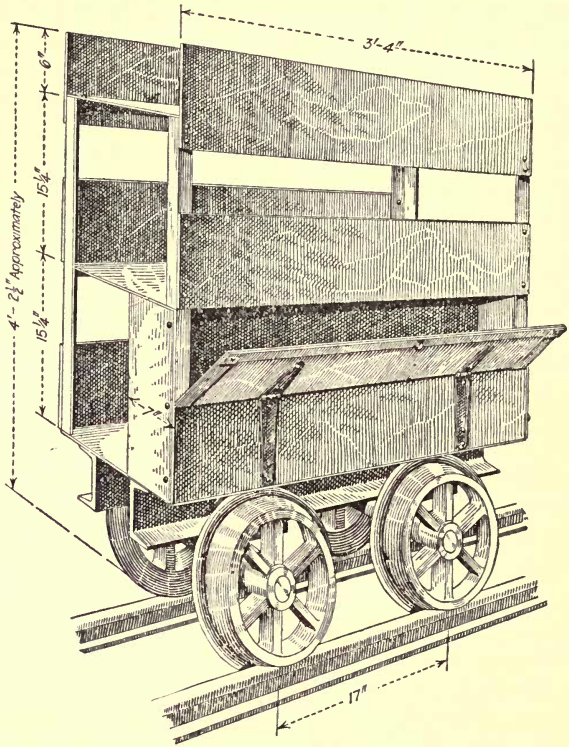


Fig. 2. Leyner Drill and Tool Car

supplies during the shift, he should be furnished with standard equipment, consisting of: 1 machine; 52 pieces of properly tempered steel; one 50-ft. air hose, and connection; one 50-ft. water hose, water valve and connection; 1 column, arm, clamp, chuck wrench, a monkey wrench, and an 18-in. Stilson wrench; 1 blow pipe and valve; 1 oil can, filled with proper machine oil; 1 ax; 1 double jack; 1 shovel; 1 jack bar; 1 light 6-ft. bar; 1 pick; 1 scraper; 2 blocks; 6 wedges; 1 foot-block; gaskets, side rods, nuts and springs; 1 powder sack; 1 cap and fuse sack; 1 tamping stick. This equipment should be sufficient to drill a standard round, and the list includes everything needed by the miner during the shift, with the exception of the powder, and is equally applicable whether large or small machines are used.

The equipment should be assembled at the tool house on the level of the mine on which the work is to be done, loaded on the tool car designed for that purpose, and sent to the working place before the miner arrives. Then, as soon as he comes on shift, he can begin setting up and drilling.

Standard Type of Tool Car

The tool car should have four compartments—the two larger compartments for the machine, steel, bar, hose, blocks, and like material, the two smaller ones for wrenches, oil can, gaskets, side rods, and smaller appliances generally. This car should be designed to hold the entire equipment in a small space, and its adoption will obviate the necessity of using several trucks or ore cars. At the end of the shift, the equipment should be loaded on the tool car, everything being put in its original place, and moved to a siding, where it should be attended to by the tool "nipper" on the next shift. He should look over the car, refill the oil can, replace dull with sharp steel, and see that everything is in first-class order. If water lines are not provided in the drift, water cars should be used. Figs. 2 and 3 are drawings of practical tool and water cars in use in several mines in the Southwest.

Standard Equipment in Raising and Stoping

A standard equipment unit for raising or stoping should consist of 1 stoper machine; 52 pieces of selected stoper steel; one 50-ft. air hose and connections; 1 oil can, filled with proper machine oil; 1 pick; 1 foot-block; 1 monkey wrench; gaskets; 1 scraper; 1 powder sack; 1 fuse sack; 1 tamping stick. If the stoper is a water machine, then 50 ft. of water hose, water

