TIMBERING PRACTICE IN THE MICHIGAN IRON MINES

BY ROLAND D. PARKS, HOUGHTON, MICH.*

Supports are a vital part of any underground mining operation. Some form of support must be provided for the maintenance of every subterranean opening, whether it be by the natural strength of the rock itself or by artificial means. In the history of mining there was an era when valuable minerals were left untouched in the ground to provide the support necessary for the mining of the remainder, but such is not the case at present. Today, if it is economical to provide an artificial support to remove values from the ground, such support is installed. It is the object of this paper to give in detail all of the timbering practices, both common and uncommon, which are used in the iron mines of Michigan.

*Assistant Professor of Mining Engineering, Michigan College of Mining and Technology.

MATERIAL.

White pine is undoubtedly the best variety of wood for underground use because of its relatively light weight and high strength. These properties of pine are attributable to the structural nature of the wood; it has long fibers which increase its strength and reduce its weight. Pine, also, is able to withstand moisture to a better degree than most other woods and is valuable underground for this reason. At present, there is little or no white pine available in the Michigan district. It was all cut years ago. To import this variety of wood for mine purposes is now too expensive and so the mines must be content with cheaper woods—which are, of course, of a poorer grade.

Hemlock, birch, maple, tamarack, and cedar are the principal woods now in use in the Michigan mines. These are given in the order of quantities of each variety used.

Tamarack is considered the best available variety of wood at present. It is comparable to western fir in its strength, life and the ease with which it may be handled and framed. It has a twist to its grain which gives the fibers a greater tenacity and tends to prevent splitting lengthwise. Nearly all of the mining men interviewed expressed a preference for tamarack for use underground.

Hemlock, although not really a preferred wood for mine use, is generally accepted and probably holds second place in the order of amounts used. It is cheap, easily obtained, and satisfactory for use in fairly dry places, though not so good in damp air or in spots where water is dropping. Being a soft wood it is easily framed.

Although yellow birch is not as strong as some woods and is subject to dry-rot, it is acceptable, since it is easily obtained, and makes a good timber, especially in wet places. The white variety is generally disliked. Most of
the timber specifications definitely state that white birch will not be accepted.

Lagging is generally cedar, tamarack, or spruce and is used in round or split form.

Round timber is used everywhere throughout the several ranges for mining purposes. Specifications always call for properly seasoned wood, but little attempt is made to further improve its quality. Local contractors cut and furnish the timber supply.

**Life of Timber.**

In its usages underground timber is subjected to conditions never met with on surface. Air is limited in quantity and often liable to be stagnant and to contain a low oxygen content. What air is available is seldom of the proper moisture content. It is either too dry or too damp. Light is practically nil, especially sunlight, which is so vital to plant life. The timber is subjected to pressure of a continuous and usually cumulative nature. Each of these circumstances tends to shorten the life of the timber; and yet under any given underground conditions the various classes of woods act relatively the same as they do on surface. The short-fibered varieties do not withstand excessive moisture as well as the long-fibered varieties, and vice versa. The long-fibered woods are more suitable for withstanding pressure because they are less liable to lengthwise splitting and have a greater tenacity between fibers. They are also able to yield more than the short-fibered woods and are better on that account. In the majority of cases, probably 99 per cent, the life of any wood in underground usage is a mere fraction of its life in structures on the surface. For these reasons considerable effort is being expended at every mine to lengthen the life of timber underground. This may be done in a number of ways—by more and better air, by better choice of varieties of wood for particular conditions, by treatment, and by the use of substitutes where practicable.

The rapid progress which has been made in the last ten years in methods of mining, in the use of more and better handling-equipment, in the reduction of underground forces, has resulted in much better air conditions. The air is cooler and less contaminated. Blowers and fans are in common use, so that one seldom finds in any mine a place that has not an abundance of clean air.

Many underground captains and timber foremen specifically instruct their crews to use hardwoods for damp places and softwoods for dry places in timbering. Such care is certain to result in a longer life for the timber and in a reduction in costs. For example, the life of a birch timber will be doubled or tripled if it is put in a wet place instead of a very dry one. Hemlock, on the oilier hand, will rot quickly in excessive moisture and should be placed in a dry spot. Tamarack is excellent in wet ground, but it too (in spite of the fact that it is a softwood) is much shorter-lived in dry spots. As an example of this quality, on a station plat of one of the Gogebic range mines tamarack planking is in use as lagging above the steel sets. There is no pressure and no water, and the air is good. The planking is merely a safety precaution. And yet, in six years these planks dry-rotted to a complete punk and had to be replaced. It would have been better to use hemlock, a much cheaper wood, in this place.

Treatment with preservatives has long been used to increase the life of woods. Either creosote or zinc chloride will lengthen the life of a piece of timber provided that the impregnation is properly done. Each of these preservatives has its faults, however. Creosote increases the fire hazard, which at best is ever present, causes excessive wear and tear of clothes of the men who handle the timber, and emits offensive odors—which are accentuated in the limited underground air spaces. Zinc chloride must be thoroughly impregnated (preferably by a pressure process) in order to lengthen the life of a wood materially and will wash off readily even when the impregnation has been carried out well. Zinc chloride is therefore of small value for certain types of woods which resist deep impregnation, nor is it of much value to treat timber by this process and then install it in a wet mine. Again, in the case of either of these preservatives the preservation problem is entirely an economic one. Will it pay to treat timber and then to place it in a mine where all the conditions are adverse to life?

Treatment by zinc chloride is being practiced at present to a considerable extent on the Marquette range. It has been found that it does pay to treat main drift timber for dry or moderately dry mines but that it does not pay to attempt to treat sub-level timber, slice timber, or timber for wet places by this process. Timber treated with creosote has been satisfactorily used in wet shafts on the Menominee range.

The zinc chloride process in use is the non-pressure or open tank method by hot and cold solutions. A description of the equipment and process is as follows: The tank used is of concrete: has an overall length of 45 feet, an inside depth of 5 feet, a top width inside of 14 feet and a bottom width of about 5 feet, and is divided by a central cross partition into two compartments each 21 feet long. Each of the compartments is thus a tank by itself and is individually piped for solution, steam and drain. A cover fits over the entire installation. The capacity of each tank is 30 logs. The process consists of an 8 hour hot bath and a 4 hour cold bath for each batch of logs. The solution is 4½ per cent ZnCl₂ with the hot temperature 170 deg. Fahr. and the cold at 60 deg. Fahr. The maximum penetration takes place during the hot immersion; hence this bath is of longer duration than the cold.

The logs to be treated are seasoned for one year, then peeled and framed before immersion. The spots on the posts and caps against which the ends of the sprags will be placed are squared off. The logs are then placed in the tank and chained down. One tank is hot while the other is cold, the solutions are changed rather than the
logs. In this way each tank will take care of two batches each 24 hours. Solutions are kept in large storage tanks. Since this treated timber is used only in main drifts no great quantity of it is required, and the treatment process need be run only as occasion demands.

In order to determine whether or not the process is economically valuable each piece of timber is dated when installed underground and the elapse is noted on the office records. When replacement of this piece is necessary the record shows its life. It has been shown that the life of treated main-drift timber is more than 4 years and will probably increase, for the process has been in use only 5 years and some of the original pieces are still in place. The life of untreated timber under these conditions is about 12 months. Since the cost of treated timber is almost exactly twice as much per lineal foot as that of untreated timber the process shows a profit when the life is more than doubled. This process is applied to about 80 per cent of the main-drift timber used by this company. Lagging is not treated.

The average penetration by this open-tank process is ¾-inch, with an absorption of slightly less than ½ lb. ZnCl₂ per cubic foot. Penetration and absorption depend to a great extent upon the condition of the timber. If the timber is properly seasoned to remove the moisture, complete penetration through the sapwood will result. Hemlock and tamarack are unsuitable for this type of treatment because they are all heartwood. Maple and birch have more sapwood; the results obtained with these woods are as previously mentioned. The use of substitutes as a means of reducing timber costs will be discussed at greater length later on.

**TIMBER FRAMING.**

At practically all of the mines in the Michigan district framing is done on the surface, although in one or two mines the framing is done underground. Since all timber joints are more or less standardized and are usually standard for the ordinary cases in each mine, it is easier to do this type of work on the surface. Not only are better results obtained, but the space in which the timber can be worked upon is not limited, as it is underground. For special installations it is very often better to frame the timbers underground, since the measurements can be made and applied to the timbers without delay.

At most of the small mines timber framing is done by surface laborers on company-account wage because it is seldom necessary to keep a crew of framers continually at the job. Surface laborers, and sometimes laborers who are on the sick list with minor injuries which prevent them from working underground, can frame timber a portion of the day and busy themselves with other surface work during the remainder of the shift. Large mines, as a rule, have regular framing crews who work at the job continually, become very expert at it, and are usually on a contract basis. The contract rate in most cases runs about 4½ cents per piece of cribbing, 7½ cents per piece for sub-level timber from 8 inches to 12 inches in size, and 10 cents per piece for main drift timber, of 12 inches and over. These prices are by no means standard throughout the district, but represent a fair average for those mines at which framing is done on contract.

In regard to the common joists by which timber is framed there is both a lack of uniformity for some classes of timber and a decided standardization for others. Cribbing is framed in the same manner at all of the mines. The standard joint consists of the removal of the half section of the piece for about 6 inches at each end. Special cribbing is occasionally used in large double-compartment raises which are intended to remain intact for a long period of time, and the joints of which do not conform to the standard. In framing posts a 2-inch hitch is usually cut at one edge of the top; caps are customarily framed with a joggle on each end from 8 to 12 inches long, about 2 inches deep on the inside. Opinion differs at the various mines in regard to the placing of the bevel at the joint. This bevel of course depends upon the rake of the set. If the set has no rake, both cap and post are usually cut square; if the set has a fair amount of rake three different practices are followed; namely—putting all of the bevel on the post, putting part of the bevel on the post and part on the cap, and putting all of the bevel on the cap. Structurally it would appear better to place all the bevel on the posts, since the cap would then he less likely to split. It is customary, however, to give the cap and post joggles more rake than the set has, and thereby to leave a gap at the outer end of a newly framed joint. In this way, as the pressure comes upon the set, the top of the post next to the joggle cuts into the cap at the inside of the joggle and produces a tighter hitch which prevents the cap from riding over the post in case of unequal pressure. There is really not enough difference between the methods of framing to create a distinction. Long experience has shown which method best suits the specific conditions found in each mine.

At least one mine is using a machine for framing its timber. This machine consists of a portable circular saw driven by a small air motor of such weight and size that it can be easily handled by one man. The saw has a guard over it fastened to an adjustable base plate so that various depths of cut may be secured. The machine is satisfactory for cutting all of the standard joints and does a better job more quickly and consequently more cheaply than can be done by hand. Cuts are uniform throughout. One disadvantage of the machine, which could probably be corrected by the manufacturers, is that in cold weather the air line is subject to freezing. This weakness probably could be corrected by devising an electrically driven machine. Some of the mines have sawmills in connection where timber can be framed without the use of a special framing crew. These are rare exceptions.
HANDLING AND STORAGE.

Timber is handled and stored in much the same manner throughout all the mines in the district. Open-air storage on surface is provided near the shaft so that the framed timber can be loaded on timber trucks and sent underground on the cage as needed. Underground storage is frequently provided on large operating levels near the shaft in the form of timber crosscuts or storage rooms where a few days’ supply can be kept at hand ready for distribution. Timber trucks are used to transport the material to the bottom of the raises, where it is hoisted to the mining places. Usually small air hoists and cradles are provided to hoist the timber from the main levels to the working’ subs, although it is still common to see this job done by hand. The cradles are light iron frames which slide on the side pieces of the ladder or on a wooden slide constructed alongside the ladder in the raise. Chains hold the timber in an upright position on the cradle and prevent the pieces from catching on the raise cribbing during the hoisting. When cradles are not used the timber is hoisted by single pieces or in bundles in the slide alongside the ladder. Scraper hoists frequently furnish the power for handling timber. A small amount of storage is permitted in the mining sub, although this space is usually limited.

