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PAPERS

MECHANICAL VENTILATION AT LAKE MINE.

BY LUCIEN EATON,*M. S., ISHPEMING, MICH.

Ventilation in the iron mines of the Lake Superior region in nearly all cases is natural; that is, it is induced by the difference in elevation between different outlets in the mine and by the difference in temperature of the air in the mine and that outside. This difference in temperature is frequently augmented by placing a steampipe in the upcast shaft; but aside from this, artificial aids to ventilation have been rare until recent years. In some of the older mines, as at the Cliffs Shaft mine at Ishpeming, Mich., in the 80's, fans have been used when there was only one opening to surface, but their use was abandoned as soon as a natural circulation of air started. In recent years, the Newport mine at Ironwood, Mich., was the first to use positive mechanical ventilation. The installation was not large enough, however, to give definite results, reliance being placed largely on natural ventilation.

With the coming of warm weather in the spring of 1914, the necessity of positive mechanical ventilation at the Lake mine of the Cleveland-Cliffs Iron Company, at Ishpeming, Mich., became evident. The workings of the Lake mine are under the bed of old Lake Angeline, which was pumped out in 1894, and the mine had been in operation for 6 years prior to that date, making a total of 26 years of continuous operation. The total production, up to 1914, amounted to over 8,000,000 tons.

*Superintendent Ishpeming District, Cleveland-Cliffs Iron Co.

The ore was first mined by square-set rooms and pillars, but this was later changed to top slicing and caving. Both methods required the use of large amounts of timber, probably 80,000,000 board feet in all, practically all of which remained in the timber mat. The slow oxidation of this timber was one of the principal causes leading to the installation of mechanical ventilation. The mine was served by only one working shaft, called No. 4, a second outlet being provided by a raise to the surface from the old workings on the south side of the mine. This raise was the “down cast;” but it was very small and the drifts and raises leading to it were too small and crooked to permit an adequate amount of air to enter the mine, especially during the warmer weather. Measurements showed the passage of only 3500 cu. ft. (99 cu. m.) per minute when the temperature of the outside air was 65° F. (18° C.) and of 7000 cu. ft. when the temperature was 32°. In addition to this air, which was distributed mostly through the haulage and timber drifts, ventilation in the working places was aided by the use of compressed air at the rate of 2500 to 3000 cu. ft. per minute; this made a total of 6000 to 10,000 cu. ft. of fresh air per minute for the whole mine. The maximum number of men employed underground at one time was 200; so that the average number of cubic feet of air per man per minute was from 30 to 50. In many of the working places, however, the amount necessarily must have been much less than this.

Tests taken in various parts of the mine showed that the relative humidity was from 95 to 100 per cent and the temperature from 70° to 80° F. (22 to 27°C). The air in the upcast shaft had a temperature of 76°, with relative humidity 100 per cent and a carbon-dioxide, content of about 1 per cent. Some of the working places showed as much as 2.6 per cent carbon dioxide. The effect of these conditions was apparent partly in the reduced efficiency of the men while working, but more particularly in their general health, loss of time from sickness being very common.

In order to reduce the temperature, humidity, and carbon-dioxide content of the air in the mine, it was proposed to increase the volume of free air furnished to each man from 50 to 225 cu. ft. per minute, and to distribute the air more uniformly to the working places. The merits of the vacuum and plenum systems of ventilation were carefully considered before making a selection. With the plenum system the increase in air pressure would tend to force the carbon dioxide back into the gob, no air locks would be necessary in the crosscuts to the hoisting shaft, and the fan could be erected on the surface at the collar of the air shaft, where doors for reversing the air current could be built, to be used, if necessary, in case of fire. On the other hand, the machinery could not be erected until a new air shaft had been completed, which would require several months, and immediate relief was necessary. Furthermore, the air shaft was at such a distance from the rest of the surface plant that it would he necessary to employ an operator for the fan on each shift. By using the vacuum system, the installation could be made immediately underground near the hoisting shaft, where the fan would he under the observation of men already employed on the level; no extra men were needed, and the cost of operation would be limited to power and lubrication. It was not necessary to wait, before starting the fan, for a new air shaft to be completed, although full efficiency could not be expected until that time. The larger volume of the air current was expected to wash the workings clear of carbon dioxide, which expectation was realized. The vacuum system also made necessary the building of suitable airlocks on the third, fourth, and fifth levels.

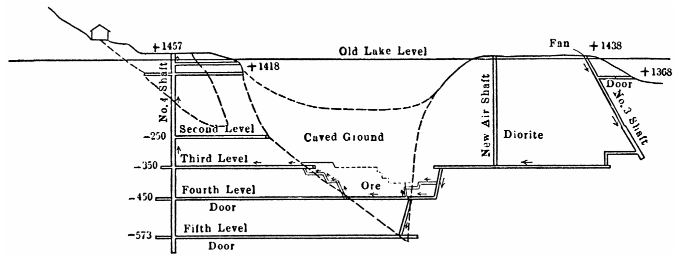

FIG. 1 CROSS-SECTION OF MINE

The advantages of the immediate installation and low cost of operation decided the adoption of the vacuum system. Accordingly a motor-driven suction fan with a capacity of 45,000 cu. ft. (1273 cu. m.) of air per minute was erected on the third level near No. 4 shaft, and airlocks were built on the third, fourth, and fifth levels in the crosscut south of the shaft. The fresh air was led from the air shaft directly to a new sublevel 35 ft. (10.6 m.) below the fourth level, which was the main operating level, this sublevel serving’ merely as a distributing passage. Here the current was split and carried to the limits off the orebody, where it was distributed to the working- places. The return air current found its way through the raises and timber roads on the sublevels to the third level, where it was discharged through No. 4 shaft. Where necessary, distribution to the working places was accomplished by small “booster fans.”

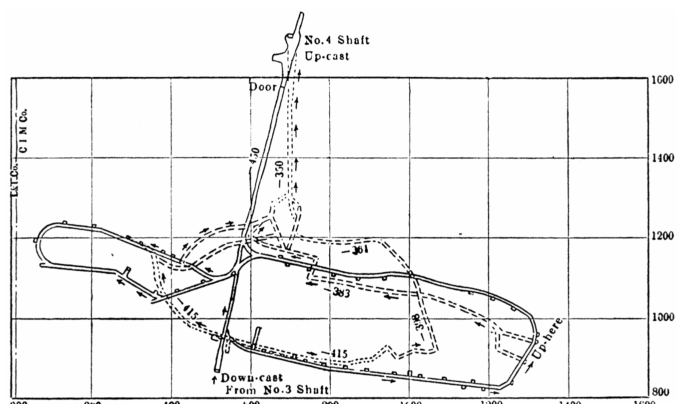

FIG. 2 PLAN OF MINE

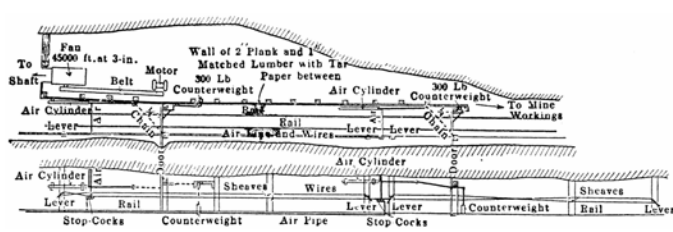

FIG. 3 FAN INSTALLATION AND AIR LOCK, THIRD LEVEL

At some places in the "down cast," the cross-sectional area was so restricted that the incoming air had a velocity of 4000 ft. per minute. This not only greatly increased the friction, but made it impossible to use the air shaft as a second outlet, for men were unable to keep their lamps burning in such a draft, and could not face such a blast of cold air in the winter. In order to reduce the velocity of the air to 1000 ft. per minute, a new air shaft was raised from the third level to the surface, a distance of 350 ft. (106 m.). This raise had two compartments, each 5 ft. square inside and also a smaller ladder-way, from which the draft was excluded as much as possible. Another raise, between the third level, and the "ventilation sublevel," as it was called, below the fourth level, was enlarged to the same size as the air shaft. The top of the air shaft was surrounded by a fireproof, galvanized-iron building, in which a screened opening with a cross-sectional area of 120 sq. ft. (11 sq. m.) was left under the eaves. Figs. 1 and 2 are a cross-section and plan of the mine, showing' the air shaft and the methods of distributing the air.

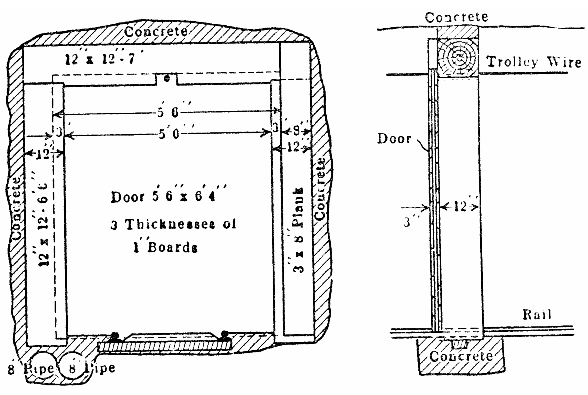

FIG. 4 FRAME FOR AIR-LOCK DOOR

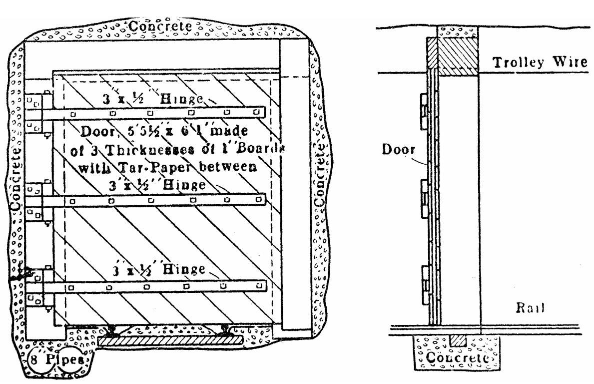

FIG. 5 DETAIL OF AIR-LOCK DOOR

The fan used is a No. 11 Sturtevant double-inlet, multi-vane suction fan, completely housed, with overhead horizontal discharge, capable of delivering 45,000 cu. ft. of free air per minute against a resistance of 3 in. of water. It is belted to a 45-h.p., a. c, 2200-volt, three-phase, 60 cycle, induction motor, and runs at 375 r.p.m. An automatic starter is provided. The power consumption is about 35 h.p. A diagram of the installation of this fan on the third level is shown in Fig. 3. The partition separating' the fan from the plat and haulage drift is made of two thicknesses of 1-in. boards with roofing paper between. The doors of the airlock are the same as those shown in Figs. 4 and 5.

Three small "booster fans" were used for some time, but changes in the arrangement of the working places on the sub-levels have made them unnecessary. Each was a No. 2 Sturtevant multivane fan, having a capacity of 2200 cu. ft. of air per minute against a resistance of 1 in. of water, mounted on a subbase, and direct-connected to a 1.4-h.p., 1365 r.p.m. motor, wound for 250 volts, d.c, and equipped with an automatic starter. These were connected to the trolley wire of the electric haulage system.

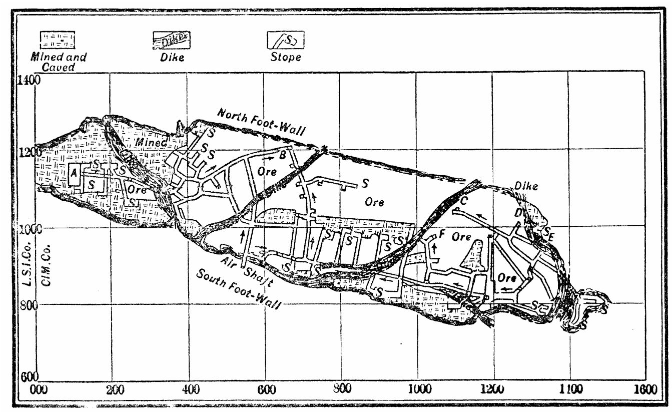

FIG. 6 LAKE MINE, DISTRIBUTION OF AIR

Explanation—The air goes down the air shaft to the 415-ft. sub-level, where it is split east and west and passes up to the 398-ft. sublevel through raises at E on the east and at A on the west. Some air also leaks directly to the 398-ft. sublevel from the air shaft, as indicated. The air passing up at the east end goes up to the 383-ft. sublevel D and C, and also travels south and west through the timber drifts, as indicated, to the main cross-cut to the timber raise B, through which it goes to the 383-ft. sublevel and thence to the third level. A small portion of this air also goes up to the 383-ft. sublevel at P. The ventilation of the stopes S along the route of the air current is by diffusion, aided by the movement of cars and by some leakage through caved ground. The air passing up at the west end through A goes east along the timber road to the timber raise B, thence to the fan on the third level.