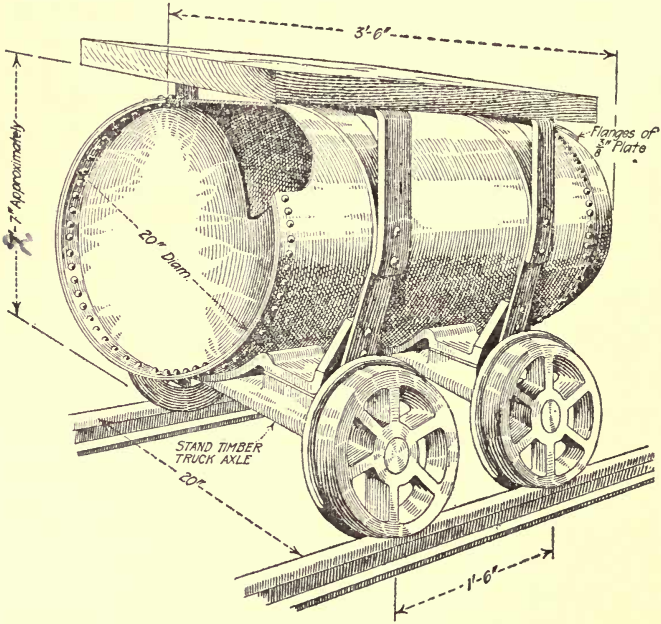


FIG. 3. LEYNER DRILL WATER CAR

Correction: Height of car is 2 ft. 7 in., instead of 7 ft. 7 in., as shown.

valve, and connection should be included. The equipment should be loaded on the tool car or small truck, and handled as in drifting.

SHOVELING

When the mucker enters the drift he should have the following equipment, which he has obtained from the tool house on the level: 1 short-handled scoop or 1 square-pointed shovel; 1 round-pointed shovel; 1 pick; 1 double jack; 1 six-ft. bar; 1 light car, obtained at the working place. Turnsheets should be laid in all drifts before blasting, so that the mucker will be more efficient in his work. Exhaustive studies have been made of mucking on the surface, and many of the principles evolved could be advantageously applied to underground work. Little attention has usually been paid to the kind of shovel which is given to the mucker, or whether its size, shape, design, or length of handle are suitable for the load it has to carry. Too much emphasis cannot be laid on this important feature, upon which depends the efficiency of the worker and the cost of the operation.

Shovels, Shoveling Machines, and Scrapers

In most drifts a short-handled, large scoop is preferable, provided turnsheets have been first laid so that the mucker can shovel from a smooth bottom. In rare cases, where sulphides are to be handled, a smaller, square-point shovel should be used, as the specific gravity of this material is high. If no turnsheets have been laid, and the mucker must shovel from a rough bottom, then a small, round-point shovel should be used. This is expensive practice, as it requires far greater exertion to shovel from a rough bottom than from a smooth surface, experiments showing that it costs approximately 40% more than if turnsheets are laid and a short-handled, square-pointed, 21-lb. shovel is used.

Shoveling machines are used in large stopes and motor drifts. Though a large amount of material per shovel can be handled and loaded in cars, serious delays are frequent, owing to breakdowns which require the services of expert mechanics in making repairs. Scrapers, when operated by small tugger hoists, are used to advantage in horizontal top-slice stopes to shovel and transport into raises the ore which has been broken in the headings driven to open up the stopes. After these headings are opened, a large number of stulls must necessarily be put up, which would interfere with the action of the scraper and prevent its use in the stopes. As much as 80 tons has frequently been handled with one of these scrapers by two men in an 8-hour shift, but such a machine can be used to advantage only in soft ground. In stopes where there is hard ground which breaks into large boulders it is not practicable unless an excessive amount of explosive is used to break the boulders, and this adds materially to the cost. The cars used should be light. Considerable effort is required to move a heavy car, and if one man must handle it alone it is impossible for him to transport much ore.

Frequent sidings and switches should be laid in long drifts to lessen the distance for hand tramming. Mule or electric haulage should be used from these sidings to transport ore or waste to its destination.

Where short trams are planned for the mucker to tram either ore or waste into raises or stopes, the bosses should always see that there is sufficient room to contain all the material which will be trammed there during the shift, so as not to cause a delay on the part of the mucker in waiting for chutes to be drawn.

Section VII

Prospecting and Development

ONE of the most important branches of mining, and one which, on account of its magnitude, the variety of its operations and amount of money involved, offers a large field for the introduction of standard methods, is that of "prospecting and development work." "Prospecting" and "exploration" are terms applied to all work directed toward the finding of ore, whereas the various headings driven through an orebody, preparatory to mining, are usually characterized as "development work."