Handling equipment (timber trucks, cradles and hoists) is so standardized and in such common use that it is not thought worth while to enter into a detailed description of any of them here.

TIMBERING PRACTICE.

Shafts.

Wooden shaft sets are no longer used in the Michigan district except for small prospect shafts. Steel sets are now standard practice. In the last two decades probably a dozen large operating shafts have been sunk to depths of approximately 2,000 feet; all of these recent shafts have steel sets. To give the details of construction of the sets in each of these recent shafts would be to lengthen this article unduly. For those who are interested in studying the subject of steel shaft sets more thoroughly there is appended to this article a list of material relevant to the subject. The information contained in these articles is of such a character that it may be considered to present an up-to-date handbook of the construction of steel shaft sets.

Briefly, the trend of modern practice is toward the use of H sections for wall plates, end pieces, and dividers, with angles for stuttles and reinforced concrete lath for lining. Some recent (shafts are lined solidly with reinforced concrete. Operators differ in opinion in regard to the merits of concrete lath. This type of lath is easily cast, is relatively cheap (the cost is about 60 cents each, approximately the same as that of good fir lath), is easily installed, offers no fire hazard, and is permanent. On the other hand, concrete lath are heavy and are not as strong as good wood of the same size. Wooden lath are easily gunited to reduce fire hazard, may be creosoted to lengthen life, and will reduce the weight of the lining sufficiently to enable much smaller sets to be used in the shaft. From the arguments offered it appears that concrete lath are now in favor in a majority of recent shafts but that it is entirely probable that they will be displaced in time. This problem is worthy of the attention of all operators who contemplate shafts. If no slabbing occurs in the hard formations through which present day shafts are sunk why put so much weight on the shaft in the form of lath which are relatively weak? Would not wire netting catch such minor spalling as does occur, offer the same fire protection, be more easily watched because the rock walls could be inspected through the netting, be cheaper to install, and reduce the weight on the beams? The walls of the shaft could be gunited to show quickly any movement and cracking.

Shaft Plats.

Steel sets are used almost entirely in plat support at present. Especially is this so in the larger mines, where the plats must be cut sufficiently large to accommodate pockets, dumping equipment, etc. In general there is no subsidence at shaft plats, and the sets are installed only to protect against minor slabbing. Steel sets occupy smaller space than wooden sets and are more permanent. No two mines use plats of the same shape, and as plats usually vary in each mine, no standard practice can be listed in respect to plat support. I-beams and H-sections are usually used, sometimes with rails on the back to hold the lagging. Sketches F and G of Fig. 7 show the details of two such installations; the one "(F)" is rather a common type; the other "(G)" is of a special sort since the plat was cut in ore and had a vertical fault running through it which gave the back considerable weight. As a rule steel does not satisfactorily withstand pressure in plats cut in ore because there is liable to be subsidence.

FIG. 1. WEAK BACK SUPPORTED BY GUNITED WIRE-NETTING
Two extraordinary conditions of plat support are shown in the views of Figs. 1 and 2. The first of these views shows the use of wire netting and gunite to prevent slabbing above the plat. In this case, when the station for this particular level was cut it was found that 3 steep-dipping fault planes converged at a point about 30 feet above and almost directly over the center of the plat. As a large pyramidal block of ground was thus loosened, the condition became serious. The entire loosened block was removed and a criss-crossed network of heavy steel girders (15 to 18 inch I-sections) was strung above the plat to form an artificial ceiling. Above this ceiling the slate formations were in danger of further slabbing. A novel method of support was used. Several coats of gunite were applied to the back and sides of the opening, and numerous short holes (about ¼ inch by 6 inches) were drilled into the walls and back at relatively close intervals. Sheets of heavy gauge wire netting (¼ inch wires with 3 inch by 3 inch openings) were welded together to form a continuous network and pounded to conform to the shape of the opening. Specially designed lag screws were driven into the holes in the walls and the network was firmly fastened in place. Gunite was then applied until the total cement thickness was about 3 inches. To date this support has held admirably and shows no signs that any movement has yet taken place or is liable to take place in the near future. The picture shows the appearance of the gunited netting, gives the relative size of the opening, and shows a top view of the girder ceiling over the plat.

Subsidence pressure is never permitted to actually come down on the steel sets, for they would buckle as any rigid material would under pressure which cannot be held. The mine here referred to is the only place in the Michigan district where rigid steel supports are in satisfactory operation in subsiding ground; and even here they are merely auxiliaries to assist the timber supports.

**Main Level.**

Main level timbering is highly standardized in the Michigan iron mines. For all ordinary openings a three-piece framed set is used if support is required. There are, however, differences in the methods of framing, blocking and spragging of sets. In Fig. 3 are shown all of the noteworthy variations in the standard timbering practice. Checking up first by a comparison between sketches A and B we find that sketch A shows a timbered set with very little rake on the legs. The joggle between the cap and the post in this set is framed horizontally, or parallel to the grain of the cap. All of the bevel is put on the post.

In sketch B is shown the maximum rake found in the district. All of the bevel in this set is put on the cap, the post being cut square at the top. For the most part, under heavy pressure, a large rake is put on the sets; while for a slight pressure (which usually comes from the top), the sets are framed with little or no rake. For this same reason sets made of large timbers usually have plenty of rake so that they may better withstand enormous pressures.

In sketch C is shown the customary single top-spragging fitted over the junction between the cap and the post. The use of a single sprag of this sort is common practice throughout the district in probably 50 per cent of the mines.

The deeper mines, usually use 2 top sprags, as shown in sketch D or 2 top sprags and 1 bottom sprag, as shown in sketch E. The sets near the face, being subject to blasting, are fitted with a protective sprag located in the corner between the cap and the post. When the pressure comes from one corner of the drift there is often danger of the cap riding up over the post. To prevent this from happening, the common method is to use a spreader wedged between the posts and nailed to the cap, as shown in sketch F. For very heavy ground 7 or 8 sprags are often used, placed as shown in sketches F and G.

In top or sub-slicing, when the side of the drift is open and the timbers thus have an opportunity to get out of line, cross spragging is sometimes used at the top of the drift between the posts, as shown in sketch H.

Common methods of spragging the cap and post to the back and side walls of the drift, are shown in sketches I, J, and K. Sketches L, M, and N shows 3 common methods of tying the cap to the post in case there is danger of its riding. Sketch O shows the practice...
previously referred to of framing the joggles of cap and post so that when they are fitted together there will be a gap between the cap and the post which forces the post to cut into the cap at the base of the joggle as the pressure comes on the set.

FIG. 3. STANDARD TIMBERING PRACTICE

Raises.

Two sizes of raises are practically standard in the district; the single-compartment raise, about 4 feet square, and the double-compartment raise, which is 5 by 9 feet on the outside and 4 by 4 feet inside of each compartment. Whenever possible, of course, raises are untimbered. Raise cribbing is almost always round poles framed by the removal of a half section on each end and fitted together with the side pieces normal to the dip of the raise. Some mines use double center-cribbing and others only a single thickness. Double center-cribbing is especially adapted to the use of branched raises wherein it is necessary for one of the branches to cross over the ladderway. If each compartment is cribbed independently the junction may be easily made by dropping the ladder-way a half width into the foot and carrying the chute branch over its top.

Special Cases of Timbering.

In Fig. 4 are sketched several timbering conditions which, although frequently encountered, may be classed as special cases in. that they require particular thought in planning and care in installation. Sketches A and B show two methods of timbering double-track haulage drifts. Both are good practice and are quite widely used throughout the district, although, for the most part, drifts of this extreme width are usually located outside the ore body, where little or no support is required. The three-piece set of sketch A is of extra heavy construction with all timbers ranging from 18 inches up in diameter. The cap is the heaviest piece because of its unusual span of 12 feet. Special attention is paid to spragging the set; in all, 9 sprags are used as shown, in addition to blocking the upper corners of the set firmly in place. This set is in use in soft ore on one of the deepest levels on the Gogebic range and is serving its purpose very well.

The four-piece set sketches in view B is found on the Menominee range in soft slicing ore at fairly shallow depth. Smaller timber is used in this construction, the pieces averaging about 15 inches in diameter, because no great amount of weight is present. Two sprags suffice to keep the set in line. Back and sides are lagged tightly. Whenever space will permit, it is good practice to use a center prop in extra wide sets because by so doing each of the pieces in the set can be materially lightened and the cost correspondingly reduced.

Several methods of timbering at junctions are in use. Each timber boss has his own little practices which he has gained through long experience. Sketches C and D show in plan two types of king post timbering and should be self-explanatory. By locating the king post farther from the corner, as in "D," only two long caps are used, instead of three as in "C."

When a timber set is crushed by the pressure of subsiding ground there is usually only one recourse if the passageway is to be kept open. Crushed sets must be removed, the back trimmed, and new timbers installed. This is the customary procedure throughout the district; in many of the mines it really amounts to an almost continuous relining process. Two conditions are frequently seen underground with respect to the maintenance of openings which are not particularly related to crushing. The one, shown in sketch E, is that of keeping a drift open for a number of years under circumstances which rot the timber rather than crush it. The method here shown is rather novel in that the rotted timber sets are not removed; each successive reliner is placed inside the old set. Three such replacements are shown in place in the sketch; the first two reliners were full sets placed inside the previous ones, and the last repair job consisted of two props immediately adjacent to the old legs and under the old cap. This process, of course, eventually cuts down the size of the opening so that further repairs will necessitate the removal of all the timber. At the stage shown, with three reliners in place, the drift, once full size, has become a mere passageway. Another method of propping is shown in sketch F, wherein two stulls are placed inside the legs. This method is used at a number of mines for various purposes. In one mine all of the subs were so propped,
prior to the shutting down of the mine for a year, in order to maintain the timbering and to reduce repair changes when the property was re-opened. In another mine this procedure is followed in the sub-levels when they become heavy.

Chute designs are as numerous as the mines in which they are used. An entire paper could be written upon this seemingly minor subject and probably not come amiss. The details of chute construction will not be entered upon here, nevertheless, the heavy chute, built to withstand continuous blockholing, is a timber problem. A splendid example of this type is sketched roughly in G. Note the massive construction and the method of backing up the two large sets which form the chute sides with other sets immediately adjacent. This type of chute is in satisfactory use under the hardest conditions found in any of our iron mines.

Sketch H shows a timber hook of novel construction. It is used to support staging in driving top slices with 10 foot legs. On each side of the slice, hooks are attached to the two legs closest to the face, and boards are laid through the hooks. Cross staging may then be built upon these hook supported planks. The hook is cheap, easily attached, and flexible as to adjustment. Since miners are charged with the hooks, losses are infrequent.

Slate and banded formations frequently offer extraordinary-support problems. This type of ground is usually not subsiding; but serious slabbing occurs which is almost as difficult to cope with. In Fig. 5, sketches A, B, C, and D show the manner in which one, two, and three-piece sets are being used in one of the Menominee range mines to meet this problem. Sketch E depicts a method of propping whereby neither head room nor base width is seriously reduced. This method is efficient, in that the support of the prop is applied to the center of the cap where breakage is most likely to occur.
superimposed upon the cap of the ordinary three-piece set. By this means the back of the drift was cut more nearly to conform with the natural arch, and some reduction in weight was thereby gained. Records showed that the set was stronger than the regular three-piece set, but the practice was discontinued because of the additional care and expense required to frame and install the set. Whenever the regular set lasts almost long enough for ore extraction it would probably pay to install a set of this type originally and thereby eliminate the one repair required on the regular three-piece set.