The airlocks used follow closely in design those of the Gardiner Shaft of the Copper Queen Mining Company, which were designed by Mr. C. A. Mitke. They are shown in Figs. 3, 4 and 5. Fig. 4 shows the framework of the door set in concrete. Fig. 5 shows the door itself. Fig. 3 shows the arrangement of the doors and the operating levers and air cylinders. Each door is opened against the air pressure by a 5-in. (12.7-cm.) air cylinder made from ordinary pipe, and is closed by a counterweight. The valves controlling the air cylinder are two ordinary iron stopcocks, coupled at right angles, so that one opens as the other closes, and are operated by a single lever on each side of the door. These levers are set up at a sufficient distance from the door to make it unnecessary to slow down an ore train that is approaching, and are connected to the valves by heavy wires, which are reversed on one lever, so that the lever is always thrown in the direction in which the train is moving, whether the door is to be opened or closed.

The levers are in such a position that they can be easily reached by the man operating the locomotive without moving from his seat. On each side of the door there is a red light which is automatically extinguished when the door is wide open, but which shines at all other times.

The results obtained by positive ventilation have been very satisfactory. The temperature, humidity, and carbon-dioxide content have been reduced, and the mine has dried out so that it is much more comfortable to work in. The temperature of the upcast air has been lowered from 76° to 65° and the humidity is 96 per cent. The percentage of carbon dioxide is negligible. The better air has not only improved the general health and efficiency of the men, but has put an end to nearly all delays from powder smoke. The cost of operating is offset by a corresponding decrease in the cost of operating the air compressor.

In spite of a rising wage scale with attendant general decrease in efficiency at the other mines, the efficiency of the men at the Lake mine has increased. Furthermore, there has not been a shortage of men at the mine since mechanical ventilation was installed.

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SPIES OPEN-STOPE SYSTEM OF MINING.

BY S. R. ELLIOTT, ISHPEMING, MICH.*

The Spies mine is located in the eastern half of the northwest quarter of section 24-43-35, near the village of Iron River Mich., and is operated by The Cleveland-Cliffs lion Company. Speaking generally, the jasper hanging walls of most of the deposits in the Iron River district dip at steep angle and are exceedingly strong, standing without caving, even after mining has been continued for years and after large excavations have been made. The ore is fairly hard and tough and Sins no slippage faces. It occurs in large masses, which are often egg shape, with the smaller end down and can be mined in open stopes without the use of timber. The common system employed in the district is the shrinkage stope, or some modification of it. The Spies system was developed to utilize the advantages of the open-stope method and to avoid the disadvantages of the shrinkage stope.

The Spies shaft was sunk to such a depth that the bottom, or third level, was in rock at a short distance below the bottom of the orebody, the shape and extent of which had been previously determined by diamond drilling. This is shown plan and by the ore contours at the first, second, and third levels in Fig. 1, and in section in Figs. 2 to 7.

In order to provide the necessary mills and raises, three parallel crosscuts were driven on 25 ft. centers on the bottom level. Drifts on the second and first levels were driven to the orebody and followed the footwall in a southerly direction to the end of the ore. In crosscut 3, Fig. 1, raises 30, 40, 50, and 60 were carried up on the footwall and holed into the second level, and were ultimately carried up and holed into the first level. These footwall raises carry the pipes and ladders, provide a means of ventilation, and furnish safe communication to all working places in the stope.

*General Superintendent, The Cleveland-Cliffs Iron Co.

From crosscuts 1, 2, and 3, raises were completed to a height of 32 ft. or the elevation of the first sublevel. They were then connected by east and west crosscuts to the main tool wall raises 30, 40, 50, and 60, shown in Fig. 4 The crosscuts in raises 1 to 5 were then driven west and the hanging wall located. While this work was in progress, raises 1 to 5, 10, 12, 14 16 18 were driven until they reached the hanging wall. At intervals of 22 ft., the raises were connected by east and west crosscuts and the hanging wall to the west was located at the elevation of each sublevel. This is shown in Fig. 2.

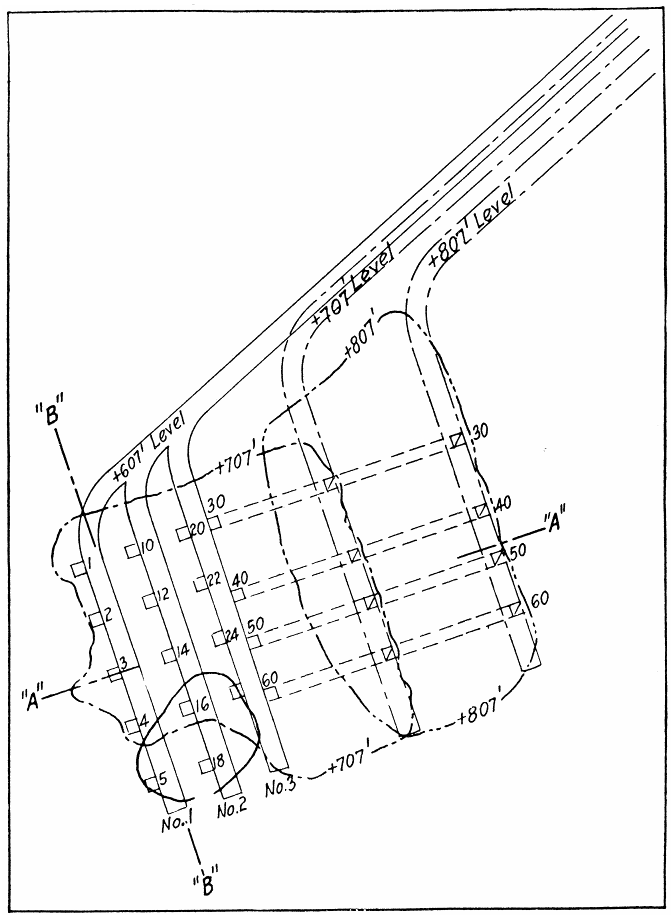

FIG. 1. PLAN OF SPIES MINE, SHOWING MAIN LEVELS, CONTOURS OF OREBODY RAISES AND MILLS.

Below the 639-ft. sublevel raises 1 to 5 were coned to an angle of about 45° to serve as mills. Miners then started in each crosscut on the 639-ft. sublevel, at points near the hanging wall and made fanned-shaped holes toward the same. By repeating this operation on sublevels at higher elevations, the ore was cut away from the hanging wall and a narrow opening existed over the mills in crosscut for the length and height of the orebody. From this time on, to the completion of the stope, the work was straight mining. Miners set up their machines in the various crosscuts at a safe distance from the edge of the open stope and drove fan-shaped holes toward the west, care being taken to pull back the east face in a vertical plane.

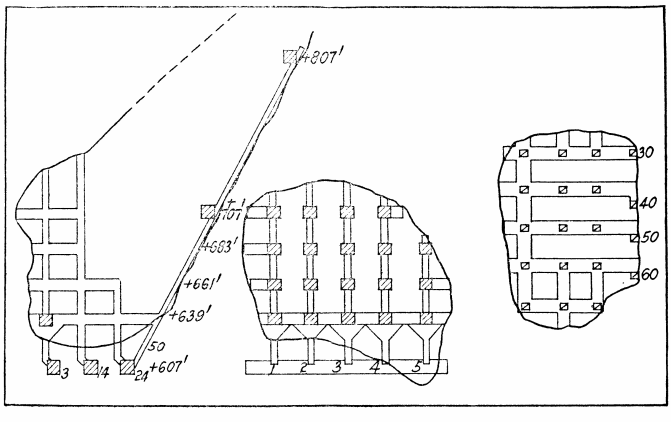

FIG. 2 FIG. 3 FIG. 4

FIG. 2 SECTION A-A BEFORE STORING IS BEGUN

FIG. 3 SECTION B-B BEFORE STORING IS BEGUN

FIG. 4 PLAN OF 639-FT SUBLEVEL

If one could stand against the hanging wall at a point opposite the center of the stope and look east, this face would resemble, in prospective, a number of pyramid shaped funnels in a horizontal position, the larger end pointing toward the observer, the crosscuts being the spouts. This is shown in section and elevation in Figs. 5 and 6. While stoping is being continued, it is necessary to complete additional raises and to do crosscutting at higher elevations, or in parts of the ore-body farther east.

DISADVANTAGES OF THE SHRINKAGE STOPE.

1. In a shrinkage stope, after mills have been made, the orebody is undercut. By setting up the machines on the broken ore and working around the perimeter of the stope, its height is increased until the top of the deposit is reached. After each blast, only sufficient ore is drawn from the mills to make room for the miners to work. A safe rule to follow is to have the back above the point where the machines are set up close enough for it to be touched by a miner when his arm is extended. With this precaution, it can be readily trimmed. Further miners should not be permitted to go out toward the center of the stope, but should be kept close to a solid wall. Observing these rules and always working around the perimeter, causes large orebodies to remain in the center of the stope which either must be blasted, by the use of long drills or if they cannot be reached they must be left until they become so heavy that they will fall because of their weight. In time, these large masses are drawn down to the mills, when they must be broken by men who enter the mills from the bottom to drill and blast them; this is slow, expensive, and exceedingly dangerous work,

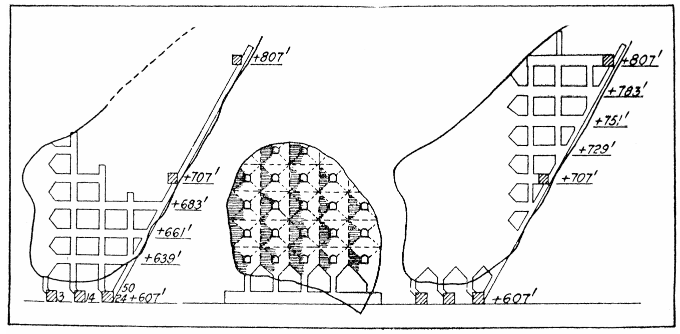

FIG. 5 FIG. 6 FIG. 7

FIG. 5 SECTION A-A AFTER STOPING IS BEGUN\
FIG. 6 ELEVATION B-B

2. As the ore is broken in a shrinkage stope, only about one-third of it can be drawn out of the mills. The pile in the stope must constantly be increased in height until the top of the deposit has been reached and the stope completed. A large investment, represented by two-thirds of the broken ore, is tied up until the stope is completed.

3. The miners spend a large proportion of their time trimming the back, trying to make it safe; their drilling efficiency is, therefore, low.

4. In drawing sufficient ore each day to keep the top of the pile at the proper distance from the back, there is constant danger that the ore will not settle properly and later on will surge and endanger the lives of the men in the stope.

5. If seams or bunches of rock are encountered, they must be broken with the ore; there is no means of separating the material.

6. Ventilation, as a rule, is poor and much time is lost after each blast.

ADVANTAGES OF THE SPIES SYSTEM.

These will be compared in the same order as the disadvantages of the shrinking stope.

1. All men are provided with a safe and easy traveling road to their working places. There is every opportunity for miners to drill their holes with a proper burden on them, so that it is unnecessary to break the ore in large masses. It is not necessary to go up into mills to drill and blast. These are the chief factors that make it possible to obtain low cost by the use of this system.

2. All of the ore broken each day is drawn from the mills, only enough being left to protect the stoppers from the shock of falling ore blasted in the stope. An accurate check can, therefore, be kept on the miners and high efficiency obtained.

3. No time is lost in trimming. The men are in no danger from falls of ground so their time is spent in drilling and blasting; their efficiency is, therefore, much higher than in the shrinkage stope.

4. There is no danger that the ore upon which the men are standing will be drawn from under their feet, as they work in crosscuts with solid ore below them. Their machines are set up on posts, which is preferable to using tripods on loose ground.

5. During the development work in the sublevels, all seams of rock in the ore are outlined and can be mined before the stope has reached that locality, the rock being dumped into raises that are not being used as mills. It is, therefore, possible to mine the ore and keep it clean.

6. On account of the large number of small raises and the connections with upper levels, no trouble is experienced with ventilation. Blasting can be done at any time during the shift and only a few minutes lost. The area of the open stope soon becomes so large that the gases are rapidly dissipated and pass off through the upper levels.

With the exception of a small thickness of ore left above the first level to support the overburden of sand, the stops in the Spies is completed. In this mine, on a comparatively narrow orebody, we have also worked the shrinkage-stope method, and, therefore, have had an opportunity to make a close study and comparison of the two systems. Our records show that the cost of breaking ore was about 4 per cent higher in the shrinkage stope than where the Spies system was used. From every point of view, the Spies system has proved more satisfactory than the shrinkage stope.

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STUDY YOUR MINE TIMBER PROBLEM.

BY GEORGE M. HUNT, MADISON, WIS.*

A few years ago when timber was more plentiful and labor cheaper, it was hard to interest mine operators in timber preservation or other possible means of saving timber. Now that timber is scarcer, its quality is poorer, and labor is quite expensive, the timber problem is more important, and it is receiving greater attention. However, an enormous and unnecessary waste of timber and labor which ought to be prevented is still taking place.

It is easy enough to point out some of the most apparent of these wastes and make general recommendations as to what should be done. Numerous articles have been published and bulletins written during the last ten years which give useful information on the subject and suggest remedies. When the mine operator reads these publications and thinks about applying their recommendations, he finds there is always something lacking. They are not complete or specific enough, and they do not tell him all he needs to know.