There are two distinct classes of mines: those whose ore reserves are defined by churn drilling before production begins, and those which prospect and develop their reserves in the usual course of mining. To the first belong the large porphyries; the second takes in practically all the higher-grade mines. These so-called porphyries have the advantage of having their ore blocked out for many years ahead, so that an accurate estimate of the tonnage can be made and the size of their reserves determined in advance, whereas the higher-grade mines have a much smaller ore reserve. In this latter division are mines with monthly productions ranging from 2,000,000 to 7,000,000 lb. of copper, which have been steady producers for many years, but have rarely had more than a few years' ore in sight at any one time. During 1916, approximately 70% of all the copper produced in the United States came from mines of this character, the remaining 30% being shipped from properties which had proved orebodies, previously explored by means of churn drilling.

One of the principal reasons why the higher-grade mines cannot follow the methods pursued by the porphyries, and prospect and develop large ore reserves at the outset, is that the nature of the ground is such that it will not stay open for any length of time without an excessive cost for repairs. Therefore, to keep pace with the continual depletion, and to maintain normal ore reserves, it is essential that their prospecting and exploration work be carried on simultaneously with the stoping.

The life of mines is a subject of vital importance to everyone connected with mining, and an interesting question arises as to what is the correct amount of prospecting that should be done. If the work is carried on too extensively it entails an excessive cost for repairs. On the other hand, if these operations are long postponed, the life of the mine is materially shortened. A precedent established by a number of companies is "to do sufficient prospecting to find one ton of ore for every ton extracted." To follow out this plan, prospecting and exploration work must be prosecuted continuously. Intensive prospecting should be carried on in the neighborhood of known orebodies, in order to make these ore-bearing areas as productive as possible. Favorable indications, faults, and small veins leading into the country rock should also be explored by means of intermediate drifts at the time of discovery, instead of postponing the work until some future date, when the records may have been lost, the incidents forgotten, and the cost of the work greatly increased, because of the necessity of reopening old workings.

In every case a golden mean should be sought, and a fixed ratio established between the amount of ore extracted and the amount of prospecting to be done. This fixed ratio should allow, in all instances, for sufficient ore to be developed in stopes to do selective mining, keep up the normal production, and maintain the required ore reserve. It should also provide for enough openings, carried just ahead of the average workings, to benefit the ventilation materially.

The exceptional conditions existing since 1914, attributable in the first instance to the outbreak of the war, secondly to labor difficulties, and finally to a decided shortage of labor, have caused operators to postpone, in a large measure, necessary prospecting work in a praiseworthy endeavor to maintain maximum production, and as a consequence the ore reserves have become seriously depleted. Prospecting is an expensive and hazardous investment, both for the mine owner and the prospector. Though an occasional heading may penetrate an orebody, exposing enough ore to yield enormous returns on a comparatively small investment, thousands of feet of prospecting are done annually with practically negative results. One of the problems at present confronting the mining industry is how to make up for the large amount of prospecting which has necessarily had to be postponed during the last four years, so that normal ore reserves may be maintained in the future. To prosecute this work at a minimum cost it will be necessary to standardize all operations connected with it. At present, working forces are constantly being changed, vacancies generally being filled by men who require a considerable amount of training, as well as frequent supervision, before a fair day's work can be expected.

The employment of competent instructors to train the new men in the standard methods approved by the operating company will do much to alleviate the conditions created by this large labor turnover. Men who are best adapted for certain classes of work should be selected, complete equipment provided, and all unnecessary loss of time eliminated. This will make possible a larger amount of prospecting for the same expenditure, lower-grade material will then become of commercial value, and thus add to the reserves of the mine, and, ultimately, the cost per pound of copper will be lowered.

The previous articles in this series describe the standardized methods which comprise the elements of prospecting and development work. Examples have been given of what may be gained by the use of instruction in training inexperienced men how to mine. The following illustrations will show what may be done by taking a number of trained and skilled miners and giving them further instructions as to the best methods of doing certain work, thereby increasing their value to the company.

Concreting a Five-Compartment Mine Shaft

In preparing the work of concreting a shaft the plans for clearing the old timbers, for moving forms and pouring the concrete were carefully made beforehand. The crew, working under the direction of a man thoroughly familiar with standard methods, was taught what was expected, and soon reduced the work to regular routine. Twelve men were employed, including the pipeman and foreman—two men to a compartment. They held the places originally assigned to them throughout the entire operations, and by constant application to the same task day after day became expert.