**Substitutes for Timber.**

In some form or other, substitutes for timber are in use in practically every mine in the Michigan iron district. Without entering into the question of whether or not all of these substitutes are successful it may be said that they are being used to great advantage in many cases. It is not an easy proposition to replace timber in its uses underground. Timber is relatively light, strong, and readily framed. And by its fibrous structure is a yieldable material. It is due to this last property that wood has maintained its vital position in the mining industry, whereas it has been replaced by stronger materials in most other construction work. However, timber has some disadvantages. It is a fire hazard and is subject to rot under certain conditions, and for these reasons substitutes have come to be used.

**Steel**

Steel is the most commonly used substitute for timber in underground operations. The tendency among operators at present is to replace timber with steel wherever it may be done advantageously. Steel is used for shaft sets, plats, main drift and main crosscut sets wherever the ground is solid and not subject to subsidence. Almost every operator who has ever tried steel underground as a means of support has learned to his sorrow of its limitations. It is a rigid material, relatively inflexible when compared with timber. Were strength alone required to withstand subsidence pressure, steel would be the best material available at the present time. But strength in a support is of minor importance. The support must be of a yieldable nature—it must resist the pressure, but, since the movement cannot be stopped, the support must yield with the load and at the same time must retain its power of resistance. It must be as a coil spring in its ability to push against the caving ground and to give way at the same time. Steel cannot do this in its customary rigid form; wood is able to because of its internal cellular structure. Hence timber has not yet been dethroned from its position as the material best adapted for use as underground support in subsiding ground.

The first five sketches of Fig. 7 show steel sets which are being used in rock drifts and crosscuts. Four of them are three-piece sets; the other is a one-piece support. Thus it appears that steel sets follow the practice of timber sets; the three-piece set is standard for all ordinary purposes. In regard to the structural shapes which are used to build up a steel set, there is no standard custom. Rails, channels, I-beams and H-beams of various sizes and weights are used with apparent indiscrimination, for each mine operator uses waste or second-hand steel to build underground sets. This steel serves as well as new for steel sets, although at present the larger mines tend to actually design main-crosscut steel sets and to construct them according to specifications. The sets here shown in sketches A, B, C, and D are given to represent the practice of using available waste steel, although new steel could be and is being used in certain cases. Sketch D shows a steel set which was designed for a main double track crosscut and built of new material.

**Gunite.**

Gunite is widely used throughout the district as a substitute for timber in rock openings. It is most frequently applied to plats, pump rooms, and footwall drifts, and is highly successful in preventing air slacking of the exposed formations. The most notable instance of its application has already been cited. Gunite is of no value in resisting subsidence movements.

**Concrete.**

Reinforced concrete is used underground, as a substitute support, in a number of ways. Since it is a rigid material no attempt is made to use it in subsiding ground. The use of this material as shaft lining has been mentioned.

An interesting application of reinforced concrete is found in a pump room in one of the deeper mines. When the room was cut in the footwall slates converging faults loosened a pyramid of rock about 40 feet high over a large portion of the opening. After the block had been removed it was found that the back was still weak, so a ribbed concrete ceiling, strongly reinforced with rails and rope, was built over the entire room. Two walls of
Concrete, each 3 feet thick and at right angles to the back ribs, were carried down to the concrete floor of the room, thus separating the entire room into three parts of equal size. The lower portion of each wall is a series of openings and pillars to permit free passage about the entire room.

Concrete is frequently used to construct bulk heads, plat floors, and shaft pockets, and on one mine a concrete pillar about 4 feet square is satisfactorily used as a king post at a main level junction in ore. In another mine concrete chutes with air operated, sliding steel gates are in operation at the bottom of a main storage raise. Other examples of the use of concrete could be cited here but they are similar to those already mentioned.

Although this paper has gone into the the every day practices of timbering in an elementary manner the writer trusts that the special cases cited will prove of value and interest to mining men. In conclusion the writer wishes to thank the men at the mines which he visited in collecting material for this paper for their courtesy and co-operation.

**ADDENDUM.**

**Shaft Details.**


"Mining Methods of the Marquette District" by S. R. Elliott, J. E. Jopling, R. J. Chenneour and E. L. Derby. Transactions of A. I. M. M. E. Vol. LXII.

"Guniting the Athens Shaft" by C. W. Nicolson. Proceedings of L. S. M. I. Vol. XXIII.


"Equipping and Sinking No. 1 Shaft at Holmes Mine" by Lucien Eaton. Proceedings of L. S. M. I. Vol. XXI.


**OUTLINE OF FLOTATION.**

**BY N. H. MANDERFIELD, HOUGHTON, MICH.*

FOREWORD—The outline of flotation as presented in this article is not an attempt to discuss any new features of the art. It is merely a non-technical description of the process to show in a general way the history, present use, and future prospects of flotation.

Use has been made of text-books and technical articles upon the subject, for which acknowledgement is hereby made.

Flotation may be defined as a wet concentration of ores in which minerals may be separated from gangue by being made to float at the surface of a liquid pulp or above it, while the gangue remains in suspension or sinks to the bottom. In general, minerals that are metallic or have an adamantine or resinous luster are easily floated, while the oxidized and siliceous gangue readily sinks. It is possible, however, in the light of present-day discoveries to separate minerals not only of different classes but within any one group. Galena is easily separated from blende; blende from pyrite; copper sulphides from pyrite; fluorite, calcite and apatite from quartz; coal from slate; phosphate rock from gangue; and some copper and lead carbonates from their gangue.

*Assistant Professor of Metallurgy and Ore Dressing, Michigan College of Mining and Technology.
Processes.
There are three general types of flotation processes.
1. Surface tension or skin flotation.
2. Bulk oil flotation.
3. Froth flotation.
   (a) Pulp body.
   (b) Bubble column.

Surface Tension Process.
Surface tension flotation was used to some extent in the early history of the art, but has never been of much commercial importance. This method is based on the fact that finely divided sulphide minerals exhibit a reluctance to being wetted and hence tend to float on the surface of water. The gangue material being easily wetted, sinks to the bottom of the vessel.

The above sketch shows one of the best known types of wet feed film flotation machines. A tube 10 inches in diameter by 6 feet in length having a central feed opening and a full-size discharge opening, is set on rollers. The tube rotates about 30 revolutions per minute, and takes a feed of about 30 mesh with the slime separated. A gentle stream of water passes through the tube with the feed; the submerged solids settle when they reach the tank, while the concentrate film passes over. Two or more of these tubes are used in series. On zinc ore concentrates assaying 45 per cent with an 80 per cent recovery have been made. High costs, low tonnages, and low recoveries have caused this method to be replaced by froth flotation.

Bulk Oil Process.
The bulk oil process consists of mixing large amounts of oil with finely ground ore and water, and allowing the mixture to stratify. The metallic particles are preferentially wetted by the oil; if the sulphide mass formed is lighter than an equal volume of pulp, it will rise to the surface where the mineral bed can be removed. This process finds no commercial application at the present time, although it was one of the steps which led to present-day practice.

Pulp Body Process.
The agitation process which is the most commonly used depends upon the introducing of minute air bubbles into the pulp by mechanical agitation. Agitation froth machines usually consist of an agitation chamber in which a stirrer, mounted on a vertical shaft, rotates at a high rate of speed, and of a frothing compartment in which the pulp comes to rest and the mineral-laden froth settles out.

Froth Flotation.
While the bulk oil and skin flotation processes are of very little importance commercially, they were logical steps which led to present-day practice. They have been universally displaced by froth flotation, an art which has now assumed a wide commercial application. Froth flotation may be defined as a process of wet concentration in which finely divided ore is agitated with a small amount of one or more reagents in water containing gas or air bubbles, and a separation of valuable materials is made at the pulp surface or above it. The method is used in general on particles 20 mesh or finer. In most cases, one of the reagents is an oil or an oily material, and the floatable particles attach themselves to the films of the bubbles which act as a raft buoying the material to the surface. The minerals that have the weaker affinity for the films are more easily wetted by the water, and they either stay in suspension or sink to the bottom of the machine. Specific gravity plays no part in this method; the sulphide minerals which are heavier than the oxide minerals or gangue are usually the easier to float.

Froth flotation is divided into two different types of processes which resemble each other in the fact that the concentrate is removed as a froth composed chiefly of mineral particles. The processes differ in the method of the mineral selection from the gangue and in the place in which concentration is done.

Bubble Column Process.
In this process, practically all of the concentration is performed in a column of bubbles above and floating on the surface of the body of pulp. This method resembles hydraulic classification with the exception that in it air is recovered by filtration and washing. The oil loss per ton of ore varies from 10 to 30 pounds.
replaces the rising column of water. All that is necessary is to form a rising column of bubbles and to have them come in contact with pulp prepared with the proper selecting reagent. Pneumatic, cascade, centrifugal bubble column, and combination bubble machines belong to this class.

**REAGENTS.**

There are many different functions of the oil and of the other reagents that are used in flotation. Some of the more important ones are as follows:

1. To lower the surface tension of the water in order to produce a more stable froth.
2. To produce certain physical or chemical changes upon the ore particles for the purpose of increasing or decreasing the tendency of these particles to float. These reagents are referred to as collecting or promoting, depressing, flocculating, conditioning, selecting, sickening, retarding, and reactivating.
3. To neutralize or modify mill waters.
4. To deflocculate particles that tend to coagulate.

The more commonly used reagents are classified according to their use as follows:

**Promoters**—
Copper sulphate.
Orthotoluidine.
Thio-carbanilid.
Xanthate—potassium.
Xanthate—sodium.
Phospho-cresylic acid.

**Frothers**—
Cresylic acid.
Pine oil.
Wood tar.
Creosote.

**Depressors**—
Aero Brand cyanide.
Sodium cyanide.
Sodium sulphate.
Zinc sulphate.
Lime.

**Conditioners**—
Soda—caustic.
Sodium bicarbonate.
Sodium carbonate.
Sodium silicate.
Sodium sulphide.

In the selection of suitable reagents for an ore, many factors must be considered. The cost of the reagents usually precludes the possibility of using a reagent that is hard to make or to obtain. The size of the mineral, the type of machine, the density of the pulp, the type of ore, and many other factors influence the kind and amount of reagents to be used for successful work. These are determined by careful test work, and by the application of experience on similar types of ore.

**FLOTATION MACHINES.**

As has been stated, there are three general types of commercial machines: those known as mechanical machines, in which mixing and aeration take place by a fast revolving impeller; those known as pneumatic machines, in which air is forced through a porous bottom; and those known as cascade machines, in which pulp falling from one cell into another mixes with entrained air.

**THE ABOVE PHOTO SHOWS A SMALL 6-CELL MECHANICAL AGITATION MACHINE**

As in reagent selection, the proper type of machine for a given ore is best found by experiment. With the phenomenal growth of flotation in the last fifteen years, many types of machines have appeared. The majority of them employ mechanical agitation. The following is a list of the more common machines and manufacturers:

**HISTORY.**

The early history of flotation is so mixed with myth and fable and the later history is so complicated with patents and litigations, that it is difficult to trace the true history of the subject. The development of the art has been very rapid, and flotation has come to be one of the most important methods of concentration used at the present time.

The patent of William Haynes of Wales, recorded in 1860, contains the earliest known reference of any kind to the affinity of oil for mineral in preference to gangue. He mixed powdered ore and oily matters until a pasty mass was formed; then the tin-selected gangue was...
driven away by water. No commercial application of this method was tried.

Bradford, in 1885, took out a patent based on the surface tension of water. This patent is the first record of skin flotation. Wet tailing from water concentrators was passed on the surface of water in a vessel; the non-wetting sulphides floated and the wetable non-metallics sank. While no commercial application was made by Bradford, his process pointed the way to film flotation. About the same time, Mrs. Carrie Everson carried the idea further by agitating the pulp with acid. This treatment resulted in a separation of the sulphides at the surface. No further progress in the art was made until 1894.

The first commercial application of flotation belongs, probably, to Elmore who, in 1898, patented a process which was really a bulk oil method. He relied on the lifting power of the oil which was mixed with the ore in large amounts. The pulp was mixed in a cylinder, and the discharge flowed into a settling tank from which the sulphides overflowed and in which the wetable gangue fell to the bottom.