This is something which cannot be avoided, for the question of mine timber utilization is too big to be covered completely in any short article. An article or bulletin which attempted to cover all phases of the subject in detail would be so long and so uninteresting that it would not be read. Furthermore, the methods of mining, the character of timber used, the rate of decay or destruction by other causes, and the life desired vary so widely for different mines that it is not practicable to make recommendations which apply in detail to them all.

*In charge, Section of Wood Preservation, U. S. Department of Agriculture, Forest Service. In Cooperation with the University of Wisconsin.

EVERY MINE A SEPARATE PROBLEM.

Each mine presents a different problem and each should be studied by itself. Every mine operator should know the details of his own timber problem. He must be thoroughly informed as to his own needs and how they are being met before he can take very intelligent action towards improvement.

The first important question to be answered is how much timber is used, and how much labor is involved in its use. If this figure is very small, the matter may end there, but usually in a mine of any importance it will be found that the figure is of considerable magnitude and the total sum of money involved is large enough to warrant further study. The cost of the timber alone may not be so very great, but the labor involved in placing or replacing it may more than double the figure. To replace a decayed set of timber in heavy ground may cost several times the original cost of placement.

The next questions to be answered are, “How long does the timber last? and how long do I want it to last?” Obviously, the answers will vary greatly with different operations and with different parts of the same operation. It may be found that practically all the timber goes into places which are abandoned before replacement is required or it may be found that a large proportion is used either on the surface or underground where a longer life is required than is now being obtained. These questions cannot usually be answered satisfactorily without careful study. An offhand answer is more than likely to be erroneous. Careful investigation may disclose some unsuspected facts of considerable importance.

WHAT CAN BE DONE ABOUT IT.

Correct answers to the above questions having been secured, the next that arises is, “What is to be clone about it?” Usually there are a number of things which can be done. One of these is to see that the timber used for any purpose is the most nearly fitted of the timber available to meet the requirements of that use. It is desirable, of course, that only sound strong timber be used, but the nature of the timber supply in the Lake Superior district and the conditions under which it is secured make this impracticable. A considerable portion of the timber delivered to the average mine timber yard is naturally of low strength and durability or has had its strength and durability materially lessened by decay.

This timber very commonly arrives mixed indiscriminately with material of much better quality.

When timber for all purposes is taken from this mixture (and this practice is not uncommon), the result is that much good timber goes into places where poor timber would do, and poor timber gets into places where only the best should be used. Segregation of the timber in the storage yard and insistence that the best be reserved for the most exacting places may result in material savings. The first response to such a suggestion is likely to be that it is not practical, but it is probable that it is practicable and can be done to very good advantage. At any rate, the operator should investigate and base his decision on a study of the facts developed rather than on an offhand assumption.

Some increase in life is to be expected by simply removing the bark from timber. The increase should be enough to cover the cost and afford a good margin of profit besides. It goes without saying that this would be an unnecessary expense for timbers whose required period of service is less than the life now being secured without peeling. There may be places, however, where an increase in life of only ten per cent will be sufficient to obviate the necessity of replacement. A few cents spent for peeling such timbers may save many dollars in timber and labor costs. Whether it will or not, the operator must determine by studying his own conditions.

TIMBER WASTED IN STORAGE.

When timber is held in storage for long periods of time, deterioration will result, especially if the storage conditions are such as to favor decay. The life of timber exposed to decay is limited. Its life can be entirely spent in the storage yard if the operator so decrees, or it may be spent partly above ground and partly underground. This is the more common. The care given the timber from the time it is cut until it goes underground will determine the percentage of its life which is wasted. Allowing timber to deteriorate in storage is as wasteful as buying supplies and throwing part of them away, or allowing men to idle part of their time away. Some deterioration, some waste, and some idleness may be unavoidable, “but how much?” “What are the best methods of storing timber?” “To what extent can they be economically applied to the mine in question?”

HOW ABOUT PRESERVATIVES.

If study shows that segregation, peeling, and proper storage still fall short of the desired end, there is still preservative treatment to be considered. It is established beyond question that the life of timber can be greatly increased by treatment with preservatives. The experience of the railroads of the country during the last fifty years has settled the question as to whether preservative treatment is an economy. Their answer is the constantly increasing number of treating plants, quantity of preservatives used, and amount of wood treated. That wood preservation applies to mines also has been demonstrated by the experience of several prominent mining companies which have been operating treating plants more or less continuously for fifteen years.

Timber preservation is not a cure-all, however, and it must be used with intelligence if the best results are to be obtained. There are a number of methods of treatment and several good preservatives. Each has its advantages and disadvantages. The best process and preservative to use must be determined by the local conditions and requirements. What is best under one set of conditions may not be at all suitable for other conditions,

STANDARD PRESERVATIVES.

Zinc chloride and coal tar creosote are the standard wood preservatives, and ordinarily no other material need be considered. Excellent results can be obtained from either of them by the pressure process or the hot and cold bath process. The pressure process is most effective, but requires the most elaborate equipment. The hot and cold bath, or “open tank” process can be applied with very simple equipment, and if the work is well done, the treatment will be almost as effective as pressure treatment. Round timbers are especially suitable for open-tank treatment. When it is known that large quantities of timber are to be treated, the erection of a complete pressure plant is desirable, because timber can be treated most rapidly in this way. For smaller quantities, open-tank plants are quite suitable.

In discussing mine timber, attention is usually given to the timber which is used underground, and the large quantities of ties, poles, posts, piling lumber, and construction timber used above ground are forgotten. Waste costs money whether above or below ground and all of the timber should be considered together.

DEVELOP A TIMBER POLICY.

This paper is written merely to point out the way in which a logical solution of the timber problem lies. It should be plain from what has been said that a sound timber policy can only be attained after careful investigation. If the amount of timber involved is not great, the investigation can be made by the regular engineering force. Where great amounts of timber are involved, it should be practicable to detail an engineer permanently to the work, or employ a technically trained timber expert. A trained man of good judgment, whose sole responsibility is to study the timber problem in all its phases and to keep constantly on the alert for opportunities to make improvements, can undoubtedly save large sums of money if his recommendations are adopted.

(Reference—Previous article on this subject published in Proceedings for 1909, Vol. XIV, p. 99, entitled “Wood Preservation With Especial Reference to Mine Timber,” by John M. Nelson, Jr., Washington, D. C. Assistant, in charge of Wood Preservation Forest Service, U. S. Department of Agriculture.)

(Elsewhere in this Volume are shown illustrations of timber in various stages of decay. These are not a part of Mr. Hunt's paper, but illustrate conditions to which the paper refers.—Secretary.)

BUILDING REINFORCED-CONCRETE SHAFT HOUSES.

BY J. ELLZEY HAYDEN,* C. E., AND LUCIEN EATON,! M. S., ISHPEMING, MICH.

The Cliffs Shaft mine of the Cleveland-Cliffs Iron Company, located in the City of Ishpeming, Mich., is the largest producer of hard hematite ore on the Marquette iron range. The two shafts, A and B, lying 280 ft. (250 m.) apart on the east-west trend of the ore formation, were sunk in the early eighties, and, except for four years, have been steady producers of iron ore. Their location, on a hill overlooking the general offices of the company on the one side and the City of Ishpeming on the other, has made the shaft houses landmarks.

In the spring of 1919, as the old wooden shaft houses had become shaky and out of line, and would soon be unsafe, it was necessary to replace them with the least possible delay. Three plans of construction were, therefore, considered: To replace the old shaft houses by somewhat similar structures made of wood; to use steel and radically change the design; or to build reinforced-concrete shaft houses outside of 'the wooden structures, completely enclosing them. The first plan was disapproved, because it is anticipated that the mine will have a long life and the proximity of other buildings makes the danger from fire rather great. Delay in receiving material, and the necessity for closing the shafts during erection, were other factors in the situation. The second plan was disapproved on account of the high cost of steel, slow delivery, and interference with hoisting during the period of erection. The presence near one of the shafts of a large bed of hard gravel suitable for concrete made the cost of the third plan considerably less than the second, and little, if any, delay in hoisting was expected. Our expectations in this regard were fully realized. Furthermore, the work could be done by unskilled labor, which was plentiful, and the erection could be quickly started.

*Engineer in charge of construction, Cleveland-Cliffs Iron Co.

! Superintendent, Cliffs Shaft Mine.

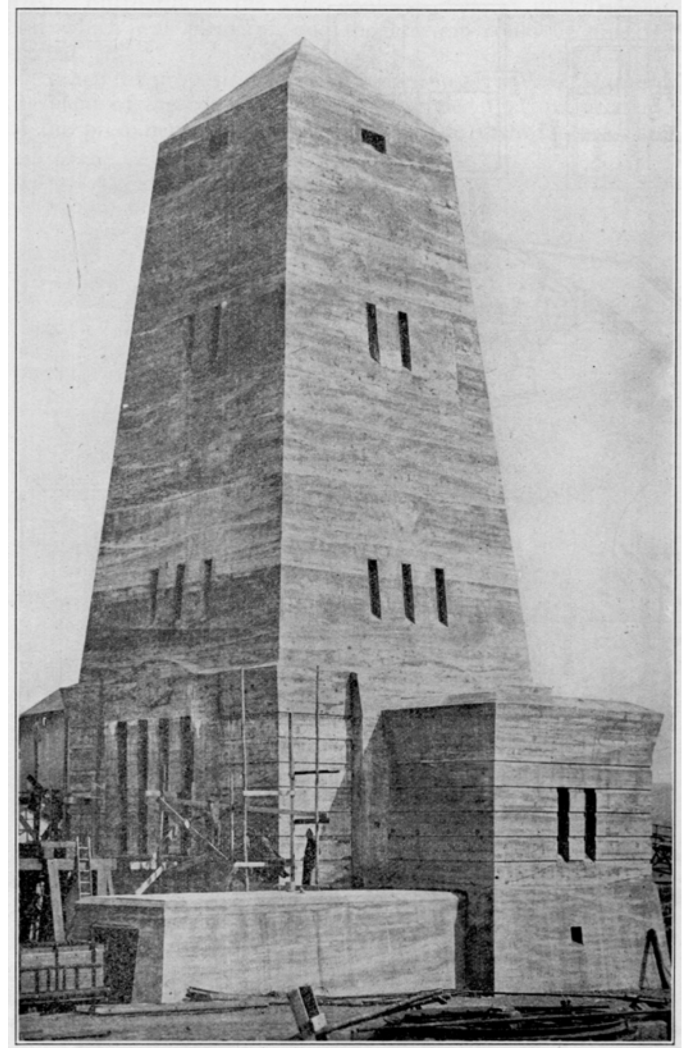

FIG. 1 THE COMPLETED *B* SHAFT HOUSE

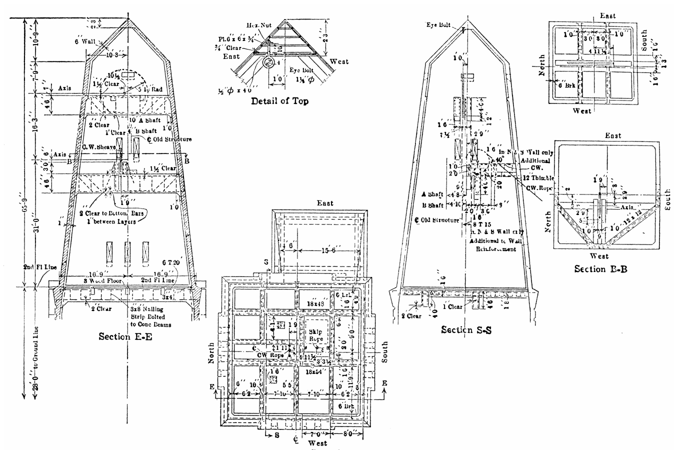

FIG. 2 PLAN AND ELEVATION *A* SHAFT HOUSE

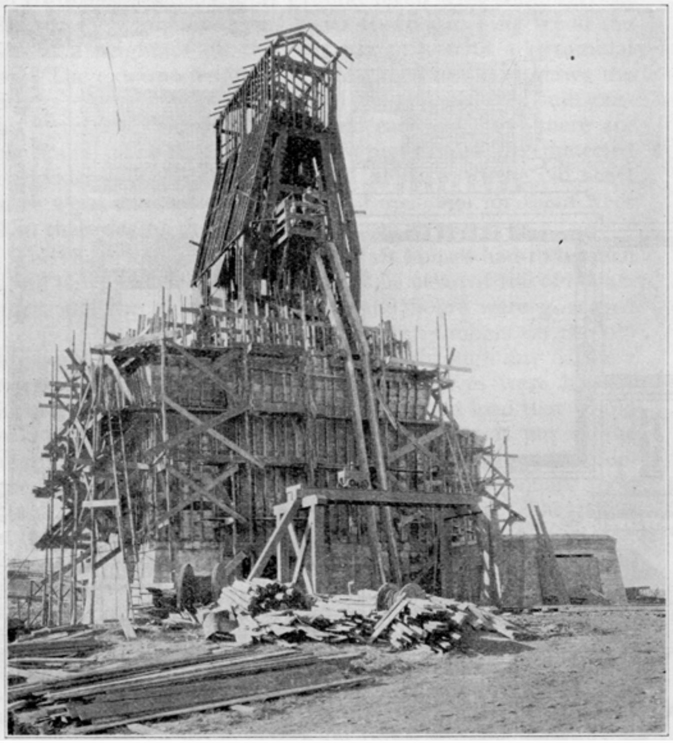

FIG. 3 *B* SHAFT HOUSE UNDER CONSTRUCTION

When the proposition was submitted to Mr. W. G. Mather, president of the company, he recommended that, on account of the prominence of the buildings due to their location, an effort should be made to combine in the design as far as practicable something of architectural beauty. Following his recommendation, the original plans were submitted to the Condron Company, Structural Engineers, of Chicago, Ill., with Mr. George W, Maher, also of Chicago, as consulting architect. Three designs were submitted by them, of which that shown in Fig. 1 was chosen.