The estimated time for pouring five feet of concrete was ten hours. This was reduced to eight in a short time, and finally the work was done so expeditiously that it became a question of how to utilize the remainder of the shift. Before long it became possible frequently to concrete two sections in eight hours, and on one occasion three sections were put in within that time. Accurate records were kept, and it was found that the average time required to complete the work of putting in a 5-ft. section of concrete was 6 hr. 14 min., which represented a reduction in the total working time (eight hours) of 22.1%. During one month a record was made of 4 hr. 31 min., or 50.6% of an eight-hour shift.

These remarkable results were achieved by coöperation on the part of the men, and because they were trained in the beginning to plan ahead for their work and take all necessary tools and supplies with them when going on shift. Illustrations of this kind demonstrate the practicability of introducing standardized methods in other classes of mining, and indicate the great advantages to be gained thereby.

Cost of Prospecting and Development Work

Prospecting and development work consist principally in sinking, drifting, and raising. Sinking is the most expensive and is therefore avoided wherever possible, deep shafts being put through in many cases by means of raises instead of by the more expensive process of sinking. Drifts are driven for horizontal prospecting, haulage, ventilation, and similar operations; raises, although used for like purposes, are vertical or inclined.

The amount of drifting and raising, or "prospecting and development work," as it is generally called, varies according to the stage of development the property has reached. In some instances as much as 30% of the total cost of mining is expended in prospect and development work, though in others it may be as low as 10%. In prospects which have not reached a producing stage, practically the whole expenditure goes into this class of work, and in the average producing mine it amounts to about 25% of the total mining cost. In extensive veins, where little prospecting is required, nearly all the headings are driven in ore, but in the majority of cases they are in waste, which is usually harder and therefore more expensive than mining in ore.

Some of the most important items in the cost of prospecting and development work are labor, timber, and explosives. Tables I and II, showing the amount of footage made during one month, give the proportionate expenditure for these items at one of the representative mines in Arizona.

TABLE I. DETAILED COSTS OF SEVEN DRIFTS, UNDER VARYING CONDITIONS

	Cost per Foot				Ft. per Shift
Example	Labor	Timber	Powder	Total	(*a*)
1	$4.47	$0.31	$1.81	$6.59	1.33
2	5.84	.50	1.45	7.79	1.05
3	4.89	.33	1.84	7.06	1.21
4	4.43	.28	2.50	7.21	1.38
5	5.80	.75	2.04	8.59	1.02
6	5.43	.54	1.96	7.93	1.08
7	4.14	.11	2.00	6.25	1.47
Average,	$5.00	$0.40	$1.94	$7.34	1.22

Of the total expenditures, the labor cost was 68.12% of the total, timber amounted to 5.45, and powder to 26.43 per cent.

TABLE II. DETAILED COSTS OF SEVEN RAISES UNDER VARYING CONDITIONS

	Cost per Foot				Ft. per Shift
Example	Labor	Timber	Powder	Total	(*a*)
1	$5.23	$1.02	$1.66	$7.91	1.12
2	5.96	3.20	.68	9.84	1.02
3	5.10	1.88	1.49	8.47	1.16
4	7.25	2.46	1.37	11.08	.82
5	8.24	1.96	1.79	11.99	.72
6	6.90	2.07	1.66	10.63	.80
7	4.18	1.55	.98	6.71	1.42
Average,	$6.12	$2.02	$1.37	$9.51	0.99

(*a*) The footage per man shift denotes the entire work which has been done at the face, such as drilling, mucking, laying track, and other labor of the sort.

The standard custom in many mining districts dictates that the drilling of one round per shift (regardless of the amount of rock broken per round) shall constitute a day's work, even though it were possible for the miner to drill and blast two rounds in adjacent faces. Demands have frequently been made for two men on a machine, which if acceded to, would further increase the already high costs. When a machine weighing 150 lb. or more is used it is often considered best to put two men on it, but this would appear ridiculous with small machines, averaging 40 to 50 lb. In the majority of cases these small machines do the work equally well.