In 1902 Potter took out an English patent in which a hot acid solution was used. His process depended entirely on gas which was generated for the purpose of carrying the sulphides to the surface. In the same year Delprat modified the process by replacing the sulphuric acid with salt cake.

In 1901 a London company was formed to take over the bulk oil process. This company instead acquired the patents of Cattermole who had discovered that when oil, water and ore are mixed together and thoroughly agitated, the sulphide particles can be removed at the surface. In 1905 Sulman and Picarcl, metallurgists for this company, discovered that if only a small amount of oil were used—less than 1 per cent of the weight of the ore—and if the mixture were violently agitated, much better results would be obtained. The company acquired many patents, and after going through a series of changes finally emerged as the Mineral Separation Limited. This company has had a very active part in developing flotation to its present status.

Most of the original work in this art was performed in England and Australia. The credit for introducing oil flotation in the United States belongs to J. M. Hyde who became connected with the Butte and Superior Company in 1911. In 1914, J. M. Callow developed a process of pneumatic flotation. Present-day flotation is essentially froth flotation characterized by the mechanical and pneumatic agitating methods or by a combination of both.

The flotation process has been undoubtedly the most important development in concentration in the present century. In 1912 a few tons only were treated by this method in this country; in 1928 approximately 60,000,000 tons were so treated. A generalized compilation of tonnages from "Mineral Resources—1925" gives the following amounts of ore treated by concentration. It is estimated that 70 per cent of the total was handled by flotation.

<table>
<thead>
<tr>
<th>Kind of Ore</th>
<th>Tons</th>
<th>Per cent concentrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>54,000,000</td>
<td>86.0</td>
</tr>
<tr>
<td>Zinc and zinc-lead</td>
<td>22,000,000</td>
<td>97.0</td>
</tr>
<tr>
<td>Lead ore</td>
<td>8,500,000</td>
<td>91.0</td>
</tr>
<tr>
<td>Gold and silver</td>
<td>5,000,000</td>
<td>6.0</td>
</tr>
<tr>
<td>Total</td>
<td>90,000,000</td>
<td>85.0</td>
</tr>
</tbody>
</table>

The importance of the process has been demonstrated by its almost universal adoption by the low-grade porphyry copper producers. Their ores are not amenable to leaching or direct smelting. The copper exists largely as sulphides, and the percentage is low.

The advent of selective flotation has solved many other difficulties. In early copper concentration practice, the iron sulphides usually exceeded the copper sulphides in amount. Today selective methods are being used whereby the iron is depressed, the grade of concentrate is raised, and the tonnage is lowered. Similarly in the lead flotation plants, much zinc and iron were floated with the lead concentrates. By the use of selecting and modifying reagents, a very clean lead, zinc, and iron product can now be made.

The development of the art in the last few years has been due chiefly to the introduction of new reagents, and the present process is distinctly one of chemical flotation.

The commercial practice until 1922 and 1923 might well be defined as oil flotation. A large percentage of the
ores in this period were floated in an acid circuit with coal tars, creosotes, pine oils and similar reagents which caused a bulk concentrate. With the discovery of cyanide as a depressor, in 1923, and with the advent of selective flotation, the method has developed into one of chemical reagents and control. The discovery of cyanide was followed by thio-carbanilid, x-cake, xanthates, aero-float and many others. These reagents have increased the amount and kind of ores that can be treated by the flotation process. Where the acid circuit and oil flotation had failed previously in the development of the process, the alkaline circuit with a combination of newly discovered chemical compounds has been of great value. In some of the combinations, some of the old oils may be utilized.

The flotation of amygdaloidal copper ores has become an established practice in the Lake Superior Copper District. Bulk methods under the old oil system gave poor results on this ore, but with the introduction of modern chemical reagents and improved machines, the process has become commercially applicable with a resulting increase in recovery and decrease in cost.

The future of the art has many possibilities. The flotation of fluor spar, mica and phosphate rock, is becoming commercially important. In the light of recent discoveries and in the trend of the art, it is not too much to expect that the low grade iron ores of the Lake Superior District may some day be beneficiated by this method. It is a safe prediction that the art has not yet reached its highest peak. Present-day developments point to an advancement in notation undreamed of five years ago.

ACKNOWLEDGMENT.

Acknowledgment is due to A. W. Fahrenwald of the U. S. Bureau of Mines, to A. C. Daman of the Denver Equipment Company and to E. L. Tucker of the American Cyanimid Company for subject matter and criticism of this paper.

MICHIGAN IRON MINING INDUSTRY.

BY F. G. PARDEE, LANSING, MICH.*

In Volume NNW of the Lake Superior Mining Institute, Mr. L. P. Barrett discussed fully the cost of mining iron ore in Michigan. In his article he showed the various factors that entered into the production of iron ore and the average costs of this work over a number of years. His statistics carried through the year 1924 and the present paper was written in order to bring this material up to date.

The mines of Michigan are assessed each year and in order to arrive at the valuations it is necessary for the mining companies to submit certain figures on their cost of producing iron ore. It has been a custom for a number of years for the appraiser to work out average cost figures for each district and for the State from the data presented. The average figures on costs and receipts for the years 1925, 1926, and 1927 are found in tables one to eleven. Practically all this information is summarized in the curve in Fig. 1.

The receipts in all cases except for the siliceous ore represent the Lake Erie price that the ore would receive if paid for on the basis of its analysis in relation to the standard 51.50 per cent ore. This is not the actual price that was paid for the ore for a number of reasons, the most important being that a large percentage of the ore is taken by consuming interests at cost. The consolidations of the past few years have increased this percentage until much more than half of the ore leaves the mine on this basis. Long term contracts, bonuses and discounts from the market price are other factors which make it necessary to use the published Lake Erie values in order to get a basis of comparison from year to year on the receipts from the sale of ore.

All of the high grade ore (that running around 50 per cent in metallic iron), which is mined in Michigan, comes from underground operations except that from the two open pits, the Wakefield and Plymouth, on the Gogebic range. The figures given in the average costs tables represent the results of underground operations as no figures have been prepared suitable for publication on the cost of producing ore at these two open pits and to include their operations with that of the underground mines would give results that are of no practical value. The mining of siliceous low grade ore has become of more importance within the last few years and the average costs of these operations are shown in tables IX and X.

*Mining Geologist, Department of Conservation and State Mine Appraiser.

In compiling these average costs the mines have been divided into four groups representing the four ranges. This division also separates the mines by counties except that the Imperial Mine which is the only operating mine in Haraga County has had its costs averaged with those from the mines of Marquette County.
The comparison of costs between the different districts gives a little idea of how the natural conditions influence the cost of mining. For instance, the tonnage of ore produced by sloping operations is greater in Iron County than in any of the other districts. This means that much of the ore is of such structure that it can be taken out without the use of large quantities of timber. As stoping operations are usually conducive to large tonnages per number of men employed it is evident that the labor cost should also be low. The costs for Iron County therefore, may be said to represent the cost of the sloping system of underground mining more nearly than any of the other average costs. A large percentage of the ore on the Gogebic range is recovered by the sub-level caving method. Other systems have been tried but this seems to meet the local conditions more successfully than any other method. The Gogebic costs are therefore representative of this type of mining.

The mining methods used on the Marquette range and in Dickinson County are not uniform enough to warrant drawing any conclusions from the study of the costs. This is especially true as there is considerable hard ore mined on the Marquette range and the cost of this mining has not been separated from the cost of taking out the soft hematite.

In 1924 the total average cost of putting a ton of ore on the docks at Lake Erie was $4.2419. In 1925 this work could be done for $3.9341. This cost was further reduced to $3.7646 in 1926 and $3.7286 in 1927. These totals include all costs except those of royalty and interest on borrowed funds, which would have raised the cost in each case about $.34. During this period the cost of taxes, transportation, royalty and interest on borrowed funds have been practically stationary which means that most of the reduction in costs has been in the actual cost of mining. It has been the development of mechanical methods for handling ore that has been responsible for a large part of these results. The slusher, power shovel and automatic ore handling devices around the shafts and stations are factors that have been of great assistance in cutting the cost of ore production.

Another factor that is less spectacular but of almost equal importance has been the reduction of lost time and increased efficiency due to the lack of accidents. The safety record of the Michigan iron mines has been an aid to the operator in his struggle to lower costs. The increased safety of the miner has been accompanied by better working conditions both in respect to safety and ventilation. These improved conditions have attracted a good class of miners, and as a large part of the actual mining is done under contract, the miner has been able to not only make better wages but to make these wages with less effort.

The safety and efficiency that has been developed is the direct result of more careful engineering and management. Operations are planned far in advance, careful supervision is maintained while the work is in progress and new methods are being considered at all times that will increase the efficiency and lower the costs.

The labor statistics found in Table XI are of interest in discussing the results of the past few years. A comparison of what was accomplished in 1925 with that in 1927 shows clearly why the cost of operation at the mines has been reduced. In 1927 the mines produced 625,119 tons more than they did in 1925. This increased production was accomplished with 780 fewer men and the average number of clays worked was one less in 1927 than in 1925. Expressed in percentages the number of men was decreased by 6.5 per cent while the production has been increased by 4.3 per cent.

The estimated reserves in Michigan have steadily decreased from the peak of over 203 million tons in 1921. The estimated reserves for each year from 1913 to 1925 are shown in Mr. Barrett’s article. Table 1 shows these figures for the first of January 1926, 1927 and 1928. A summary of this data from 1911 to date is shown by the curves in Fig. 2.

The estimated ore reserves are naturally only those which are shown by mine operations or developed by some form of exploration. The decrease in ore reserves since 1921 and the resultant lowering of the mine valuations has been attributed to a number of things but a study of the conditions that exist in the Michigan mines leads directly to the conclusion that more ore is being shipped out of the State each year than is being developed by mine operation or located by exploration. From 1911 to 1921 the natural development of the mines was able to show up enough ore each year to balance the shipments and provide for an appreciable increase in the reserve tonnage. Since 1921 the reverse has been the case. It would appear from the curves that the iron mining industry in Michigan has passed its peak and is on the decline. That would be true if all the favorable places for exploration had been tested and found barren. The large areas yet unexplored both adjacent to the existing operations and in present unproductive territory that are known to carry iron formation are a sufficient
guarantee that the iron mining industry in Michigan has many profitable years ahead.

With the increased use and efficiency of geophysical prospecking, better geological knowledge and more accurate exploration methods, the location of ore bodies becomes less of a gamble and more of an engineering problem. The need for additional ore reserves has not been an item of major importance with the mining companies during the past ten years. It is becoming more of a problem every year and there is already some evidence of increased activity in exploration. It only remains now for this demand for larger reserves to become acute enough and the location of new deposits together with the knowledge of how to use some of the present unmerchantable ores will again force the curve of ore reserves in Michigan to show an upward trend.