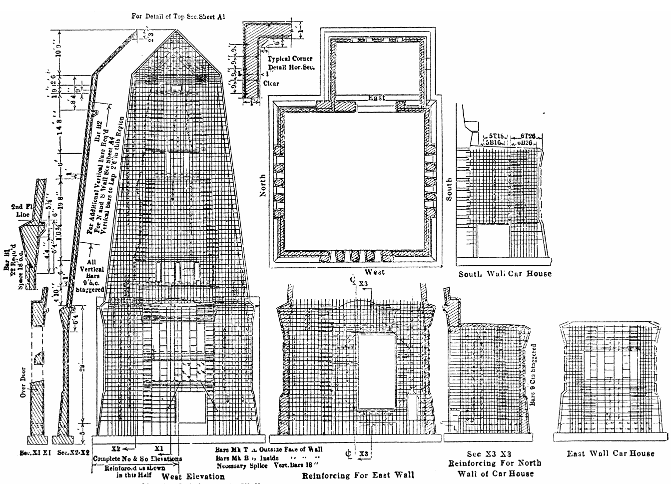

FIG. 4 REINFORCEMENT FOR *A* SHAFT HOUSE

The two shaft houses are not exactly the same in design, being right and left hand and differing in several minor details; the plan and elevation of the A shaft house are shown in Fig. 2. The design calls for a reinforced-concrete building 33 ft. (10 m.) square inside at ground level, with solid vertical walls for 31 ft, then tapering to 21 ft. (6.4 m.) square at the eaves at a height of 88 ft. 9 in. (27 m.), with a pyramidal roof. The extreme height is 96 ft. 9 in. (29.5 m.) above the footings. Except where additional sheds have been built outside, there are fourteen windows on each side, and there are three doors. The three floors above the ground are connected by a ladder way. The pockets, built in 1910, in the old shaft houses were retained unchanged, and openings for them were left in the sides of the new shaft houses.

The shape and size of the new shaft houses had to be such that all new construction work would be clear of the old shaft houses, and the positions of beams and floors were governed largely by the available openings between timbers on the old shaft houses, as it was impossible to cut through any of these timbers. The beams for carrying the sheaves were heavily reinforced and made strong enough to carry a load that would break the hoisting rope. Extra reinforcing was put in the walls under these beams. The beams for the floors were designed for a safe load of 200 lb. (90.72 kg.) per square foot, and the floors were made of 3-111. (7.6 cm.) plank. The guides for the skip and cage are carried on vertical 12-in. (30.5 by 30.5-cm.) fir timbers, which are securely fastened to the concrete beams.

Work on the new shaft houses was started on July 21, 1919, both houses being built at the same time. The A shaft house was completed on December 6, and required 725 cu. 3d. (554.3 cu. m.) of concrete; the B shaft house was completed on December 11 and required 1014 cu. yd. (775.3 cu. m.) of concrete. The work of tearing down the inside forms at both shaft houses was commenced soon after. A total of 132 working days was required for the work; 55 working days were required for pouring concrete and 77 working days for building forms and reinforcing. The maximum amount of concrete poured in any clay was 52 cu. yd. (39.75 cu. m.)

The gravel for the work was obtained from a pit 200 ft. (60.96 m.) west of B shaft, where a bin was constructed, with a chute to feed the mixer for the B shaft house and a side chute for loading into wagons for transportation to the A shaft house. All gravel for the latter was hauled by teams. A 1¼-yd. (0.95 cu. m.) gravel car, hauled up an inclined track by an air-driven hoist, carried the gravel from the pit to the top of the bin, where is was passed over a 1¼-in. (3.2 cm.) grizzly, all over-size being raked off and wasted. From this bin, the gravel for the B shaft house was drawn off into a measuring box, which was tilted into the mixer by an Ingersoll-Rand Little Trigger Hoist. The ½-yd. air-driven mixer was set below this measuring box and the concrete was drawn off into ½-yd. buckets, which were set on low trucks and trammed on a narrow-gage track to a skidway up the shaft house. At the A shaft, an inclined platform was constructed and the gravel wheeled in barrows to a 1-yd. mixer. A narrow-gage track carried the bucket to the skidway at the shaft house, as at B shaft. At both shafts, air-driven hoists installed on the second floor of the old shaft houses were used to raise the concrete to the hoppers, from which it was run through wooden chutes to the forms. These hoppers were raised as the work progressed. In order to prevent separation of the aggregate, the vertical drop of the concrete into the forms was kept as low as possible, being seldom more than 6 ft. (1.52 m.).

At B shaft, the skidway was built outside the forms for the concrete shaft house, the upper end only being embraced on the old building. When the top of the old shaft house was reached, a temporary framework of 6 by 8-in. (15.3 by 20.3 cm.) timbers was built 30 ft. higher and the skidway was connected to this. The legs that extended beyond the new roof were cut off when the concrete had been poured high enough in the forms. At A shaft, the skidway was built outside the old shaft house and inside the new one, and was carried up on a temporary framework to the roof of the new building. The concrete for the top part of the roof was dumped into a box and hoisted through a trapdoor in the roof by means of a 14-qt. (13.16 l.) bucket. This hoisting was done by hand, but less than 15 cu. yd. (11.5 cu. m.) of concrete was handled. The ground around A shaft was hard and compact and offered no* difficulty in placing the footing's, which were put in to a depth of 3 ft. (0.91 m.). Two courses of 25-lb. (11.34-kg.) rail were placed in the footings, the bottom course of five rails, and the top course of three rails. A total of 119 cu. yd. (90.98 cu. m.) of concrete mixed 1 to 5 was used in these footings. At B shaft, considerable difficulty was encountered in placing the footings. The old shaft had been put down through 60 ft. (18.28 m.) of quicksand, which had formed a crater around the shaft during sinking, and this crater had been filled with rock, which was loose and full of voids. It was therefore necessary to go down to a maximum depth of 26 ft. (7.92 m.) to obtain a secure base for the footings. The ground under the old shaft house and a round the shaft was then treated to a wet mixture of concrete, which closed the voids in the old rock fill. Three courses of 25-lb. scrap rail were placed in these footings, five rails in the bottom course, four in the middle, and three in the top course. Vertical rails were also set into the footings to tie them to the shaft house proper. A total of 339 cu. yd. (259.19 cu. m.) of concrete was put in for the footings of this shaft-house.

The lumber used for the forms was as follows: 2 by 6-in. (5.08 by 15.24 cm.) hemlock studs were used throughout and were placed 16 in. (40.64 cm.) between centers. For the first 10 ft. (3 m.) above the footings, 2-in. rough hemlock plank was used, but above this 1-in. (2.54 cm.) hemlock, dressed on one side, was used; the change from rough to dressed lumber was made for the architectural effect. The lumber was given a coat of paraffine oil before being placed in the forms.

No. 9 annealed iron wire was used throughout in holding the forms. It was placed on every studdle at intervals of 2 ft. (0.6 m.) in elevation. Patented "EZ" clamps were used to draw up the wire and hold the forms to correct dimensions. Deformed steel ½-in. (1.27 cm.) square was used throughout for the reinforcing, except over the doors and in the beams, where 1⅛-in. (2.86 cm.) square twisted steel was employed. The reinforcing was tied together and held in place with 6-in. (15.24 cm.) wire ties. Patented auger twisters were used to tighten these tie-wires. Huron Portland cement was used throughout the work, a 1 to 5 mixture being used in the footings, and a 1 to 4 mixture in the shaft house proper.

The shaft houses were built and poured in sections, varying from' 6 ft. (1.83 m.) to 16 ft. (4.88 m.) in height. While the forms at one shaft were being filled, those at the other were being extended. On the entire job, hoisting in the shafts was interfered with only once; that was for 4 hr. one Saturday night when it was necessary to stop the skip while the beams in the A shaft were being poured.

The many architectural features of the design, together with the fact that it was impossible to brace the new construction on to the old shaft houses, on account of their constant vibration during hoisting, made the work of form building difficult and slow. To help hold the forms to correct dimension during construction, concrete block spreaders were used at 6-ft. intervals. These spreaders, together with the "EZ" clamps, permitted the tightening of the form wires so that all heaving of the forms during pouring was eliminated. Great care had to he exercised in the distribution of the concrete into the forms, to prevent the weight from coming unevenly on the forms and pushing them out of line.

At first the pouring of concrete was done on both the day and the night shifts, in order to reduce to a minimum the number of lines in the walls. When cold weather set in, the height of the pour was reduced to such an amount as could be successfully completed on the day shift. After each pour the top surface of the concrete was mauled and roughed up, all refuse was blown off by a compressed-air blast, and before the new pour was commenced the top surface was washed with a mixture of cement and water. Also, when cold weather set in, each mixer was provided with a Hauck kerosene blower, which delivered a hot flame into the aggregate as it was being mixed, so that the concrete was delivered into the forms at a temperature of about 80° F. (27° C). Large canvas tarpaulins were hung 8 in. (20.3 cm.) away from the form line, on the outside of the shaft, to reduce radiation over the section to be poured, and burlap bags were used for covering the top surface of the completed pour.

The very cold weather that existed throughout the last three weeks of the work necessitated further precautions against freezing. Steam radiators were installed on the inside near the top of each shaft house; the outside forms were packed with straw between studdles; and a second line of boards was put on. In addition to this, tarpaulins were hung on the outside. When the thermometer was at zero, the concrete 24 hr. after pouring was warm to the touch.

The crew employed consisted of fifteen carpenters, including one boss carpenter; nine reinforcing men, divided into three gangs of three men each; and two puffer men; in addition, twenty-four men were used only when pouring was being done. A blacksmith and helper were used part of the time for cutting and bending bars. The job was carried to completion without a serious accident, only a few minor cuts and bruises being* sustained. The monograms placed on the panels near the cornice were cast separately in a mold, and were put in place after the rest of the building was completed.

The accompanying table shows the distribution of costs:

COST OF ERECTING TWO CONCRETE SHAFT HOUSES AT THE CLIFFS SHAFT MINE, ISHPEMING, MICH.

	TOTAL			PER YARD		
	Labor	Supplies	Total	Labor	Supplies	Total
Concrete—						
Stripping gravel pit	$ 273.84	$ 334.68	$ 608.52	$ 0.158	$ 0.192	$ 0.350
Loading and hauling gravel	2,584.30	582.83	3,167.13	1.486	0.335	1.821
Cement	516.80	5,065.31	5,582.11	0.297	2.913	3.210
Forms, erecting and tearing down	13,411.99	7,185.71	20,597.70	7.712	4.132	11.844
Excavation and grading	511.93	112.55	624.48	0.295	0.064	0.359
Mixing and placing	4,821.05	743.92	5,564.97	2.772	0.428	3.200
Dressing surface	49.45	....	49.45	0.028	....	0.028
Special tools	12.79	20.30	33.09	0.007	0.012	0.019
Preliminary construction	2,225.14	404.26	2,629.40	1.279	0.233	1.512
Reinforcing	4,924.83	3,401.51	8,326.34	2.833	1.956	4.789
Total	$29,332.12	$17,851.07	$47,183.19	$16.867	$10.265	$27.132
Sheaves, floors and runners	3,250.90	1,040.77	4,291.67	1.869	0.599	2.468
Lighting and heating	246.11	169.61	415.72	0.141	0.098	0.239
Tearing down old shaft houses	762.59	19.51	782.10	0.439	0.011	0.450
Moving tracks and chutes	620.34	8.01	628.35	0.356	0.005	0.361
Office, supervision, and consulting engineer	....	3,242.45	3,242.45	....	1.865	1.865
Total	$34,212.06	$22,331.42	$56,543.48	$19.672	$12.843	$32.515

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ATHENS SYSTEM OF MINING.

BY S. R. ELLIOTT,* E. M., ISHPEMING, MICH.

The principles of the caving system, as they apply to mining of soft iron-ore deposits, are well known, as this method has been in use for many years. It is, however, necessary to give a general description of it before describing the Athens method.