Necessity of Increasing Footage To Lower Costs

To reduce the cost of prospecting and development it is necessary to increase the footage per man shift, just as in stoping the tonnage per man shift must be increased if the cost per ton is to be lowered. In other words, this means the drilling of deeper rounds, and the blasting and shoveling of more rock, in the same time and with practically the same number of men as were needed for the shorter round. To accomplish this it is absolutely necessary to have a complete equipment on hand for the driller, a regular program for the handling of the work, a type of round that will prove most effective, and a clean place to set up, which has been previously cleared by the mucker. In addition to these essential requisites, many other factors contribute to standardization underground, such as transportation, explosives, compressed air, and ventilation. These should all be given careful attention.

One of the most important considerations is the type of round to be drilled. The great problem is to "pull" as much ground as possible, consistent with the size and shape of the working face. The blasting of deeper rounds and the doing of more efficient work do not involve greater effort on the part of the miner than his usual day's work, in which a large part of his time is spent seeking tools and supplies, and only a small part in drilling and blasting. It does mean, however, the elimination of waste effort and the concentration of his energy along the most productive lines.

Stages in Drilling a Round of Holes and Shoveling

In general, the stages in drilling a round of holes, as practiced in many mines, are as follows: The foreman or shift boss comes into the face of a drift, raise or winze, and, after taking in the situation hastily, usually remarks to the miner: "Set up and drill a round of holes." He rarely tells him where to find the complete equipment. He may mention the place where a machine may be had, but never gives all the informaton necessary to drill the round. Consequently, the miner gets to work, and after finding the machine and column, brings both and makes the "set-up." Then he begins to search for the remainder of the equipment which was used by the preceding shift. He finds most of it in a reasonable time, but some things are generally missing —a few necessary wedges, a hose, wrench, wooden block, or some other minor part of the outfit.

The steel must next be obtained. In some mines racks are placed conveniently, but in others it is necessary to go a long distance to the shaft stations to get the steel. In a mine where a number of different kinds of machines are used, the miner often makes a mistake and brings the wrong size, which necessitates his returning for steel which will fit his machine. He then connects the hose and water lines and is ready to start drilling after one-quarter to one-third of the shift has been expended in preparations. After drilling for a few minutes, he finds it necessary to get oil for the machine. As no special oil cans are available, a bottle or ordinary tin can is used. Often the miner mixes car oil with machine oil so that the machine will not require frequent oiling. He next pours the oil, with the grit and dirt which has dropped into it, into the hose. Apart from the injury arising from the black oil and dirt entering the machine, the oil soon attacks the rubber in the hose, and small pieces break off from time to time and clog the air passages at the valve. This soon results in machine trouble.

Normal Procedure Needs Standardization

The type of round is of next importance. In approximately 90% of the rounds drilled in metal mines, the cut is put in the bottom of the drift. With the exception of the lower corners, this is the most difficult place in which the cut can possibly be put. The powder has no opportunity to break a deep round, on account of the unfavorable placing of the cut.

When the round is drilled the miner fills some paper bags with gritty material, or gets some clay to be used as stemming. He is now ready to go for his powder and load the holes. By this time the shift is so far gone that he usually finds only five or ten minutes left before tally. He hurries to get the powder into the holes, in almost any fashion, cramps and doubles the fuse, hastily forces in some stemming, spits the fuse, calls "Fire," and leaves the face. He then counts the shots and chalks up the number of missed holes.

The entire shift, normally for the purpose of placing and loading the holes in such a manner that the maximum amount of ground will be broken, may be rendered ineffective by hasty loading and firing; and this most particular stage of the operations is nearly always the most carelessly attended to and frequently results in missed holes and a short round, which means higher costs, to say nothing of increased danger to the men.

Drilling is usually done on one shift and shoveling on the next. After the drift has progressed far enough, track is laid, the ditch cut, and, if necessary, the drift is timbered. As a preparatory to shoveling, the turn sheets are frequently forgotten, and the rock is blasted direct on the ground. This makes it difficult to shovel from the rough bottom, causes delays, and, as a consequence, generally means that the entire round is not all removed by the end of the shift, leaving some near the face. When the machine men arrive, they will be delayed, and it will be necessary for them to shovel back from the face on account of their not having a clean set-up. If the turn sheets have been forgotten, the mucker may not have the proper kind of shovel, and so be handicapped in his work.

The Value of Time Studies

The following time studies are examples from a number made to obtain an accurate record of the distribution of the miners' time and to ascertain the proportion of the shift spent in actual drilling.