### Table I

<table>
<thead>
<tr>
<th>Year</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Nickel</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Copper</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Manganese</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>1,600</td>
<td>1,600</td>
<td>1,600</td>
<td>1,600</td>
<td>1,600</td>
</tr>
</tbody>
</table>

### Table II

<table>
<thead>
<tr>
<th>Year</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Silver</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Platinum</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

### Table III

<table>
<thead>
<tr>
<th>Year</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Silver</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Platinum</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td>400</td>
</tr>
</tbody>
</table>

### Table IV

<table>
<thead>
<tr>
<th>Year</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Silver</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Platinum</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
<td>170</td>
</tr>
</tbody>
</table>

### Table V

<table>
<thead>
<tr>
<th>Year</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
<th>1928</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Silver</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Platinum</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

**TABLE VI.**

<table>
<thead>
<tr>
<th>Cost of Mining—Underground Mines—Marquette Range.</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>1,181</td>
<td>1,644</td>
<td>1,188</td>
</tr>
<tr>
<td>Supplies</td>
<td>427</td>
<td>629</td>
<td>1,829</td>
</tr>
<tr>
<td>Total</td>
<td>1,608</td>
<td>2,273</td>
<td>1,917</td>
</tr>
</tbody>
</table>

**Deferred costs**

| | 490 | 923 | 1,080 |

**Taxes**

| | 477 | 243 | 243 |

**General Overhead**

| | 650 | 789 | 694 |

**General Superintendence**

| | 241 | 243 | 243 |

**Fire Insurance**

| | 243 | 243 | 243 |

**Contingent**

| | 948 | 948 | 948 |

**Depreciation**

| | 1,080 | 1,080 | 1,080 |

**Total**

| | 4,945 | 4,945 | 4,945 |

**Transportation**

| | 402 | 774 | 774 |

**Rail**

| | 674 | 674 | 674 |

**Bust**

| | 243 | 243 | 243 |

**Cost Insurances**

| | 243 | 243 | 243 |

**Total**

| | 1,080 | 1,080 | 1,080 |

**Marketing Expenses**

| | 674 | 674 | 674 |

**Selling**

| | 243 | 243 | 243 |

**Analysis**

| | 243 | 243 | 243 |

**Total**

| | 1,080 | 1,080 | 1,080 |

**Lake Erie Value per ton**

| | 6,080 | 6,080 | 6,080 |

**Goods are profit**

| | 243 | 243 | 243 |

**Other Over Cost**

| | 243 | 243 | 243 |

**Royalty**

| | 243 | 243 | 243 |

**Interest**

| | 243 | 243 | 243 |

**Net operators profit on Lake Erie price basis**

| | 243 | 243 | 243 |

---

**Net operators profit on Lake Erie price basis**

| | 243 | 243 | 243 |

---

**TABLE VII.**

<table>
<thead>
<tr>
<th>Cost of Mining—Underground Mines—State.</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>1,181</td>
<td>1,644</td>
<td>1,188</td>
</tr>
<tr>
<td>Supplies</td>
<td>427</td>
<td>629</td>
<td>1,829</td>
</tr>
<tr>
<td>Total</td>
<td>1,608</td>
<td>2,273</td>
<td>1,917</td>
</tr>
</tbody>
</table>

**Deferred Costs**

| | 490 | 923 | 1,080 |

**Taxes**

| | 477 | 243 | 243 |

**General Overhead**

| | 650 | 789 | 694 |

**General Superintendence**

| | 241 | 243 | 243 |

**Fire Insurance**

| | 243 | 243 | 243 |

**Contingent**

| | 948 | 948 | 948 |

**Depreciation**

| | 1,080 | 1,080 | 1,080 |

**Total**

| | 4,945 | 4,945 | 4,945 |

**Transportation**

| | 402 | 774 | 774 |

**Rail**

| | 674 | 674 | 674 |

**Bust**

| | 243 | 243 | 243 |

**Cost Insurances**

| | 243 | 243 | 243 |

**Total**

| | 1,080 | 1,080 | 1,080 |

**Marketing Expenses**

| | 674 | 674 | 674 |

**Selling**

| | 243 | 243 | 243 |

**Analysis**

| | 243 | 243 | 243 |

**Total**

| | 1,080 | 1,080 | 1,080 |

**Lake Erie Value per ton**

| | 6,080 | 6,080 | 6,080 |

**Goods are profit**

| | 243 | 243 | 243 |

**Other Over Cost**

| | 243 | 243 | 243 |

**Royalty**

| | 243 | 243 | 243 |

**Interest**

| | 243 | 243 | 243 |

**Net operators profit on Lake Erie price basis**

| | 243 | 243 | 243 |
The scraper method of handling broken ore and rock is well established in the iron mines of the Lake Superior district and needs no discussion of its merits as compared with hand shoveling. Although the latter method is still used in a few places, it is practiced mainly because of the remote location from sources of power and the small amounts of material that exist in the bodies to be handled.

The general scheme of scraping layouts is fairly standard throughout the district, but considerable differences exist in the method of carrying out these schemes in the details of equipment, and in the development of ore bodies, to adapt them to this method of handling ore. The individual problems—cost of material, facilities of surface equipment, and character of the ore to be scraped at each mine—will have an influence on equipment in use as well as on the methods of using it. It is a question, however, whether the present differences would be so great if a wider knowledge of details of equipment used in the district existed. Variety in development of ore bodies for scraping purposes is readily understood; but recent innovations in the general scheme of ore handling at the soft ore mines have been made possible through the use of scrapers. Reference here is made to three methods of providing storage space for broken ore which will be described later. Such changes in development need not be radically different for any one mine.

Articles written heretofore on scraping have either pertained to practices at some one mine, or, if the articles included more than one mine in the discussion, they have aimed at narrating the practices of each mine and not at classifying the various methods employed. This technique has its advantage, in that a detailed description of conditions at every mine is possible; however, if information pertaining to any one phase of a subject is desired, the reader has to refer to each narrative separately. This entails considerable time, if numerous mines have been visited. The writer has here tried to classify the subject matter pertaining to each phase of the scraping problem and to group it into as many topics.

The writer wishes to express grateful acknowledgment for the facilities and information given him by the mining companies and their officials at considerable expense both of money and of valuable time. Personal recognition is merited, but such a procedure would result in an extensive list of “who’s who” in the mining of the Lake Superior district.

*Assistant Professor Mining and Civil Engineering at Michigan College of Mining and Technology.

CHAPTER I.

SCRAPERS.

The great variety in construction of scrapers used in the iron mines of the Upper Peninsula is primarily caused by lack of definite choice of the most suitable type, by numerous designers’ variation in detail, and somewhat by different characteristics of dirt handled and by the amounts which it is desirable to move at one time. Although we are most concerned with soft ore mines, the characteristics of the ore are almost as varied as the number of mines. Soft ore may vary greatly from dry, friable ore, ideal for scraping, to the so-called lumpy “chocolate ore,” sticky, wet and disagreeable to handle. It will be desirable, therefore, to have some classification of the types of scrapers in use. It is a difficult matter to draw sharp lines of distinction on whatever basis such a classification is to be made. Some articles which have discussed scrapers have used hard and soft ores as a basis. This may be all right if scrapers in use outside of the iron mines are to be discussed; but since it is intended to limit the discussion to iron mines only, such a classification is not sharp enough.

Scrapers have been classified, in this paper, into three main groups. This classification is arbitrarily based on three terms which are most commonly used in...
connection with scrapers. The terms are "Slip," "Box," and "Hoe." They are not all descriptive of the same functions of a scraper but happen to be terms which are most often used in describing scrapers of the district. "Slip" scrapers were the first used; the word itself is descriptive of the manner in which the scraper performs its work. "Box" and "Hoe" are words descriptive of the appearance of construction rather than of the functioning of a scraper. The three classes overlap in both of these basic facts; nevertheless, a fair method of classification is possible.

**Slip Scrapers**—The first type of scrapers in this class were operated by small "Trigger" hoists and man power. (See Fig. 1). A man at the breast assisted the hoist in the loading operation. When loaded, the scraper and load were dragged to the raise or car by the hoist. The man then pulled back the empty scraper. The type is obsolete at present.

The important feature of this slip scraper is that when it is loaded the scraper slides with the load. This would be a desirable characteristic for mechanically operated scrapers, and some of them do approach it. Further discussion of this principle of operation in scrapers will be taken up later.

The "Sauerman" scraper illustrated in Fig. 3 is neither like a box nor like a hoe scraper, either in its general outline or construction. It has one characteristic, which is common to the slip scraper. When it fills it will ride the dirt and does not dig into the floor. For further information on the details of this scraper see Table 1.

The type illustrated in Fig. 4 is similar in theory of design to the type just discussed, but is cheaper and lighter. Both of these types work well in restricted spaces. Obstructions such as waste rock, timbers, etc., are easily cleared by this type because of the curved shape of the back. This feature of its shape is also a disadvantage in that it cannot scrape out of corners.

**Box Scrapers**—Roughly, this group includes all the scrapers with a straight back which have side plates extending to or beyond the bail. The first box-type scraper used in the Upper Peninsula was the "Quincy" scraper shown in Fig. 5. It was designed after the "Bagley" grader, illustrated in Fig. 2, which is a bottomless type. Although it is claimed that the first box scraper used in the iron mines was designed after the Page drag-line scraper which has a bottom, most box-type scrapers at present have no bottom. They are similar to the "Quincy" and "Bagley" types in this respect. In the iron district, box scrapers have been used almost exclusively in the soft, fine ores, although one mine does use a heavy scraper of this type in soft ore where large chunks prevail.

The scraper illustrated in Fig. 6 is the most common type in this class used on the Gogebic range. It is made at the mine at a low cost. Labor and material do not exceed $15 for the small size. The light-weight plates are burned with a torch and bent into shape with steam hammer and dies. The weight is about 150 lbs. Fig. 7 is of the same type, only it has no curved plates in the back. The same design is made into sizes up to 60-in. in width. This larger scraper weighs about 790 lbs., has a capacity of 14 cu. ft., and is used in dirt which has a prevalence of large chunks.

Fig. 8 is characteristic of the box-type scraper used in the soft-ore mines of the Marquette range. The bottom of this scraper is longer, compared to the total length, than in the "Gogebic" type. Stress in design is laid on the space between the lip and the side plates. The latter approaches the lips with a wide curve, for reasons which will be discussed later.

The type which belongs next in order in the classification is illustrated in Fig. 9. It was used on the Marquette range and differs from the straight box type in that the side plates toe-in as they approach the bail. Better loading and riding qualities when it is dragged with a full load were claimed for it on that account.

The box-type scrapers which have been discussed are all nonreversible and are not suitable for lumpy ore unless heavily weighted. An essential feature of the "Quincy" scraper is the heavy teeth used to rake chunks into the path of the scraper. This is emulated in the box scrapers of the iron district by such types as are illustrated in Figs. 9, 10 and 11. The first two of this group are known as "arrowhead" box-type, and the last as a light "Quincy" type. The "arrowhead" scrapers are widely used on the Gogebic range in soft dry, friable ore. Fig. 9 shows a style of construction which gives a light, strong scraper that can be made for about $20 for labor and material. Where no chunks are handled, the heavy teeth are left out. Fig. 10 differs from that just mentioned in that the side plates are extended far enough to give curved corners for gliding past timbers. The arched bail also is more adaptable for angle slushing than a straight one. The so-called light "Quincy" scraper shown in Fig. 11 is the arrowhead type with the peak of the V flattened out. In the mine where this was designed the ore was of such a sticky nature that it was retained in the peak of the arrowhead types used. The improved design lightened the weight of the back-haul considerably. The sketch also shows extra pieces of steel on the front end of both side plates. Such pieces serve as a shoe to save replacement of side plates because of wear.

**Hoe Scrapers**—The scrapers classed as of the hoe type include all those which have two side arms connecting the bail with the back plate. The sides may be open or may have side plates fastened to the side arms and the back plates. This class of scraper is more adaptable to hard, chunky ores than any other, but recent designs have given very satisfactory service in fine, dry, friable ores.

The first scrapers of this type used in the iron mines were tried in the hard ore mines of the Marquette range. The "Zinc Field" scraper shown in Fig. 12 was the design copied. The straight bail did not prove satisfactory, so a curve as shown in the dotted lines was introduced and
proved to be much better. This was in turn improved upon, as will be shown later.

Figs. 13 and 14 are types of hoe scrapers developed on the Gogebic range. They are satisfactory in soft, fine dirt and are made in widths up to 60 in. They can be made at a low cost from common materials around a mining plant. (See Table 1). The most satisfactory material for the side-arms is 40 to 60-lb. rail which can be bent to the required shape. It will be well to note the position of the bail with reference to the line of pull and the lip of the scraper. Side plates are not used in this design and are considered a hindrance to the filling qualities of the scraper. The reason for the use of side plates, by some operators, is that they retain the load. Wherever these scrapers were being used, enough loose ore was left to the side of the scraping trough so that the ore in the scrapers did not have a chance to get out. There was very little friction, for the dirt handled was fine and dry. All of the following types of hoe scrapers to be discussed used more or less of a side plate. The use of such side plates may be the result of these particular types being used in more or less chunky ore.