The shaft and surface equipment should be placed at a sufficient distance from the orebody so that the caving and pulling of the surface will not disturb the operations of the mine. Levels are started at the proper intervals, and when raises are completed, slicing commences at the top of the ore-body and progresses downward. The necessary precautions are taken to avoid the occurrence of large open rooms and it is customary to break sufficient capping to form a mat to prevent heavy falls of ground from crushing through to the lower sublevels and endangering the lives of the workmen. Slicing is continued, and when sufficient width and length are undercut the capping commences to cave, and in time a settlement occurs at the surface. As soon as this caving commences, the pressure on the timber naturally increases; after it extends to the surface, the amount of pressure has a certain relation to the depth. In other words, the pressure increases with the depth, but not in direct proportion. At great depths, such as that found at the Athens, 2500 ft. (760 m.), the pressure might be so excessive that the cost of keeping working places open would be prohibitive.

The actual caving of the surface in a deep mine, with a great thickness of capping, is slow and often takes years to accomplish. After sufficient width and depth have been undercut, the capping starts to break away, but through arching large masses of rock fill the opening, support the capping, and retard the continuation of caving. Caving to the surface is, therefore, retarded until either a sufficient thickness of the orebody is removed, or the width and length of the undercut part have been greatly increased. I wish to emphasize this fact of slow caving, for it is on this principle that the success of the Athens system largely depends.

*General Superintendent, Cleveland-Cliffs Iron Co.

Assuming that work is begun at the top, in this case at an elevation of about 1500 ft. (456 m.); that there is a thick bed of sand saturated with water, which, in certain areas, reaches a thickness of 150 ft.; that the body strikes about east and west and pitches on an angle of about 120 to the west; when sufficient width and length and depth have been removed, a settlement will occur at the surface and the water, and possibly quicksand, will then find its way to the workings. As mining is continued on successive sublevels, which are constantly increasing in depth, additional capping will break away and the size of the hole at the surface will increase. As the depth increases the pressure on the timbers will increase, until at great depths this pressure might become so excessive that it will be impossible to keep the main drifts open, to say nothing of working places in sublevels.

For the successful operation of the caving system, it is necessary to plan sublevels so that as soon as a gang completes its work on the top sublevel, there is a working place for it at a lower elevation. In other words, in a given territory the removal of the ore and the undercutting of the hanging wall is going on at several elevations, but the work on the top sublevel is always farther advanced than on the succeeding sublevels.

The Athens system is the reverse of the ordinary caving system. The ore, under the capping, at the greatest depth in the mine is removed first and the work gradually extends from the bottom to the top of the deposit. The shaft is sunk to its ultimate depth and drifting on the bottom, or 2500-ft. level, is started. As soon as this drift is far enough away from the shaft for another gang to work with safety, drifting is started on the 2400-ft. level.

When the orebody on the 2500-ft. level has been crosscut, as shown at D, in the accompanying illustration, raising is started, commencing at 1 and gradually working back toward 11. In the meantime crosscut E has reached its limit and raising is started in 12, and is progressing back to 22. The work on the 2400-ft. level is only slightly behind and crosscuts F and G are driven. Raises from crosscut D are connected with crosscut F and are then continued, to their ultimate height, which is the top of the orebody or the capping.

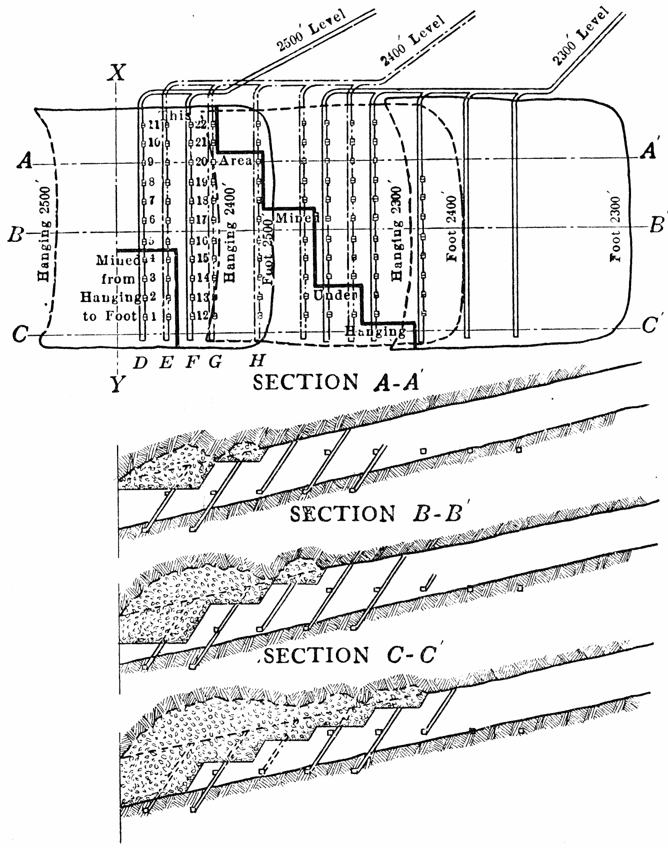

FIG. 1. IDEAL PLAN AND SECTIONS.

As soon as the first raise 1 reaches the rock, slicing is started. This gang works on a pillar, the northern limit of which is a vertical plane midway between raises 1 and 2 and the eastern limit is a plane running north and south midway between raises 1 and 12, and stepping down to the west on the same angle as the inclination of the raises. The same method of slicing is used as in the ordinary caving system. As soon as a few slices have been taken under the capping, sufficient rock is blasted to form a mat to protect the men, in the sublevel below, from heavy falls of ground. When the part undercut has increased sufficiently, the rock will fall of its own accord and blasting becomes unnecessary.

After a few slices have been taken around raise 1, work is started at the top of raise 2, and then at the top of raise 12. The method of mining in steps, and gradually increasing the depth, is shown on the accompanying plan and sections. The plan shows one area mined from hangingwall to footwall; the part of the crosscut D in this area has, therefore, been abandoned. As mining continues, all of the ore adjacent to the bottom level is removed and the level abandoned. The line of retreat for the ore on the footwall is approximately parallel to the same line under the hangingwall; it is marked on the plan "Area mined under hanging."

Caving to the surface, as previously stated, is a very slow-process, and at such a great depth as is worked at the Athens mine, we feel confident that a hole will not appear at the surface, until long after a large part of the ore has been completely removed from the hanging to the footwall. Even if a cave does extend to the surface, it will be over an area that has been mined; it will be below the working places and not above them, as is the case in the ordinary caving system. In the ordinary system, the water enters above the workings and is present during the life of the property making the ore wet and giving bad working conditions. This is not the case in the Athens system.

The Athens system is practicable only in a comparatively flat deposit. The principal argument against its use is the interest on the investment. Against this argument we expect: (1) To avoid prohibitive pressures, thus making a large saving in timber cost. (2) The orebody will be drained and no surface water will pass through the working places, because if caves to the surface occur they will be below the workings. By draining the ore and providing dry working places the efficiency will be increased, and the cost lowered. The saving in freight, by shipping a dry ore, will amount to a large sum of money over a period of years. (3) Pumping will be less than in the caving system, because it will take years to break the surface, and we shall, therefore, for this length of time, only handle the water that is in the orebody. After the cave occurs and the size of the hole on the surface increases, draining a larger area, the head will constantly be decreasing, as successive levels are abandoned. (4) It is thought that the system is safer than the ordinary caving system, because a large proportion of the gangs are always working under a solid capping, and when a hole occurs at the surface it will be over a part of the mine that has been abandoned.

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A MECHANICALLY OPERATED DOOR TO CONTROL AIR CURRENTS ON MAIN HAULAGE LEVELS.

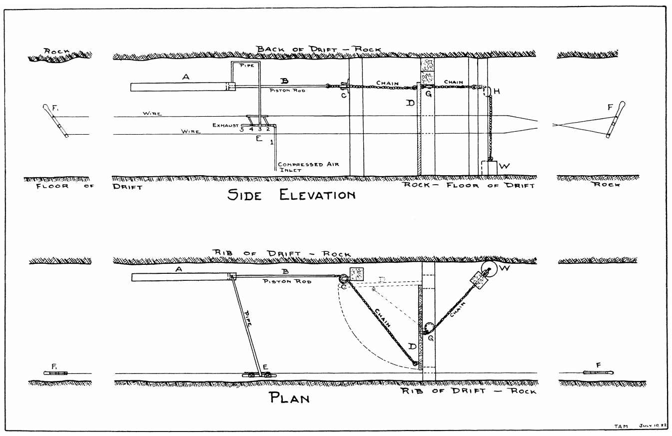
BY TOM A. MILLER, ISHPEMING, MICH.*

At the Holmes mine on the Marquette Range the main hoisting shaft is strongly downcast and during the winter months freezing temperatures were carried to great depths, the ice so formed becoming a serious problem. A means had to be found which would decrease the velocity of the downcast but at the same time put no obstacle in the way of the output.

By bratticing off the main haulage levels, the velocity off the downcast would be greatly reduced and the problem then was to design a door which would open for a train and close after the cars and motor had passed through. If this could be done without stopping the motor with its train of cars, production would not be retarded. The type of door finally adopted which is in operation at the present time is shown in the accompanying sketch.

A study of the sketch explains the operation. "A" is an air cylinder controlling piston rod "B" which is connected by a chain around pulley "C" to door "D." A pipe leads from cylinder "A" to valve arrangement "E" as shown. Door "D" is also connected by a chain around pulleys "G" and "H" to weight "W." In the sketch the door is shown closed and held so by "W." The levers "F" and "F_1" are connected to the valves "E_2" and "E_4" and in operation close one valve while opening the other. As shown, valve 2 is closed shutting off the compressed air source 1 and leaving the cylinder connected through tee 3 and open valve 4 to exhaust 5. By throwing levers F or F_1 valve may be opened and valve 4 shut, allowing compressed air to travel by route 1-2-3 to cylinder "A" where a pull on piston rod "B" is immediately set up which acting through a chain opens door "D" and lifts weight "W." Throwing FF_1 back to the position in the sketch shuts off the pressure on the piston and opens exhaust E_5 allowing weight "W" to pull the door shut.

*Mining Engineering Staff, The Cleveland-Cliffs Iron Co.



In operation the motorman reaches out and throws lever F_1 opening the door for his train and passing through closes the door behind him by means of lever F_1. At the Holmes mine these levers are situated at a distance of 175 ft. from the door, or the length of the longest train plus a factor of safety. This factor is determined by the speed of the train, and should be long enough to allow the cars to be brought to complete stop before reaching the door, in case it fails to open because of a drop in air pressure, or a mechanical break. At first some trouble was experienced by the motormen forgetting to throw the lever and running the train into the closed door, their excuse being that the door appeared to be open. This difficulty was overcome by placing red lights at the doors which burned when the door was closed hut were switched out when it was opened.

By installing these doors in pairs on all four haulage levels leading to the shaft, a complete control of the downcast was obtained.

THE MAYNE LOADER.

BY GEORGE R. JACKSON, NEGAUNEE, MICH.*

The Mayne Loader has been in successful operation since April, 1920, at the Negaunee mine, Negaunee, Mich., operated by the Cleveland-Cliffs Iron Company. This machine was designed for use on sub-levels and was constructed with that idea in mind, that is to say, it can be dismantled and handled through the ladder way of an ordinary raise. T he inventor, John Mayne, of Negaunee, Mich., is a practical miner and his idea was to develop an inexpensive machine which would not only be simple in operation but also in construction, so that repairs could he made by the miners or pipemen. The Mayne Loader was built with these specifications and has fulfilled his most sanguine hopes, for the original machine has been in operation daily since its installation two and three-quarters years ago, the cost of repairs being nominal.

In the working places where it has been used, it has nearly doubled the tons per man per day at a much lower cost per ton to the company, and at an increased daily wage to the miner. The loader is operated by the regular miners.

DESCRIPTION.

The Mayne Loader is a shoveling machine which is operated by compressed air. The dipper is pushed into the pile of broken material after which it is drawn back, elevated and the contents deposited in a car which has been pushed upon the platform of the machine. The platform revolves through a full circle of 360° on a turntable attached to the lower plate. The lower plate rests on the mine track. Four cylinders which operate the dipper, are attached longitudinally to the top plate of the machine. The machine is moved ahead or backwards by its own power, except when necessary to move some distance, when it is placed on a truck, which is part of the equipment supplied by the manufacturers.

*Superintendent, The Cleveland-Cliffs Iron Co., Negaunee District.

When the truck is not in use for moving the machine it is used by the miners for tramming timber from the raise to their working places.

The machine will load at any angle and the dipper empties directly into the car, which being on the top plate, revolves with the machine and is always oriented. It is always balanced and loads equally well at an angle as it does straight ahead, without the use of clamping devices to hold the top plate in position.

The top plate is 4⅜" above the rail of the sub-elevel. A short section of loose rails 2' 6" long is used in getting the car on and off the loader.

The complete machine, including truck, weighs about 2,000 pounds, overall length 5' 6", overall width 3' 11", overall height when operating 6' 4¾". The dipper is 2' 2" wide and 1' 9½" long.