TIME STUDY—DRILLING HOLES 5 FT. DEEP IN HARD PORPHYRY

Distribution of Driller's Time	Minutes	Per Cent
Walking to working place	5	1.1
Hunting blocks and putting up bar	50	10.4
Putting up clamp and machine	11	2.3
Building staging	3	0.6
Connecting hose	9	1.9
Adjusting clamp and arm of machine	17	3.5
Machine out of order, changing, and procuring new machine	118	24.6
Drilling	103½	21.6
Changing steel	36½	7.6
Oiling	7	1.5
Picking ground	1	0.2
Cleaning plugged steel	2	0.4
Talking	4	0.8
Lunch	30	6.3
Drawing out steel	2½	0.5
Moving machine for new holes	56½	11.8
Looking for tools	1	0.2
Tearing down machine and column	3	0.6
Cleaning out drift	2	0.4
Blowing out holes	4	0.8
Loading	11	2.3
Cutting fuses and spitting	3	0.6
Total	480	10000

TIME STUDIES ON DIFFERENT GROUND

	A		B		C		D	
	Min.	Per Cent.	Min.	Per Cent.	Min.	Per Cent.	Min.	Per Cent.
Drilling	102.8	21.4	88.3	18.4	99.3	20.7	64.5	13.4
Loading	7.9	1.6	20.5	4.0	11.4	2.3	17.8	3.7
Cutting fuse and spitting	6.4	1.3	2.5	0.5	4.2	0.9	8.1	1.7
Setting up, oiling, hunting tools, changing position, lunch, etc.	362.9	75.7	368.7	77.1	365.1	76.1	389.6	81.2
Total	480.0	100.0	480.0	100.0	480.0	100.0	480.0	100.0

Note—*A* was drilled in very hard ground, consisting mostly of silica and pyrite; *B* in medium hard ground, principally limestone; *C* in oxidized limestone, and *D* in hard silicified limestone.

After averaging the figures recorded, it was found that only about 20% of the miner's time was spent in actual drilling, 3% in blasting, and the remaining 77% in searching for tools and supplies, or, in other words, "preparing and quitting."

Standardization of Operations

The studies show that by far the larger part of the miner's time is not spent in productive labor, even though his efforts are equivalent to the energy expended in a good day's work. The aim of standardization of drilling operations is to eliminate waste efforts so far as possible, and to make a large proportion of this 77% of the miner's time as productive as that spent in actual drilling.

When a drift is to be driven, the shift boss should look over and carefully examine the face during the preceding day. He should then instruct his tool "nipper" to assemble the entire equipment on the car designed for that purpose and take it to the working place before the miner comes on shift. He should also see that turn sheets are laid at the face. Then, when the miner arrives he finds everything ready. All that is necessary is to set up his machine, make air and water connections, and begin drilling.

By this time the shift boss makes his visit and inquires regarding the number of holes and type of round to be drilled. If the miner has previously received instruction in drilling other drifts in this particular mine, he will be able to satisfy the boss as to the kind of round he is preparing to drill; but if he is not familiar with the type which has become standard, the shift boss sends the drill instructor to him, who helps him in drilling a standard round. This should be the same under all circumstances, with the exception that in soft ground some of the holes around the edges of the drift are omitted, whereas in hard ground the number is increased. If a ditch is necessary, one of the lifters should be kept down. Great care should be exercised in having the drift kept on lines, and a uniform grade should be maintained wherever possible. It is also important that the air pressure be kept up, in order that the machines may do effective work.

If, in the course of drilling, the machine should get out of order, or the supply of steel run low, the miner may obtain a new machine and a fresh supply of steel from the tool house on the same level, where a surplus should always be on hand, so that he may not be delayed longer than is absolutely necessary. The old machine should be taken back to the tool house and checked in before the new machine is taken out. This provides for a perpetual inventory of all such equipment. The man in charge of the tool house, who is also the powder man, sends the machine to the repair shop, either on surface or underground, as the case may be.

All machines require oiling from time to time during the shift, and a can filled with proper machine oil should be included in the equipment on the tool car. The injurious effects of constant oiling through the air hose should be explained to the miner, and he should be instructed to pour the oil into the receptacles designed for that purpose.