The only reversible hoe-type scraper illustrated is shown in Fig. 15. Although this is not the only type in use, there is a general tendency to get away from turning the scraper over to handle chunks. The cutting edges are so adjusted to the line of pull that the scraper can wedge itself behind the chunk. The side plate in this scraper comes close to the lip and extends about one-half the distance to the bail. This scraper was used in a mine where the ore was soft and quite chunky. The reason given there for the use of such a plate was that it eliminates rolling friction of the dirt in the runway during the load pull. Before these plates came into use burned armatures were very frequent. After careful study the cause was attributed to the lack of side plates in the scraper. In four months after their installation there have been no burned armatures.

The scraper illustrated in Fig. 16 is a light hoe-scraper used in soft ore. It will be noted that in this case the side plate has a wide curve from the lip; in fact, so wide a curve that its size is almost negligible. The ore handled was soft, fine and a little wet. When larger plates were used, trouble in filling was experienced. Another feature with the use of side plates in this ore without a board floor was the packing of the runway. It had to be loosened by picking frequently until the plates were cut down to their present size.

The only hard-ore scraper truly to be claimed as such, which is described in this paper, is illustrated in Fig. 17. It is of the hoe-type and designed after the “Zinc Field” scraper shown in Fig. 12. After the latter had been used, it was found to be too light, and the result of a new design was the “Cliff” hard-ore scraper, weighing about 1,500 lbs. No single part of this scraper weighs more than the counter weight, which is 400 lbs. Every piece is capable of being passed through a 2-ft. hole. The wearing parts—draw-head, side plates, and back plates—are of manganese steel. The latter piece is so constructed that it can be reversed when one edge wears. The life of the scraper under every-day wear is about 16 months, or about 10,000 tons of ore handled. The angle of the back plate with the ground is about 30 deg.

The hoe-type scraper illustrated in Fig. 18 was designed to handle semi-hard chunky ore, and is quite heavy. Two features of its construction are noticeably different from types already described. The cylindrical type of counterweight mounted on the back is one, and the scalloped teeth in the scraping edge the other. The bail has numerous points of attachment which can be used when scraping various sizes of chunks. Side plates are considered necessary on account of the chunky ore handled.

The types of scrapers just described and illustrated are not the only types in use in the Lake Superior iron ranges. They are, however, representative of the essential designs of scraper used; and others not mentioned can be classed in similar groups differing in dimensions and in some small points of construction. A very recent design in the experimental stage will be discussed later.

Table 1 deals with data pertaining to scrapers. The weights and capacities are more or less approximations; however, considerable time was spent in making comparisons of known weights and capacities to obtain the figures shown, and they should not vary greatly.

**Table 1—Data Pertaining to Scrapers.**

<table>
<thead>
<tr>
<th>Type</th>
<th>Dimensions—Inches</th>
<th>Approximate Weight, Ib.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slip</td>
<td>6 to 8</td>
<td>300</td>
</tr>
<tr>
<td>Slip</td>
<td>8 to 10</td>
<td>400</td>
</tr>
<tr>
<td>Hoe-type</td>
<td>10 to 12</td>
<td>500</td>
</tr>
<tr>
<td>Hoe-type</td>
<td>12 to 14</td>
<td>600</td>
</tr>
<tr>
<td>Hoe-type</td>
<td>14 to 16</td>
<td>700</td>
</tr>
<tr>
<td>Hoe-type</td>
<td>16 to 18</td>
<td>800</td>
</tr>
<tr>
<td>Hoe-type</td>
<td>18 to 20</td>
<td>900</td>
</tr>
</tbody>
</table>

*Feature tool.
*Gross includes material and labor only, unless stated otherwise.
*Life of scraper about 16 months. Wearing parts manganese steel.
*Weighted.

**Scraper Design**—The design of scrapers has been largely a matter of copying the principal features of two or three standard types and of varying the details to get the best possible performance; consequently box-type scrapers have been used successfully in both fine and chunky ore, and the hoe-type has been adapted to all grades of soft and hard ores. The latter type is perhaps the most flexible of the two. An ideal scraper should satisfy the following requirements: be self-loading, get into corners readily, handle the largest possible load with low sliding resistance, get around obstructions, be well enough balanced to remain erect on the back pull, and be light and compact. This is quite some bill to fill, but recent designs in the experimental stage are approaching it.

The one feature which is common to mechanically-operated underground scrapers is that they are all...
bottomless. The result is that when the scraper has been filled a large portion of the load is being pushed or rolled before it, causing more or less resistance according to the texture and dampness of the ore. In most cases the floor is boarded to relieve this friction; however, some box and hoe-type scrapers are so designed that the position the scraper takes when full assists in the pulling in of the load. This approaches the principle of the slip scraper in Fig. 1, and may be a desirable feature, although, not to the extent that the full load would ride on the scraper. It would be poor practice to limit the load which a scraper can haul when it could just as well handle twice as much under favorable circumstances.

The box-type scraper, Fig. 8, and the hoe-type, Fig. 18, are so designed that under fair conditions no floor is necessary. The two scrapers mentioned are made contrary to the generally accepted idea that the weight of the ore prevents this. Both of them, if allowed to come to rest from a horizontal position, would lie on the flat slope of the floor. When pulling in a load the greater portion of it is carried in the scraper, and the whole is so tilted that the cutting edge does not drag; however, the load is not limited to that which is in the scraper, for any loose dirt can still be pushed before it. At the mine where the scraper shown in Fig. 8 was used, stress was laid on the use of a curved piece of steel for the scraper lip. Presumably this aids in the function just discussed. To assist in getting the proper angle to the scraper when loading and dragging, the ball has numerous holes vertically spaced for rope attachment.

The sliding or slipping feature just described has been attained at some disadvantage in loading. Under ordinary circumstances both of these scrapers require assistance at the breast in tilting the scraper to get a full load. Fig. 3 illustrates a scraper which, when full, tilts back somewhat to slide on the curved bottom with part of the load. It needs no manual labor to assist it in filling. Perhaps the best type for self-loading is the hoe-type scraper illustrated in Figs. 13 and 14. Boarded floors are necessary with them to get the best results.

Combined Box and Hoe Scrapers—A scraper recently designed by Howard Funkey of the Oglebay-Norton Company, Montreal, Wisconsin, embraces desirable features of the box and hoe-type scrapers. Hoe-type scrapers were used without the sides in soft, fine ore but did not hold the load when filled. Box-type scrapers were preferred for two-thirds of the pile of dirt, but, for the remaining one-third, difficulty was experienced in getting into the corners, where the hoe-types would have been superior. The designer has combined these desirable traits in a new scraper which is simple in construction and can be made at low cost. A hoe-type scraper, such as is illustrated in Fig. 13, is used for the loading feature; the angle of the cutting edge being about 50 deg. and allowing easy approach to corners in both sides and bottom of a slice. The side arms are not curved as shown in the illustration but are parallel and have a bar at point “A,” which serves as a bail. Two side plates pivoting at the end of the bar provide full coverage of the sides of the scraper from the curved back to the bail. This makes a true combination of box and hoe-type scraper. The side plates are free to swing in a vertical plane. The objection to side plates in hoe-type scrapers has been that they prevent complete filling of the same. With the hinged side plates the hoe part can dig into the pile and when it comes out of it the sides drop down to retain the load. A stop chain connects both sides with the hoe and prevents them from swinging too high. On the return trip these plates serve as runners, for they extend a fraction of an inch below the cutting edge of the hoe. This scraper is still in the experimental stage but has given very satisfactory results in soft, fine ore.

Angle of Cutting Edge—The cutting edge of a scraper should theoretically lie along the resultant line of the pull of the rope and the force of gravity of the load and scraper. Both of these forces are so variable that no definite angle will satisfy all conditions. In soft ores box-type scrapers have angles of from 25 to 30 deg. in chunky ore. When the weight of the scraper is light compared to the load, the resultant angle becomes steeper. This is true in the light types of hoe scrapers designed for soft ore, and angles up to 50 deg. are used. In the heavier hoe-types, angles ranging from 35 to 45 deg. are common. When the ore is chunky the back should be curved enough to get behind the lumps and also to retain the load. This makes it necessary to use quite flat angles for the cutting edges.

Line of Pull—The application of the line of pull of the rope to the scraper varies, depending on what performance is desired. In the box scrapers and in some of the hoe-types, a number of holes spaced vertically in the bail allow any desired change in the angle of the cutting edge. Horizontally spaced holes in back and front allow scraping around corners. Hoe-type scrapers designed for soft, fine ores, have balls placed so low that the line of pull hits the cutting edge. A ball in such a position helps to maintain a constant scraping angle on the load pull and in the process of filling.

Side Plates—Some mention having already been made regarding side plates, a brief summary only will be necessary.

With the steeper angles of the hoe-type scrapers, side plates in soft ore prevent loading. Lack of them causes loss of load during the load pull, but, if a defined trough of loose ore is formed, its sides will help to maintain a load in the scraper. After observing a scraper of the type illustrated in Fig. 15 working in soft, lumpy ore, it was evident that the side plates were a decided detriment to loading but an advantage in maintaining the load in a wide open floor.

Cutting Edges—Lips—The wear of scraper lips is dependent upon the weight of the scraper used and the hardness and size of the material handled. Crucible steel, ½ by 5-in. bevel edge stock, is the most common lip material and costs about $3 per yard of length. In soft
ore it will last a year without replacement on a light scraper, whereas, if the ore has some chunks and contains a little hard material new edges will be needed every two months. At a mine where an 800-lb. box-type scraper was used to handle semi-hard chunky ore, unannealed carbon tool steel was used. A new lip was replaced every two weeks. Small scrapers are usually taken to the shops for replacement of lips, but, in the case just cited, this work was done underground. The first lip on the large scraper was riveted and, when worn, the rivets were drilled out underground and replaced on the new piece with countersunk bolts.

Recent attempts to repair worn scraper lips have been made by welding the worn parts with the comparatively new product called "stellite." Its composition is 60 per cent cobalt, 22 per cent chromium, and 18 per cent tungsten, and comes in three grades of varying toughness and hardness. One objection to its use is the cost. To stellite an edge of scraper lip 30-in. long, takes $2.50 worth of material; however, the life is increased three to four times. The present price of stellite is $4 a pound. Satisfactory results have been obtained by applying this material to other wearing parts of a scraper, such as the shoe of the bail.
CHAPTER II.

SHEAVES AND BLOCKS.

The scraping problem offers no phases more difficult to solve than those of the Sheaves and Blocks. The question of size, material, weight, and lubrication is hard to fix for any type of work. In some methods of mining, sheave blocks at the breast of a slice may often be lost, and the cost of the block and sheave will then overbalance all other considerations.

Size and Weight—These two topics are treated together because any change in one will affect the other. In this problem it is almost impossible to satisfy the safe working stresses of ropes passing over the sheave. They must be sacrificed on account of the combined weight of the assembly of sheave-pin and block. If it were mechanically practical to keep the plane of the sheave in that of the ropes, the problem would be materially simplified. The change in the direction of pull is so variable and the amount of stress applied is so variable and so sudden, that any mechanical appliance which might do the work would probably be considered too much refinement. Two methods used to remedy this condition are illustrated in Figs. 20-B and 25-B. The former keeps the plane of the sheave in a vertical position while allowing it to swing laterally. This method was tried for some time but was not entirely satisfactory and is not in use now. The latter method employing blocks suspended at frequent intervals from the caps in a slice, as shown in Fig. 25-B, serves to keep the tail rope away from the level of scraping, and also to approach the head-sheave from above or at the same elevation. This arrangement helps to keep the head-sheave in a vertical plane at all times.