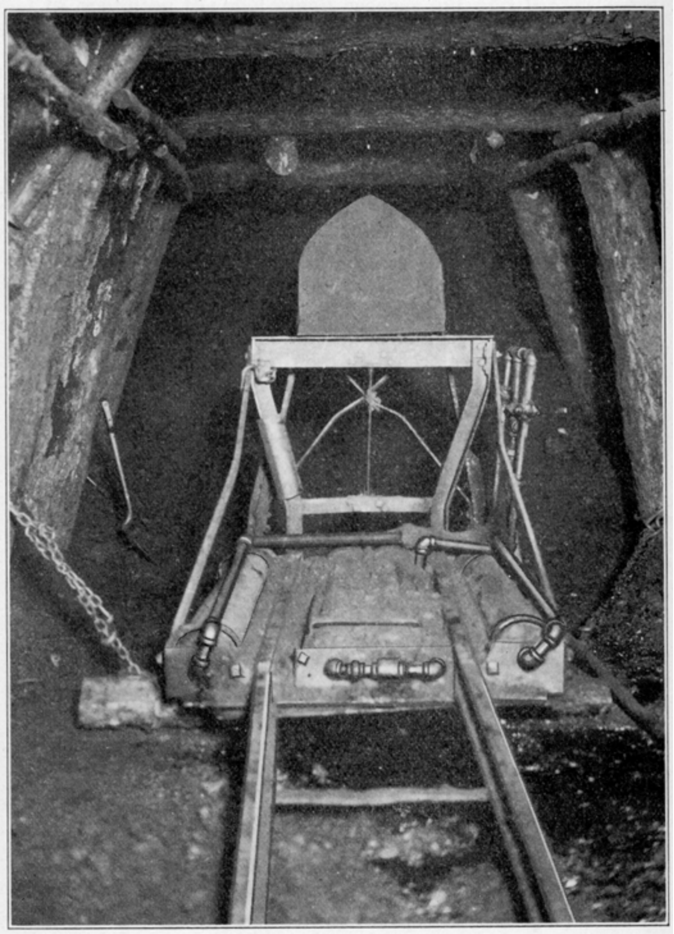
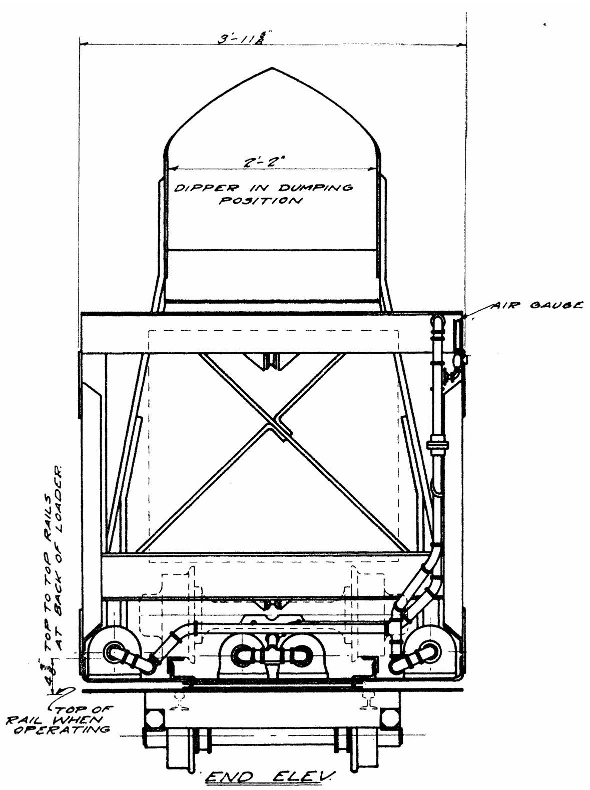


FIGURE I SHOWING POSITION OF LOADER IN THE BREAST OF DRIFT WITH CHAIN FASTENING AND SHORT RAIL SECTION LEADING FROM REAR OF PLATFORM.



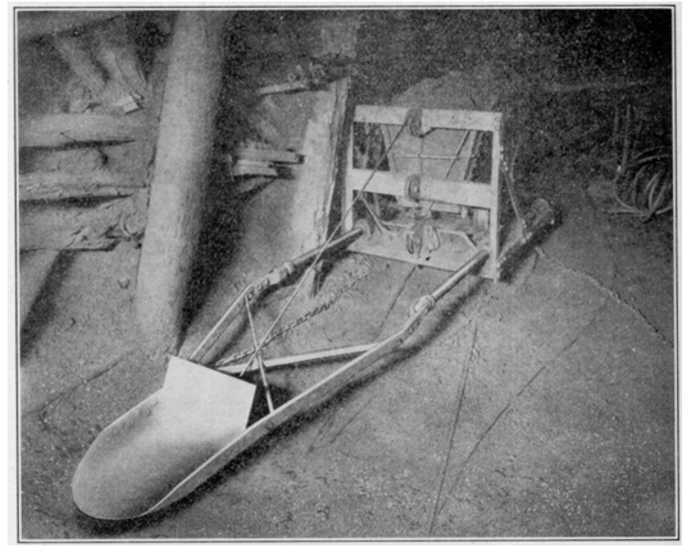
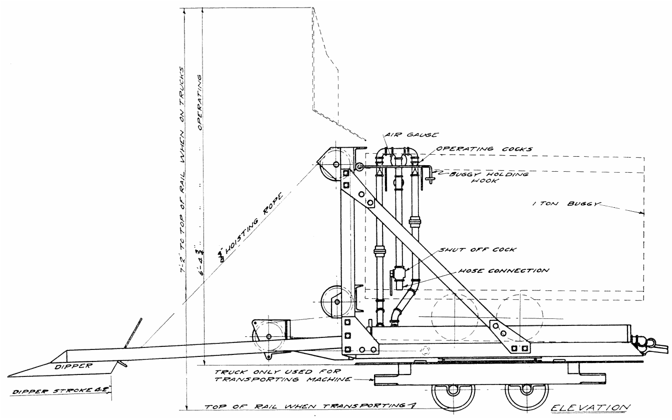


FIGURE II SHOWING CROWDING PISTONS EXTENDED FULL LENGTH.

OPERATION.

The operator stands on the ground to the right of the machine and operates the two 3-way valves which control the pistons. When ready for loading, the machine is about 5' from the broken ore. A chain is fastened from one of the front corners of the bottom plate to a leg of the last set in the drift to prevent the machine from sliding back. The dipper is dropped to* the bottom of the drift, air is admitted to the two 6" crowding cylinders, the 2" pistons of which are connected by a hinge to the arms of the dipper. The pistons move forward forcing the dipper into the ore pile. The stroke of the pistons is 42". After the dipper is filled, or the full stroke made, the air is shut off the crowding pistons. The two 5" hoisting or elevating pistons lie side by side in the center of the machine. The front ends of these pistons are tied together with a cross-head to which a 6" sheave is attached. A ⅜" rope fastened to the top plate of the machine passes over this sheave, thence to two sheaves on the front end of the machine, one being 26" directly above the other—from the top sheave the rope connects with the back of the dipper. As air is turned into the hoisting cylinders, the pistons move forward transmitting a pull on the rope connected with the dipper. The dipper is drawn backward forcing the crowning pistons back into their cylinders. When they can go no farther, the hinge at the connection of the pistons and dipper arm opens and permits the dipper to rise, through the arc of a circle, until the arms stand vertically, where they are stopped by the frame of the machine. By the force of this impact, the ore is thrown backward into the car. In order to control the elevating force, when the dipper is being raised, springs are placed ahead of the pistons on the rods in the cylinders. After a little practice the operator becomes expert and can throw the dipper full of ore at will to any part of the car. The back of the dipper is at an angle of 120° to bottom. When the dipper arms are vertical, this acts as a slide for the ore into the car, preventing spillage on the front of the machine and track.



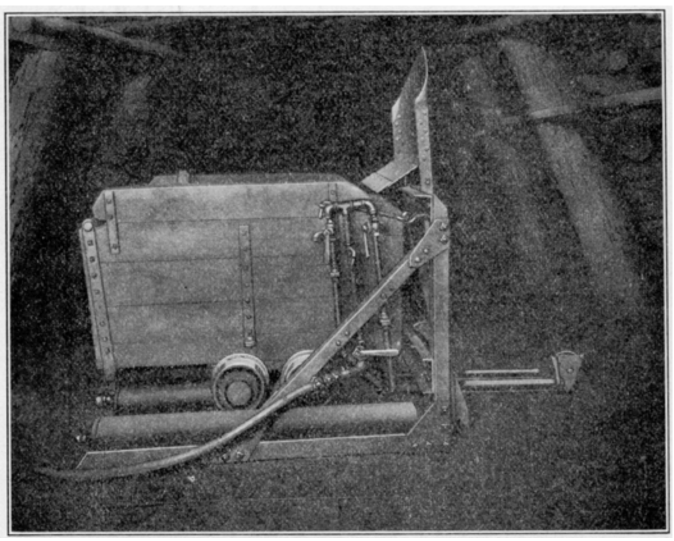


FIGURE III SHOWING AIR CONTROL LEVERS AND SHOVEL IN DUMPING POSITION.

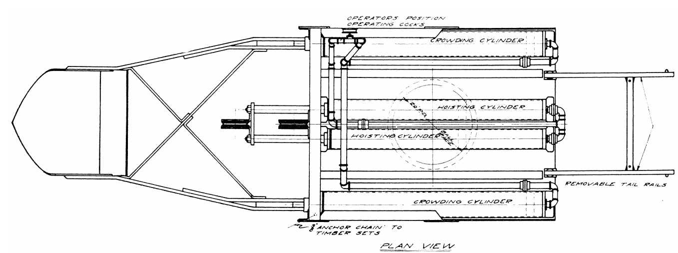
After cleaning up the ore as far as the pistons will reach, the machine is revolved 180° on the bottom plate, the dipper lowered to the track and rail-clamps placed on the rails in front of it. The two clamps are fastened together by a chain, and tighten automatically when pressure is brought against them. When air is turned into the crowding cylinders, the dipper is caught by the chain between the clamps which prevents the dipper moving farther, this forcing the whole machine towards the breast the length of the crowding pistons. The clipper is then brought back to the vertical and the machine revolved to its front position. A grab hook takes up the slack in the chain attached to the leg, and the machine is again in position to start loading. The time of moving ahead requires about two minutes.

At times, instead of using the rail-clamps and chain to engage the dipper when moving the machine ahead, a pole extending from the track to a cap is placed in the drift. The dipper hitting this pole is stopped and the exerting force moves the machine toward the breast.

The ordinary sub-level car is used. The track, on the top plate, on which the car runs, is elevated about one-half inch on the front end so that the car can leave the machine without effort on the part of the operators. The car is held on the machine by a hook which engages an eye-bolt on the side of the car.

The sub-level cars hold 16 cu. ft., but recently side boards have been added and the bottom of the car widened so that the capacity is increased to 25 cu. ft. After filling the car the miners tram it to the chute. They prefer the larger car as it cuts down the number of trips.

The original machine was equipped with a truck which was fastened to the bottom plate. This raised the top platform several inches higher above the rail than the present models. When leaded cars were run off of the machine, there was a tendency to clump. To obviate this a spool was placed on one of the front angles of the machine, several turns of rope taken around it and the end attached to the car. By this snubbing arrangement, a car could be taken off without danger of dumping. This, however, slowed up the operation, and as a machine is seldom moved for a great distance, it was decided to do away with the truck and place the lower plate directly on the rails. Short pieces of angle iron were attached to this plate to engage the track; being short they do not interfere with the machine in going around curves or passing over frogs. By placing the lower plate on the rail, the machine is much more stable, and the action of the crowding cylinders is practically in a straight line.



The simplicity of the machine is one of its chief advantages. Any miner of ordinary intelligence can operate it, and it is always ready for work. The repairs are slight. Occasionally a new sheave has to be installed which takes but a few minutes. About once every six months new leathers are needed for the pistons. If ore works in between the top and bottom plates, the top plate is removed and the turntable cleaned. In soft ore this may be necessary once a month and the time required is one and one-half hours.

A daily record is kept for each machine that shows exactly what each is accomplishing. In the working places where they are used, the miners do their own drilling, blasting and timbering, the same as the other contractors, but by using the loader they are able to earn higher wages with less work. The company, on the other hand, gets a higher product per man at a smaller cost per ton.