Having drilled the round, the miner disconnects the air and water lines, tears down the machine, loads the outfit on the tool car and pushes it back into a siding, where it should remain if he is to drill in the same face the next day. On the following shift, the contents of the car should be checked over by the tool "nipper," who exchanges dull steel for sharp, refills the oil can, looks over the equipment and sees that everything is complete. The ventilating pipe near the face should next be removed, and the miner should see that sufficient turn sheets have been properly laid.

The Use of Explosives

The miner then clears the holes with his blow pipe, takes his powder and fuse sacks, and goes to the powder magazine, where he is supplied with the number of sticks of powder and capped fuses for which the order he has previously obtained from the shift boss calls. The powder man also gives him a supply of stemming to be used in tamping the holes. He places all these things in the sacks provided for the purpose, and then returns to the face and starts loading, being careful to use a wooden tamping stick, and to slit the paper covers on the sticks of powder (except in the case of wet holes), so that in forcing it in he will eliminate all air spaces. Having placed the powder and primer in the holes, he fills the remainder of the space with stemming to within about 6 in. of the collar, and thoroughly tamps it, taking care, however, not to damage the fuse. When ready to spit the fuse, he calls another miner to his assistance and lights the fuses, igniting them *in the order in which they should be fired,* which is usually the cuts first, then the side holes, back holes, and, finally, the lifters. Having done this, he leaves the face and waits at a safe distance to count the shots, seeing that no one enters the working place. The number of missed holes is then chalked on the blackboards placed for that purpose for the information of the next shift.

It usually takes the miner the entire shift to drill, load, and fire a 6- or 7-ft. round in a drift 5½ ft. wide by 8 ft. high, in average ground. With the use of the standard round, described in a previous article, this depth of ground has been blasted consistently for periods of 15 consecutive days. In smaller drifts, such as 4 x 6 ft., it is not practicable to use as deep rounds as in the large drifts, and consequently it will not take the miner a full shift to drill a small round under average conditions. Consequently, wherever possible, two working faces, near each other, should be chosen. The miner in this case, having drilled a round in one face, can tear down and set up in another; and it would be entirely possible for him to drill, if not two whole rounds, at least a round and a half. In this event he would, of course, leave the loading and firing of the first round until near the end of the shift.

Clearing the Face and Timbering

The mucker, when coming on shift, should get his complete equipment from the tool house on the level where he is to work. After completing his shift, if he is to continue working in this particular place, this equipment should be left in the drift until he comes on shift again. When the tool "nipper" makes his rounds, he should look over the mucker's outfit at the time he inspects the miner's tool car, and replace the dull picks with sharp ones and make other necessary adjustments. It is the mucker's duty before going off shift to see that the turn sheets are laid near the face. His work should be planned beforehand by the shift boss, who arranges for cars, the transportation and destination of the waste, and does everything possible to facilitate the work, so that when the driller comes on shift the next morning he has a clean place in which to set up and drill.

Mine cars should be light and easily handled, and the track carried as near the face as possible in order to avoid unnecessary shoveling. Tracks, ties and rails should be standardized as far as practicable.

If the drift requires timbering, it should not be arched; but, generally, three back holes are needed to square it up so that timbers can be put in without extra plugging. The timber man as a rule is not put in the drift until the face has progressed 30 or 40 ft., but sometimes it is necessary that the timber be kept up close to the face. In general, the timber man should get his timbers at the timber station on the level and take them to the drift in question. He usually has a helper to assist him in setting them up; and, as they are all of standard size for this character of drift, they require no cutting underground.

Details of Raise Drilling

The operations connected with the drilling of raises may be standardized along lines similar to those described in driving drifts. The miner should find his equipment waiting for him; and, soon after taking the machine and necessary parts up the raise, should be ready to begin work. The shift boss should outline the work and see that the driller is prepared to put in the standard round for raises. If necessary, the drill instructor should be sent to his assistance. When rounds have been drilled, loaded, and fired, and the rock has been drawn down the raise far enough to be out of the way, the back of the raise being about 12 ft. above the floor, it is necessary to put in a set of timbers. In timbering, the principle of putting in standard sets should be followed, carrying up a standard raise with chute, manway, and timber compartment as far as practicable.

These standardized operations apply equally well to stoping, inasmuch as stoping operations are usually, in the broad sense of the word, a combination of both drifting and raising, followed by timbering, with or without waste filling.