The weight may sometimes be reduced by leaving holes in the casting of a sheave such as is shown in Fig. 24-A and B. In one instance a 6-in. cast iron sheave weighing 17 lbs. was cut down to 10 lbs. by leaving eight 1¼-in., holes in the casting. It is better in the assembly of sheave, pin and block to have the center of gravity of the whole as near the hook as possible. The blocks shown in Fig. 23-A and B are of comparatively light construction and the weights are well distributed. Fig. 20-A shows a light block. Welding the parts makes for lightness in construction eliminating rivets, bolts, spacers, etc. The use of alloy steels would make for lightness but cost is also increased.

Determination of Sizes—The sizes of head sheaves used under ordinary scraping conditions range from 6 to 8¼-in. (See Table 3). The sheave with a small tread diameter, however, is likely to be detrimental to the ropes used with it.

The following discussion deals with a 6 by 9 Seale construction rope which has a hemp center, and is based upon the recommendations of a well-known company manufacturing wire rope. This rope is about as flexible as the majority found in use. For a ¾-in. rope of this type the preferable sheave diameter is 10½ in. in other words, the diameter of the hoisting drum should be at least 10½ in. as should be the diameter of all sheaves used. However, it is impossible at present to use a 10½-in. head-sheave at the breast because the common materials used in the sheave are entirely too heavy for common sizes of ropes.

Although the rope will work with smaller diameters of sheave a certain size is reached below which the rope strands cannot slide past each other to adjust themselves to the bend, and as a result constructional restrictions are set up within the rope. Needless to say such restrictions will soon wear out the rope. This particular size of tread in a sheave is called the “Critical” sheave diameter.

For a 6 by 9 Seale construction rope with a hemp center the “Critical” Ratio D/d is 20. “D” is the tread diameter of the sheave used and “d” the rope diameter. Suppose for example a 6-in. sheave with a ¾-in. rope is used, D/d=R=6/¾. The computed value of “R” is 16, proving that this size of sheave is too small. If “R” equals 20, a ¾-in. rope will require a 7½-m sheave. Any size smaller than this will be used at too great a sacrifice of rope service. The following table will be of interest in this connection.

<table>
<thead>
<tr>
<th>Table 2—Critical Sheave Diameter Ratios.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rope Construction</td>
</tr>
<tr>
<td>Critical Ratio D/d</td>
</tr>
</tbody>
</table>

SHEAVE MATERIALS.

Cast Iron—The use of cast iron for sheave material is more general than Table 3 would indicate. Since loss of head-sheaves is common the cheapness of both material and manufacture of cast iron sheaves makes them popular. A good many mines are equipped to make their own castings, and if they are not, there are foundries close by that can furnish them at low cost. Roughly, the ratio of cost of cast iron sheaves to manganese steel sheaves is about; 1 to 3 or 4.
The wearing of cast iron sheaves is rapid, especially in gritty ore. In soft wet ore, under ordinary working conditions, a sheave of this material rarely lasts over 6 weeks. Thus the average sheave has a life of about 3,000 tons handled. When hard ore is being scraped, 4 weeks is considered a good life for a cast iron sheave. Another objection to cast iron is that since the average life is so short it is doubtful whether any attention should be paid to systematic lubrication. Brass bushings are sometimes used.

**Manganese Steel**—Manganese steel sheaves are quite common as can be seen by referring to Table 3. Although their cost is high, there is no question but that when sheaves of this material are used over a period of years they will average lower in cost than sheaves of cast iron, provided, none are lost. The life of a manganese steel sheave is indefinite, but it lasts a very long time. Although the specific gravity of manganese steel is little more than that of cast iron, a 12-lb. manganese steel sheave may be used for the same stresses as a 17-lb. cast iron sheave. (See Figs. 22, 23-A and 24-A for types of construction of manganese steel sheaves.)

**Cast Steel**—Cast steel as a sheave material was found in use at two mines, and does not seem to be very common, although the finished factory products cost about one-half as much as those of manganese steel. The latter material must, of necessity, always be bought as a finished product, while the former can be worked at the mines provided that lathes are available. The wearing qualities of cast steel are much superior to those of cast iron, although not comparable to those of manganese steel. Another good feature of cast steel is its lightness. In view of the many good features which cast steel offers as a material for sheaves, it would seem that it should be in more general use. Fig. 24-B shows the type of cast steel sheave of light construction which is used under average conditions of scraping soft iron ore.

**Billet Steel**—At one mine, sheaves which were made of a piece cut from a forged steel billet showed excellent wearing qualities.

**LUBRICATION.**

The problem of designing practical lubricating devices for sheaves and of keeping them lubricated when in use, is a most difficult one. When the ore is damp and gritty it offers a very serious form of the problem. Table 3 shows that the methods of lubrication are almost as numerous as are the mines which use the blocks.

The most common method is that of pouring machine oil on the pin at intervals during the scraping. This oiling should occur about three times for each cycle of scraping; but all miners will not be consistent about it. A little more refinement is given to the lubrication by having a brass bushing on the sheave. Oil is then poured through a hole in the side plates of the block as in Fig. 23-A. One such sheave in use under heavy duty has had brass bushings and cold rolled steel pins which have lasted 2 or 3 years. However, the blocks are kept oiled systematically by a man whose fluty it is to oil each block at least once a day.

When the duty of a sheave is comparatively light, an effective method of lubrication is to perforate the brass bushing with small holes which are then filled with graphite—the only application of grease during the life of the sheave. This practice is not satisfactory for high speeds or for heavy loading because of the danger of overheating the bearing.

Grease cups are sometimes used, and ordinary machine grease is applied to them every few days. Fig. 21-B illustrates a good scheme for such a method. It will be noted that tire pin is of large diameter and that there are four openings to its surface from the grease supply.

Home-made roller bearings have been tried, as shown in Fig. 22, but have not been entirely satisfactory. Due to the lack of spacers which can not be made cheaply at the mines, the rollers wear unevenly and soon break and stick because they are no longer parallel. Spacers can be bought from the manufacturer but their cost is almost as high as the cost of the sheave. Hyatt bearings, with pin through each roller, are not practical. Timken bearings are used on the larger factory-built blocks, but as yet are too elaborate to be used on the smaller blocks. At the Cliffs Shaft hard ore mine, Lucien Eaton has developed a bearing which employs large pins in the block and two bushings in the sheave.

At one of the soft ore mines a cast steel sheave was made with an oil reservoir, packed with oil-soaked waste which would last a long time. (See Fig. 24-C). A tap was provided in the side of the sheave for refilling the reservoir. Roller bearings with casting and sheave of standard make were used. The sheave worked well, but others of the same type have not been made because of the high cost.

The following sketches are self explanatory in showing methods of lubricating sheaves. (See Figs. 21, 22, 23 and 25). Attention is called to Fig. 21-A which represents a home-made snatch block used at the breast of a slice. Block supports will be discussed in detail later, but mention will be made here of a method for attaching two blocks to the same eye-bolt as shown in Fig.

The reader will please bear in mind, when referring to Table 3, that all the types of blocks and sheaves in use in the Upper Peninsula iron mines are not represented. The table is, however, a list of the various kinds which have been observed by the writer. The significant fact is the great variety in sizes and weights of the sheaves and in methods of lubrication in use in ten of the most active mines of the district. It would seem that a closer standardization of these phases is possible, for conditions of general use do not vary to the extent that present practices indicate.
### Table 3 – Block and Sheave Data

<table>
<thead>
<tr>
<th>No.</th>
<th>Sen.</th>
<th>Steel</th>
<th>Size (in.)</th>
<th>Stead</th>
<th>Curvature</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>15</td>
<td>9</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>150°</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>150°</td>
</tr>
<tr>
<td>C</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>150°</td>
</tr>
</tbody>
</table>

**Fig. 20 – Light Cast Iron Sheave**

A light cast iron sheave, where hawser from mild steel plate and welded.

**Fig. 21 – Handy Block**

A handy block by releasing bolt with wing nut front face can be shifted to allow placing of rope on sheave.

**Fig. 22 – Support and Block with Sheave**

Support and block with sheave to be used with machine post jacked in horizontal position.

---

**Slide of Bearing**

Sheave block with roller bearings designed for lubrication.
CHAPTER III.

HEAD-SHEAVE SUPPORTS.

The methods and types of head-sheave supports used in the Michigan iron district are almost as many as the mines which use them. This lack of uniformity results from the fact that each designer has different ideas and materials with which to work, rather than from the fact that variable conditions exist in the working places.

There are, however, two distinct methods in use—boom and to-the-rock attachments. This classification is based upon the differences between the supports used in soft ores and those used in hard ores.

Types of Booms—The types of booms vary, as may be seen in Figs. 26 and 27. Three classifications are made of them according to the manner in which they may be used with relation to the breast and to the first set of timber. “Class 1”—Those which are set between the breast and the first set of timber. (See Figs. 26-B-C-D and E). “Class 2”—Those which are supported by the last two sets of timber with the sheave-end free. (See Figs. 26-A and 27-G-H). “Class 3”—Those which are supported at the middle by being fastened to the first set of timber while the rear end is fastened by two chains to posts on both sides of drift.

The stresses which enter into the problem of designing a boom are not large. In the cycle of filling the scraper,
dragging it into the raise and hauling it back empty to the face, the return trip offers the most constant work for the boom. There are times, however, when the boom may be subjected to sudden stresses. Such occasions may arise when, in the process of getting its load, the scraper is jerked forth and back quite suddenly. At times, when the scraper is partly loaded, such stresses will be considerable. The steady load on the boom occurs during the back haul of the empty scraper.

Class 1—Booms of the first class are used when the amount of advance of the opening is fairly constant. This interval is usually the distance between sets. In this method it is necessary to cut a hitch into the breast for the forward end of the boom to rest in. The position of this hitch may vary in some kinds of ground, and since the rear end is fastened to the nearest cap, some mode of adjustment is used. In types shown in Fig. 26-E and C, telescoping bars or pipes with set clamp are used. Another method of adjusting for the interval is shown in Type D. A timber hook is fastened to a clamp which envelops the bar or pipe; this clamp is quickly shifted to any desired position by lifting the bar and pushing up the slip-ring when the boom is set for operation; the weight of the bar tightens up the clamp and the ring falls in its gripping position again. The chains off the timber and off the device ring are safety factors in preventing the boom from falling, in case the timber hook loses its grip or the clamp opens. Type E shows a non-adjustable boom of this first class. A timber hook is riveted to a solid bar and the only means of changing its position is by swinging or shifting either end of the boom. This method has worked well when the distance to the breast changes but slightly.

There are a number of things to be considered in choosing the best type of boom to use, such as weight, length, safety, and ease of handling in many kinds of places. Type B can be rigged up in 18 minutes. Both "B" and "C" are light and quite easily adjustable; however, Type D is just as easily adjusted and is probably safer in operation because of the safety chains as discussed above. It is also simple in construction.

Type E is the easiest to make and is easily rigged up; however, it is heavy and has not the factor of safety in operation that Type D has. A very simple and effective boom is often made by using a piece of 4-in. lagging, fastening the rear end by a chain to the first cap from the breast and wrapping a chain around the forward end for the sheave block.

Class 2—Booms in Class 2 are advantageously used when the pile of dirt varies considerably from the breast and when the distance between the breast and the nearest set of timber is great. In openings where there is no immediate need to timber close to the breast this type of boom has an advantage. Its disadvantage with booms in Class 1 is that of weight, for it must necessarily be about twice as long.

Type A, G, and H in Figs. 26 and 27 are of this class; "A" and "B" being straight bars, and "H" being bent so that the rear end rests under the cap of the second set from the face. Either 3 or 4-in. pipe is the material best adapted for the bar. Type A is the easiest to manufacture and makes an efficient boom. The rear end is fastened to the cap either by nailing spikes into the timber or by reversing the spikes in the hole and wrapping a chain around the cap and between the spikes.