The following table which shows a year's record by our No. 1 loader,—the original machine made in the mine blacksmith shop which has been in operation two and three-quarters years,—is concrete evidence of what is being accomplished:

Month	Number of Men	Class of Work	Days Worked	Tons Per Man Increase Over Avg. of Mine	Contract Price Per Ton Less Than Other Miners	Increased Earnings Per Month Over Other Miners
May, 1921	2	Ore drifting	25	45.7%	30%	8.5%
June, 1921	2	Ore drifting	21	51.0%	30%	12.2%
July, 1921	2	Ore stoping	20	64.0%	29%	7.1%
August, 1921	2	Ore drifting	10	74.0%	30%	15.0%
September, 1921	2	Ore stoping	15	102.0%	36%	41.2%
October, 1921	2	Ore stoping	26	138.5%	36%	26.1%
November, 1921	2	Ore stoping	24	160.3%	36%	26.1%
December, 1921	2	Ore stoping	24	128.2%	36%	20.4%
January, 1922	2	Ore stoping	26	117.5%	36%	21.3%
February, 1922	2	Ore stoping	22	118.3%	32%	20.3%
March, 1922	2	Ore drifting	27	46.5%	30%	16.1%
April, 1922	2	Ore drifting	25	77.3%	30%	20.0%
Average				93.6%	32.6%	19.5%

The consumption of free air per ton of ore shovelled is about 250 cubic feet. The loader has operated on air pressure as low as 60 pounds.

The accompanying drawing shows the machine as it is now being manufactured by the Webster Manufacturing Company Chicago, Ill. The photographs show the machine in actual operation underground.

The Negaunee mine is now operating five of these loaders, all of which are giving excellent results. More are to be installed as soon as they can be obtained.

(December, 1922.)

FRAGMENTARY HISTORY OF POWERHOUSES OF CLEVELAND IRON MINING COMPANY FROM 1880 TO 1903.

BY S. T. NELSON.*

I started to work for The Cleveland Iron Mining Company in the spring of 1880, 42 years ago. There are two men at Ishpeming who are still living who were connected with the mechanical department previous to my time; Thomas Nelson, who was for a number of years engineer at one of your public schools, and John Painter, who was for some time engineer at the Lake mine engine house where the Nordberg compressor and the Sullivan first-motion hoist are located.

When I came to Ishpeming the first half of the Brownstone engine house, that is now used as a supply storage, was erected, and in it were installed a hoisting plant built by Dan H. Merritt of Marquette, then manager of the Iron Bay Foundry, now the Lake Shore Engine Works, and consisting of two slide valve engines having cylinders about 22” in diameter x 36” stroke (which was the type and size built for sawmills in those days) and four geared drums equipped with internal gear and pinion friction drives of precisely the same type as is still used on hoisting drums on the Bullock and Sullivan diamond drills. This internal gear and pinion device used for engaging and disengaging the drums for hoisting and lowering, with engines running constantly in one direction, was the invention of a German draftsman by the name of Jacker. It was a very ingenious device, and for slow speed hoisting it fulfilled the purpose very nicely. It was designed for the purpose of getting around J. S. Lane’s band friction clutch.

These four drums were all of them used at that time for hoisting out of what we called, in those days, the Incline Pit which, up to about two years previous to that date, had been worked as an open pit, so that the opening underground did not extend more than 500 feet from this open pit at the greatest distance. In fact, some of the openings were so close to the open pit that when they blasted, all those employed outside had to get out of the way.

*Superintendent Sullivan Machinery Company, Chicago, Ill.

These engines were all of the ordinary slide valve type, equipped with throttling governor and hand-operated cutoff. This cutoff, of course, had to he set to admit a sufficient amount of steam for the maximum load. In other words a sufficient amount of steam had to he admitted to pull all of the four drums at the same time, which condition occurred only once in a great while—perhaps not more than once or twice in an entire shift. Generally only one drum was hoisted at a time, so that the tremendous steam consumption for the amount of work done when they were hoisting only one drum with the cutoff set for four of them, can readily be imagined. The engine shafts of the two engines were connected by means of couplings, and in less than a year after the installation one of the shafts broke. I remember well how angry D. H. Bacon and J. C. Morse were about it. Mr. Merritt was there from Marquette with his engineers to prove with figures that the shaft was big enough to do the work. A large amount of time was spent in figuring and discussing the reason for the breakage, and production was tied up for some time before a new shaft could be made and installed.

A short time afterward a similar accident occurred in what was called the “Sellwood” engine house to a hoisting plant consisting of a small slide valve engine and two drums about 5 ft. in diameter. When it was found necessary to increase the size of the plant, an old slide valve engine was taken from the engine house that was torn down before the Brownstone engine house was built, and hitched to the shaft of the first engine. These two engines did not have the same size or stroke,—each had its own fly wheel, and each was operated with a throttling governor. As soon as the second engine was started the engine shafts commenced to break, in the same manner as in the Brownstone engine house, and the breakages occurred quite frequently. Then they discovered that the two engines could not work satisfactorily together, each having its own separate governor, as it was impossible to adjust the governors to such a nicety that the two would work in unison. Part of the time one governor would be closed entirely and the engine on the other end of the shaft would be doing all the work, because its governor was open. The next moment the governor on the other engine would be shut off entirely, and the engine on the opposite end of the shaft would be doing all the work.

The only time when both of the governors would be wide open would be when the load was so heavy and the speed reduced so that the centrifugal force of the governor balls could not close either of them. The result was that the engine to which steam was admitted had to pull the drum that was hoisting, and in addition the engine on which the governor was, closed against the atmospheric pressure, making a vacuum pump out of the cylinder on one part of the stroke, and an air compressor on the other. The conclusion was reached that it was the inability to get the two separate governors to work in unison that caused the breaking of the shafts. The engines were separated, and the breakage of the shafts stopped. It was then evident that this was also the cause for the breakage of the shafts in the Brownstone engine house. The two engines were separated, with the result that no breakage of shafts occurred from that time on, as long as the engines were in use. It seems strange how long a time was required to locate such an apparently simple cause that led to so much, trouble.

In this same Brownstone engine house was installed what was considered the most modern compressor ever conceived up to that time. It consisted of two slide valve cylinders about 16" in diameter x 30" stroke, with a Meyer hand-operated cutoff on each, but with no means for keeping the speed of the compressor proportionate to the amount of air used. The engineer had to be on the go constantly, adjusting the cutoff by hand, in order to keep the air pressure at 60 lbs., which was the maximum to be carried. The air cylinders, of course, were single-stage, with the air piston rods extending through the rear heads of the air cylinders. These extension piston rods were made in the shape of hollow tubes that terminated in hollow pistons. Through these, cold water was circulated for keeping the pistons in the compressor cool. This idea was patented, and great claims were made for the superiority of the compressor, due to the cooling effect upon the air of these water-cooled pistons. Two-stage compressors were unknown at that time, but compound condensing engines were known. Why compressors of this type were installed where unlimited water was available for condensing purposes we never knew, but evidently no one at that time thought of the tremendous differences in the thermal efficiency between compound condensing and simple noncondensing engines of this type. This type of engine used with a maximum boiler pressure of 75 lbs. had a steam consumption of not less than 45 to 50 lbs. of steam per I.H.P. per hour, whereas with a compound condensing engine this could have been reduced one-half, or more, and one-half of the coal saved.

The engineers in those days had an idea that a great saving could be effected by keeping the temperature inside of the air cylinders as low as possible during the process of compression, so Duncan Gilchrist conceived the idea of putting a plunger pump on each of the compressor frames, driven with a separate eccentric from the compressor shaft. These pumps were to pump cold water into the cylinders in the form of a spray for the purpose of taking the heat generated during compression out of the air. This was the method of condensing steam in the cylinders of the first type of steam engines built by Travittan, Peppin and also by James Watt, so Mr. Gilchrist and his associates naturally tried to reduce the temperature of the air by the same process as these early engine inventors used for taking the heat out of the steam in order to create a vacuum in steam cylinder. But after these pumps had been in use for awhile they discovered that the condensing of steam in steam cylinders differed very greatly from the cooling of air in the air cylinders.

In the first place the rock drills underground froze up on account of the great amount of moisture in the air, so that the drill runners had to wrap old wornout overalls around the steam chests of the rock drills, saturate these with gasoline, and set fire to the gasoline-soaked rags, in order to keep the cylinders and steam chests free from ice. This process had to be repeated every hour or two. That, however, was not the worst trouble. Most of the water of course, was evaporated by the heat of the air and condensed in the pipe line leading from the Brownstone engine house to the incline and the Sellwood pits, which was quite a distance. I remember one very cold winter night when this entire pipe line was found frozen up from end to end on account of the moisture thus formed. The only way they could thaw it out was to go to the dry house where the miners had thrown away their old overalls and other discarded clothing, cover the pipe from end to end with the old clothes, saturate them with oil, and then set them on fire. This thawing-out process required several hours, as the pipe had to be opened at every second or third joint in order to drain out the water as it melted. Underground production was necessarily delayed, but they never gave up pumping water into the cylinders until this had occurred many times. They had to be convinced, by several experiences of this kind that the plan was a failure before it was abandoned. Two or three years after pumping water into the air cylinders had been abandoned, one very cold winter's night, this same pipe had filled up with ice from the natural moisture condensed from the atmosphere. In thawing out the pipe they had taken all the bolts out of one of the flanged joints in order to drain cut the moisture, whereas they should have left in one or two of them, after the nuts were loosened up, so as to support the weight of the pipe. The nearest support of the pipe, ice and all, was a cast-iron flange joint three pipe lengths away. When this flange broke from the weight, the pipe fell on the shoulder of William H. Armstrong, the assistant superintendent. It broke his back and killed him.

After this accident drains were provided by means of valves in this pipe line in several places, and a live steam connection was made between the boilers and the pipe line. When subsequently freeze-ups occurred these bleeders would be opened and live steam turned into the pipe, in order to thaw out the ice. Even with this improvement it would take 5 or 6 hours to get the ice out of this pipe line. This method of thawing out had to be resorted to quite frequently in cold weather, even after the idea of pumping water into the cylinders had been given up.

In this same engine house were installed three tubular boilers about 60” in diameter and about 16 ft. long. The maximum boiler pressure carried was 75 lbs. For some time after this engine house was built there was no feed water heater in use. With all that steam going to waste we pumped cold water into the boilers. A feed heater was afterwards installed and connected up to the exhaust of the air compressor, but it was so inefficient that you could hold your hand on the feed water pipe leading to the boilers at any time.

To prove how low the temperature of this feed water was I shall refer to the fact that a large old-fashioned Hancock inspirator was installed, upon the strong claim of an inspirator salesman that it was more efficient to feed a boiler with a Hancock inspirator than with a pump, as all the heat that was necessary to operate a Hancock inspirator went back into the boiler, whereas the exhaust steam from a feed pump went out into the open air. Of course it sounded so very plausible that they believed it, and you can readily imagine how low was the temperature of the feed water that came from the feed water heater, that it condensed the steam in the Hancock inspirator and injected the water into the boiler against the boiler pressure. If the temperature of the water in the feed water heater had been as high as it should have been an inspirator of the Hancock type could not have been used at all. Well, in spite of the salesman’s claim that the Hancock inspirator was a more efficient means for feeding a boiler than a feed pump, those of us whose duty it was to shovel coal into the furnaces soon found out that this was a fib. The difference in the amount of coal required when the feed pump was used and when the inspirator was used was so great that it was not necessary to resort to any fine-haired system of weighing and measuring. We could readily tell it by the number of shovelfulls handled in a given time. In other words the tired feeling consequent upon hard work, and an aching back from more shoveling than we could’ stand, were the only instruments necessary to determine the difference in the efficiency of the two methods for feeding the boilers. Consequently we used the Hancock inspirator just as little as possible. The Hancock inspirator people wanted to refer to that installation as an advertisement, pointing out to prospective customers that it was installed in this modern engine house of The Cleveland Mining Company. Many is the time when the salesmen came in and found the thing not in use. Then they went to the general office and complained that we did not use this great heat-saving institution for feeding the boilers, and we were, in plain language, “jacked up” very frequently for not using it. Had it not been for the fact that the feed pump was needed for washing out the boilers, it would have been disconnected, as that was the recommendation of the Hancock inspirator people to compel us to use that new and “efficient” device.

In those days we in the engine house took great pride in cleanliness and maintenance. We would not allow a leaky gasket or a leaky stuffing-box anywhere. Once I asked Mr. Gilchrist if he would give me some paint if I would paint the breeching, boiler front, feed pipes and other auxiliaries in connection with the boiler house,—so I did the painting more than once. In the engine room the floors were scrubbed with soap and water once a week. They were as clean as any residence. The interior walls of the engine house were plastered and painted with oil paint. Roof trusses were painted black and the wood planks on top of the trusses white. The engine room windows were full of flowers that the engineers took good care of. Every piece of brass, such as handrails, valve bodies that were machined and smooth were polished every Saturday. So were cylinder heads, connecting rods and all bright work about the engines. Clean rags, waste, and all kinds of metal polish were furnished by the company. This system of cleanliness was kept up as long as I was with the company and, I believe, for some time afterwards.