Provision should be made for good ventilation in all drifts, raises and stopes; and, where necessary, blowers with ventilating pipe should be installed to keep a supply of fresh air at the working face.

The night-shift bosses should come early enough to consult with those on the day shift, so that they may plan the work intelligently before the men arrive; and when going off shift should leave a complete record of what has been done during the night, in order that the day bosses, when they come on shift, may continue the work without delay.

The Importance of Coöperative Effort

A continuous repetition of the above operations forms the basis of prospect and development work; but, that it may proceed smoothly and without serious interruption, many other matters should receive consideration. The personal equation is one which should not be overlooked. The attitude of the shift bosses and foremen should be such that they can maintain discipline, but at the same time have the full coöperation of the men. It is impossible to produce the best results unless harmonious relations exist.

The shift boss should make a study of each man to learn the particular class of work for which he is best adapted. One man may be especially fitted for raising; another may do better at drifting, timbering, or some other detail in mining. It is sometimes necessary to change a new man around until he has been finally placed in the right job; but frequently mistakes are committed by bosses who make a practice of changing men around constantly, thereby preventing their making the showing possible were they permitted to become thoroughly familiar with one particular working place.

THE LABOR TURNOVER PROBLEM

One of the economic wastes in mining is in hiring and discharging men—a problem which has not, as yet, been satisfactorily solved. An endeavor is being made at several camps to eliminate this expense by having a central employment office. In case a man does not make good in the division in which he is first placed, he is sent back to the employment office, where he obtains a transfer and is tried out under another foreman. This practice is continued until he either finds the work for which he is suited or is discharged as incompetent to hold a job. In the majority of camps, however, though the hiring is done by the central employment office, the discharging is left entirely to the individual judgment of the bosses. With this system the bosses should, and in many cases do, receive specific instructions to discharge a man only for absolute inefficiency or for conduct contrary to company rules.

Experiments in various forms have been tried out in order to provide an incentive for additional footage over and above that made on day's pay by the average miner. One plan was the contract system, whereby a man was paid so much per foot, regardless of the total footage. Another was the bonus, which guaranteed a day's pay to every man, and at the same time compensated him for any additional footage made over and above the average.

TIME STUDIES LEAD TO MUTUALLY ADVANTAGEOUS RESULTS

To arrive at something which might be considered a basis for an equitable bonus system, time studies were made in drilling the standard round, to determine what would constitute a fair day's work. By this is meant not the maximum amount of work produced by the exceptional driller, but that which can be produced by the average man using standard methods.

The purpose of time studies is to furnish the necessary information upon which a day's work may be planned and an efficient system built up, and it is not intended to speed up the men or to induce them to work any harder. As may be seen from the few time studies given in this paper, the miner who puts in a round of holes by drilling 20% of the time, and spends the remainder in obtaining tools and supplies, would not work any harder if he should put in 40% of the time drilling, complete two rounds, and have all equipment and accessories brought to him.

In the minds of the men, unfortunately, the idea of time studies is so closely associated with "speeding up the work" that they are inclined to look upon them with suspicion, and much good which might be attained is therefore lost. This prejudice on the part of the miners to stop-watches and time studies has some foundation, because many of those who have made time studies have been novices at the work themselves, and the bosses, not understandng the principle underlying these studies, proceeded to order the men around and speed them up. This has greatly retarded the work which might have been accomplished by these methods.

One of the principles adopted by the National Industrial Conference Board for the period of the war was that "maximum production should be maintained, and anything which interferes with it or tends artificially to increase the cost of production is discouraged."

This is well stated. Only by the use of time studies and cost sheets is it possible to arrive at the various weaknesses in underground mining systems. Until these weaknesses have been discovered and eliminated, it is impossible to operate with the highest degree of efficiency, which means maximum production; and until definite figures for a fair day's work have been ascertained, no satisfactory bonus system can be evolved.

After the deficiencies in the different underground systems have been fully brought to light, and a definite program has been outlined for the miner, it will be far better for him personally, as well as for the company, to make a good showing; for in this way the cost of mining will be lowered, more low-grade ore will be made commercial, and the life of the mines thereby increased. The company will be in a position to pay a substantial bonus to the man who has gone through a course to make his average day's work an achievement in which every move has been made to count.

INDEX

VI

VII


10