Type G is similar to "A" but is made with spikes and chain fastened to the bar. Both of these types are effective when spikes alone are used, for the pull of the load on the forward end acting with the middle connection as a fulcrum, helps to make the grip of the spikes firmer. In Type H the only advantage of the bend is that of enhancing the grip of the spikes in the timber. This advantage, however, is offset by the increased difficulty of handling due to the shape of the bar. Booms of this class are not as liable to become loose and cause injuries by falling on workmen as those of Class 1.

Class 3—Booms of this type are used in cases similar to those of Class 2, where there may be occasion to shift the head sheave laterally as in wide drifts and slices. (See Fig. 27-F and K.) This boom is supported near the center of gravity to the caps nearest the breast, and the
rear end is attached with guy chains to the most-convenient timber, usually a post, on either side of the drift. Types F and K are quite similar in construction with the difference that "F" is provided with a speedy arrangement for shifting the clamps along the bar. A pin and wedge is used which can be instantly fixed or loosened by a blow on the wedge. It will also be noted that pin, wedge, and clamps do not come apart, because there is a \( \frac{3}{8} \)-in rivet placed at the small end of the wedge, after it and the pin are assembled with the clamps.

**Fig. 27.**

*To-the-Rock Attachments*—It would not be right to say that the use of to-the-rock attachments is limited to hard ores. This method can be used in comparatively soft ores provided these ores are not too friable and do not cause the breaking of the ground around the hole. Development work in rock where timbering is not necessary offers the most common application of this method.

Types L, M, N, and O, of Figs. 28 and 29, show various applications of fastening an eye-bolt or spike into the rock or ore. The sketches are explanatory in themselves and need no extended discussion. The parts shown in "L" and "M" are fastened or loosened by giving a blow with, any pounding tool to either pin or wedge. This type of attachment is used in the softer ores. Type N is used in hard ore and the size shown in the drawing is capable of withstanding great stresses. In hard ore the hole made for the eye-bolt is comparatively uniform in size. In softer ores it is difficult to maintain such uniformity, and in consequence a bolt of this type is out of the question. The wedge would require a solid backing when the bolt is being driven in, and the spread of the ends of the bolt would not be sufficient to effect a grip in soft ore. Therefore, the pin and feather which offers a greater spread of material in the hole is more effective.

**Time Savers**—The time used in making a hole for eye-bolts is considerable. It depends, of course, on circumstances in each place; but in rigging up the machine and in making the necessary hose connections for air and water, an hour is easily consumed. Type E shows a method which has worked satisfactorily in comparatively soft ore. The wooden plugs at the bottom of the hole save sufficient space for pin and feather after the blast takes place. In hard ore where it is desirable to save the eye-bolts, an inclined hole, as shown in Type N, is drilled at the same time as the hole for the bolt. This inclined hole is later charged with one-half stick of dynamite which loosens the bolt.

**Fig. 28.**

*Miscellaneous Method*—In wide open stopes where scraping is done, the lateral position of the piles of dirt to be handled may vary greatly. In such cases the head sheave must also be moved often and will require numerous positions of support. Types O and P, of Fig. 29, illustrate such conditions. The former shows a "back rope" with a shifting ring for the head sheave. In this method the "back rope" is attached to two sharpened eye-bolts driven into a hole with wooden plugs inserted. These eye-bolts are usually placed in such a manner...
that the direction of pull is at an angle with the bolt. This
effects a good grip and the bolt will not pull out. Type P
shows a somewhat similar arrangement except that the
block is attached to slings made in the “back rope” itself
at convenient intervals.

Where scraping is done at points other than the face of a
drift, as in methods where storage drifts are used, the
methods illustrated in Types R and S, may be used.
With such attachments a change in position of sheave
can be made in about three minutes. Rope slings, such
as are shown in “S,” can be made at the shops from
used scraper ropes. Where the width of the working will
allow the simplest type of support is probably that of
fastening the block to a horizontal sprag wedged
between the last set of timber and the breast.

CHAPTER IV.

SCRAPER ROPES.

It would be difficult indeed to say that any one particular
size, material, type of construction, or make of wire rope
is most suitable to any one type of scraping problem.
The size and type of construction probably can be fairly
well fixed, but the material of which a rope is made, and
the manufacture of it, is largely determined by the life-
cost of the rope.

Rope Manufacture—Out of the fifteen mines using
scraper ropes continually, five had rope manufactured by
the Roebling Co., four by Williamsport Co., four by
American Cable Co., one by American Steel & Wire Co.,
and one by Monitor Cable Co. Any one of these mines
will back the rope it is using, at the same time admitting
that other makes would do as well. The question of
price therefore is the governing factor regarding the
make used, provided that the manufacturer can supply
the type of construction desired.

Size and Material—The weight of the load to be handled,
and the length of haul are the factors that decide what
size of rope should be chosen. The kind of steel used in
making the rope is not of great importance as far as size
goes, for other requirements than straight pull on the
rope have a bearing on the question of rope diameters.
Plough steel, however, is almost universally in use in the
Michigan iron district. In one mine Crucible steel was
used. Although long life was obtained from it, the cost
was considered prohibitive. In another mine cast steel
was figured to be the cheapest in the long run. If the
working conditions of a rope are not too severe, a
difference in price of 8 per cent between cast and plough
steels may favor the use of the former.

In fourteen mines visited, where the broken ore was
about the same in density, in size of particles, and in
other qualities that bear on the problem of handling, the
following facts were found: Seven of these mines used
a main and tail rope, ⅜-in diameter; three of the seven
had 30-in. box-type scrapers and the other four had 36-
in. hoe-type scrapers. Data taken in loading show that
the working capacities of these two types were about the
same; namely, ⅓ to 4 cu. ft. This type of ore when
broken weighs about 175 to 200 lbs. per cu. ft., making
a dead load in broken ore of about 700 lbs.

In seven other mines, where a 36-in. box-type scraper
was used; the main rope was ⅝-in. in diameter and the
tail rope ⅜-in. The 36-in. box-type scraper handled a
load equivalent to 6 to 7½ cu. ft. which, with the weights
above, means a dead load in broken ore of about 1,300
lbs. The added weight of a larger scraper, the greater
amount of resistance in the form of friction, and the
larger volume of ore pushed or rolled aside increase
materially the stresses on the pull rope when the 36-in.
scraper is used. The work of the tail rope in this case is
not changed greatly, and since it has to run through the
head sheave, the smaller the diameter the less will be
the wear on the rope.

Two mines working a soft but rather lumpy grade of ore
were using a 42-in. box-type scraper. The working
capacity of this scraper is about 9 cu. ft. making a dead
load in broken ore of about 1,600 lbs. A ⅜-in. main and
tail rope was used in each mine; however, the head
sheave was of quite a large diameter and could handle
the tail rope without undue wear. There was no reason
why a smaller tail rope and sheave could not have been
used in either mine.
In another mine where storage scraping drifts were laid out, a 60-in. hoe-type scraper with a 25-h.p. hoist was used. The average working load of this scraper is about 14 cu. ft. or about 2,500 lbs. of broken ore. The pull rope used was ⅜-in. diameter and the tail rope ½-in. diameter. At the Cliffs Shaft hard-ore mine, a 48-in. hoe-type scraper weighing 1,500 lbs. is used. The ore is very dense, averaging 9 cu. ft. to the long ton (2,240 lbs.). It breaks into large chunks, and the stresses subjected on the rope in loading the scraper are comparatively large. When loaded and on a level such a scraper may have a capacity of about 10 cu. ft. The dead load of broken ore would be about 2,000 lbs., assuming density of broken ore at 200 lbs. to the cu. ft. The scraper layouts are such that a total length of 435 ft. of tail rope and 325 ft. of pull rope are used on each hoist, the former being ⅜-in. and the latter ½-in. diameter.

In the discussion above no attempt is made to determine all the stresses to which ropes may be subjected when in action. A basis for comparison of the sizes of rope used is the gist of the matter set forth. The following table is given to present the argument in a more concise form. The table; but is objected to because it costs 25 per cent more than ordinary rope. Whether or not the cost will prohibit its use depends on relative costs of other phases of the rope problem.

**CONSTRUCTION OF ROPES USED.**

Scraper ropes must be so constructed that they are flexible and at the same time stiff enough to withstand crushing. The flexibility is desired when it is necessary to have them go around a small-diametered head sheave, and to a lesser extent in going around the hoist drums. The latter are usually large enough in diameter to take care of bending stresses in the rope, but head sheaves, because of the requirement of lightness, are often of small diameters. A rope must be stiff enough to withstand crushing when subjected to sudden loads. This crushing will take place on the drum where, because of the narrow width, rope must pile on itself. It is not possible with present arrangements to make the rope follow the groove between each rope; as a consequence crossing of loops is common. When sudden strains occur a great cutting and crushing stress takes place at such crossings. Some device to make rope track better on the drum would be of benefit. Although the writer has not attempted to work out any one plan in detail, it seems that an idler or roller mounted on the rope guard would alleviate this trouble somewhat.

The writer has made a sketch in Fig. 40-B which roughly presents the idea. The method shown can be varied according to the types of rollers used and the methods of placing rope guards on the hoist.

At the present time, where such stresses are involved as have been mentioned, a rope with an independent wire strand in the center can be used; however, this decreases flexibility and many companies would rather bear the cost of wear due to crushing than use too stiff a rope.

The following tabulation will give the reader an idea of types of construction of ropes preferred by operators.

**Table 5—Types of Construction of Ropes.**

<table>
<thead>
<tr>
<th>No. of Mines</th>
<th>Types of Construction of Ropes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6 x 19 cast steel—hemp center,</td>
</tr>
<tr>
<td>1</td>
<td>6 x 19 crucible steel—hemp center,</td>
</tr>
<tr>
<td>1</td>
<td>6 x 19 plough steel—hemp center,</td>
</tr>
<tr>
<td>1</td>
<td>6 x 19 plough steel—hemp center,</td>
</tr>
<tr>
<td>1</td>
<td>6 x 19 plough steel—hemp center,</td>
</tr>
<tr>
<td>1</td>
<td>6 x 19 true-lay plough steel—I. wire center.</td>
</tr>
</tbody>
</table>

One company has recently experimented with 6 x 38 plough steel rope with hemp center and prefers it to types listed above.

Preformed or true-lay rope is of comparatively recent date. The wire and strands in tin’s rope, having been preformed in the making, will not have undue increases of internal stresses when going around sheaves of the sizes being used. This quality also prevents broken wires from fraying out of the body of the rope. The use of this type of rope is quite prevalent as shown by the table; but is objected to because it costs 25 per cent more than ordinary rope. Whether or not the cost will prohibit its use depends on relative costs of other phases of the rope problem.

**Wear and Care of Ropes**—This phase of the rope problem has been discussed more or less in what has been written before, but a few more words about it would not be amiss. The care of ropes underground presents a difficult problem and needs no explanation of reasons for discussion of it. A scraper pull rope gets most of its wear near the scraper, on account of continual lashing and breaking due to fatigue of the metal. This breaking is not serious, since only short lengths have to be cut off; but time is lost making such repairs. The tail rope has to put up with small-diametered head sheaves and the breakage is liable to be anywhere along the working length of the rope. A splice or knot here is hard to handle at times and too many will make it necessary to replace the rope. Lubrication of ropes underground would help such matters a little but it is difficult to do and is rarely done. Recently manufacturers have started to treat the strands of such ropes with some lubricant before they are made into rope. Results of the use of such ropes have shown a 75 per cent increase of life.

Table 6 will show the life of ropes used; however, since it is impossible to supply all the conditions affecting the wear of each rope, the reader will be governed by the few statements pertaining to kinds of ore handled, length of time of trials, etc., given in the “Remarks” column.