About 1884 the Brownstone engine house was doubled in size. A hoisting plant consisting of four slide valve engines with about 18”x42” cylinders and four drums 8 ft. in diameter, gear-driven and equipped with Lane band friction clutches, was installed. Two of these drums hoisted from the J and K shaft, and two were used for hoisting from what was called the Incline Pit part of the time, and one of the ropes was afterwards run to the old sawmill mine, which up to that time had a small engine house of its own. This was abandoned and torn down, and the hoisting all done from the Brownstone engine house. A great part of the time one of these drums, and sometimes two of them, were idle. After these engines had been installed it was found that the valve motion, which was of the slide valve type, was not properly designed, that the exhaust passages into these engines were entirely too small, causing an excessive back pressure. Duncan Gilchrist, then the master mechanic, designed and had made a new set of valves that were double-ported, and in addition to the one exhaust, opening in the bottom of each cylinder, two additional exhaust openings were provided, which were located at each end of the cylinder, thus providing additional port area. This re-designing of the valve gear and providing additional discharge opening was considered a considerable engineering feat in those days, and attracted quite wide attention. All the master mechanics and engineers in the surrounding country came to see this great improvement. The Webster, Camp & Lane people who sold this hoist had tried to induce The Cleveland Iron Mining Company to buy a pair of engines having an automatic cutoff,—a modified type of Brown’s automatic cutoff made by the Brown Engine Company at Fitchburg, Mass. The Lake Superior Iron Company bought a pair of these engines provided with this automatic cutoff. They proved to he as good and economical as the Corliss engine, but for one reason The Cleveland Iron Mining Company did not want to pay the price, and a cheap type of slide valve engine was purchased instead. These engines were equipped with an ordinary throttling governor. They were of the same type as the slide valve engines that were being used in the coal mines. The coal mine operators were afraid of the Corliss engine, because they considered it too complicated. Besides, they claimed they could not afford to pay the difference between the slide valve and the Corliss, as they had plenty of coal and could afford to waste it. They have changed their minds on that point since.

An additional compressor was also installed in the new addition to this No. 3 engine house, an exact duplicate of the one they had, which was a Rand slide valve single-stage duplex compressor. After the new addition was completed it was next to the largest power plant in the Lake Superior iron country, and it was a beautiful looking equipment for those days. But as no automatic cutoffs were used on the hoisting engines, and the compressors were made up of simple engines non-condensing with single stage air cylinders, thermal efficiency was naturally very low in comparison with the power plant equipment that came into use shortly afterwards.

I might also mention that the first Corliss engine that came to the Lake Superior iron district was built for The Cleveland Iron Mining Company, for the old Nelson mine. It was made by the E. P. Allis Company, and had cylinders about 16”x42”. It was geared to two drums about 5 ft. in diameter. The drums were made by the Lake Shore Engine Works at Marquette. They were designed by Duncan Gilchrist who was then the master mechanic, and instead of using band friction clutches Mr. Gilchrist designed a cone-shaped friction drive for each drum. The friction discs slid on the drum shaft, the drums being loose. The outer diameter of the cone-shaped sliding element was faced with vulcanized fibre. These cone-shaped sliding friction discs were engaged with the drums by forcing them into a cone-shaped recess in the end of each of the drums, and this was done by hand power. The hoisting engine man had to handle the brake with one hand and the clutch-engaging mechanism with the other. So much more power was necessary to engage the friction device than a man could exert with one hand, that he had to use two hands on the friction drive and had no hand left to operate the brake with, so the thing of course turned .out to be a failure and had to be modified. It was operated for some years until the mine was abandoned.

This being the first Corliss engine installed in the iron country, people came from long distances to see it, and as they had been used to nothing but plain slide valve engines, it was considered an unnecessarily complicated claptrap mechanism, and very undesirable. It was this spirit that George Corliss had to combat during his entire lifetime, when he was the only builder of this type of engine.

A second-hand Corliss engine had been purchased by what we called then the Barnum and Iron Cliffs Company. It was lying in one of the mine yards near Negaunee until it was installed at the Barnum shaft for driving a ventilating fan. The rock building that is now used for the laboratory, located only a short distance away from the present general office, was originally built for this fan house. It was installed there about 1883, but the first Corliss engine to be installed and put into service was the one previously mentioned at the Nelson hematite mine.

The new power equipment of the Cliffs Shaft mine of the Iron Cliffs Company, now owned by the Cleveland-Cliffs Iron Company for the two shafts located near the general office, attracted my attention a great deal. This building was copied from the Cleveland Iron Mining Company’s Brownstone engine house, and is still standing. A Rand compressor of the same type as the one installed at the Brownstone engine house was purchased for what is now the Cliffs Shaft; but the hoisting engine and the Cornish pump were purchased from the Hodge Iron Works at Detroit, Michigan. The hoisting plant consisted of two independent 8-ft. drums, one to hoist out of each shaft, and slide valve engines of the standard sawmill type used in those days, having cylinders about 28”x28” with the steam chest and slide valve located on top of the cylinder, and equipped with hand adjustable cutoff. The cylinder guides and crossheads were mounted on the old style box type of bed, that is, it was not of the girder type which was afterwards adopted. Instead of a gear-and-pinion there was a small grooved friction pulley located on the engine shaft, or rather one for each drum, and a large grooved pulley located on the drum shaft. The grooves on the two were turned so as to match one another. The engine shaft on which the two smaller grooved pulleys were mounted naturally had to remain stationary. The two 8-ft. drums and hearings rested on planed slides on top of the girder. The grooved pulley on the engine shaft and the grooved pulley on the drum shaft were engaged by means of a jack screw arrangement that was hand-operated, to slide the entire drum toward the grooved pulley on the engine shaft. When the screw pressure had jammed the two pulleys together sufficiently tight so that the friction would pull the load, the skip, or rather the cage as the shaft was vertical, would start from the bottom and everything would go well until flat spots here and there began to form on account of slippage and sliding in the grooved faces of the pulleys. Then the cage would stop but the engine would still continue to turn, and of course the flat spots were made flatter and more numerous than before. A turning mechanism was rigged up on the drum frame for the purpose of truing up these grooves, but it did not take long to cut away the entire pulley, as the re-turning had to be done very frequently. It was only a short time until these friction pulleys had to be discarded, and gear and friction drives introduced in their place.

This engine room equipment was installed about 1881. I was then 18 years of age, and, it seemed very interesting to me, so much so that when I was working on the night shift I used to make frequent trips up there during the daytime and watch the installation of the machinery, and how I would wish that I could get that kind of a position,—installing or working around so great a plant. I tried two or three times, but of course was turned down, so I had to continue to work in the Incline Pit of The Cleveland Iron Mining Company. Little did I think at that time that that company would ever give me the contract for the hoisting engine to take the place of this, as it appeared to me, great piece of machinery. The hoisting plant that is now in use, driven with an electric motor, was built by our company to fit the foundation made for the old hoisting engine installed in 1881. The plant as installed at first was driven with a Corliss engine, which was afterwards replaced with the electric motor.

The pumping engine for the Cliffs Shaft installed at the same time as the hoist was of the Cornish type, and was planned to pump out of both shafts. There was a slide valve engine, of the same size and type as the one used for hoisting. By means of a pinion the engine drove a large gear with a crank on each end of the shaft. Reach rods were connected at one end to the crank pins, and at the other end, outside of the building, were attached cables to actuate the pumps. When the crank came to its lowest point on the downward stroke these wooden reach rods went down through a slot in the floor. When men had to come and go they either had to jump over these rods when the crank was at its lowest point, or duck under them when the crank was at its highest point. This was something that the “safety-first” movement of our day would not permit. If a man should happen to fall, and be caught by the descending rods, he would be cut in two against the slot; if he was caught by the rods coming up, there would be nothing for him to do but to stay on top of the rod until he came back down again.

In the light of present pumping equipment this was certainly a crude affair, and it came very near being as much of a failure as the friction drive for the drum. The pumps were in a measure balanced against each other, but the two shafts did not produce the same amount of water, and the pumping engine had to run fast enough to take care of the water in the shaft that produced the greatest amount. There was no way of making a long stroke for one pump and a short one for the other, and these Cornish pumps had to be very carefully speeded up in proportion to the amount of water that they were pumping, because if they drew water part of the stroke and air the other part of the stroke, they would hammer, jar and vibrate so that you would think that the entire building was coming down. To equalize the two pumps a bypass had to be opened on the pump in the shaft with the least water and the water pumped over and over. It was not long however, before this equipment was abandoned, and more modern means for pumping water adopted.

The boiler equipment in this engine house and the style of firing are especially worthy of note as a matter of early engineering history. These boilers were set such a great distance from the grates that it seems as though I could walk in under the boilers and stand almost full height under them. While I was only 18 years old at that time, I had been around my uncle's flour mill where boilers were used, and the bottoms of those boilers were not more than 36” from the grate. I could not understand why the distance from the bottom of the boilers to the grates at the Barnum should be 5 ft. or more.

But when the equipment was installed I soon noticed the reason. These furnaces were made to burn wood, which required a lot of room; that is, they used wood and coal mixed. If they had used dry hard wood it would have been what they were doing in a great many other places; but the swamps around Ishpeming were still full of cedar trees, and the wood that they were burning in this engine house when it was first started was cut in the swamp which is opposite the old cemetery. There was not a stick of hardwood in it. It was all cedar, and it was hauled out of this swamp and put under the boilers without summer drying it, and with as much snow as would stick to it. The fireman would throw in a layer of this wet green good and then a layer of coal, then another layer of wood and another layer of coal, until the firebox was full. It reminded me of charging a charcoal kiln, instead of firing a boiler. The wood would not burn of itself, so they had to use coal in order to make the wood burn.

I am satisfied now that if the furnaces had been properly designed they could have left the cedar in the swamp-and they would have got all the heat needed out of the coal. As the coal had to evaporate all the moisture that the wood contained, plus the snow and ice that was on it, I feel sure that if the same number of heat units had been transmitted to the boilers in a properly designed furnace and with a feed water heater the wood could have been saved. It was one way of getting rid of the wood. They probably used better wood, later on, but there was nothing; but cedar and a few swamp-grown spruce trees in that swamp.

I became quite familiar with the mechanical equipments around Ishpeming and Negaunee. When I was working on the night shift I spent a great many of my waking hours in the daytime going around from one engine house to another, as I was then, as now, very much interested in all kinds of mining machinery. I had permission from Mr. Gilchrist to go to the machine shop and make up any small pieces of machinery that I wanted to make for my own amusement. When he noticed my bent for mechanical matters he purchased for me the first engineering book I ever bought, and I still have it here on my desk.

The mechanical equipment at the Lake mine goes back only as far as 1890, so there must be quite a number of men still living that were there at that time. After the mine had been opened up and the shaft sunk, one of the Rand Drill Company’s slide valve single stage compressors was removed from the Brownstone engine house to the Lake. At that time the economy of the compound Corliss engine, as well as the two-stage air compressor was well known, and there was also an abundance of water available for condensing purposes, but still this uneconomical, inefficient machine was installed at this property, in those days considerable compressed air was used for pumping purposes, so that the compressors were very often running 24 hours a day, month in and month out, and a lot of money could have been saved had a compound condensing engine been used. But instead of buying an economical machine for this constant, uninterrupted service they ordered from the Bullock Manufacturing Company, a 20" and 32"x48" cross compound hoisting engine with two drums 12 ft. in diameter x 42" face. The order for this hoist was placed with our company June 1, 1890. This hoisting engine equipment was for the time, as well as for the conditions then prevailing at the Lake Shaft, a very elaborate and expensive affair. It was equipped with an indicator designed by the late Frank P. Mills, who was then the agent. A system of automatic stops was also attempted in connection with this indicator, but they were used only a short time and then abandoned. Now, if the money had been spent for a cross compound condensing Corliss compressor, and a pair of simple steam engines used for hoisting purposes it would have been quite a rational engineering decision, as the Lake mine was at that time very shallow and in fact isn't very deep even now. If I remember correctly when this hoist was started the mine was about 400 ft. deep, and 750 ft. was expected to be its ultimate depth.

Anyone familiar with hoisting engineering knows that a pair of drums 12 ft. in diameter would be about right for a depth of 3,000 ft. instead of 300, and the compound engines for this shallow depth could only waste steam instead of saving it, as the high pressure cylinder had to be made large enough to start the load when the low pressure cylinder happened to be on the dead center. In fact all hoisting engines were so figured that one cylinder could start the load, and with a high pressure cylinder so large and a low pressure cylinder in proportion, the engine would be so much too big for the work after the load was under way, that the terminal pressure became so low and the initial condensation therefore so great, that no steam could possibly be saved by using a compound engine. Besides, with a drum 12 ft. in diameter for so shallow a depth the engine had barely time to start and get under way when it was time to shut off the steam and the lift was completed under the momentum stored up in these large and heavy 12 ft. drums. In later years, when economics played a different part in hoisting engineering than they did at that time this size of drum became, you might say, standard with all of the hoisting engine builders for a depth of from 2,500 to 3,000 feet. It was also pretty well determined that it did not pay to use compound engines even at this depth, as the size of cylinders for the load to be lifted had to be determined on the leverage basis in order to start the load with one cylinder and not on the horsepower basis which had been the practice when determining the size of engines for geared hoists that carried a heavy fly wheel, as these engines were first started, and the load thrown on afterwards.

Nearly 13 years later, February 7, 1903, our company received an order for a new hoisting engine to be put in at the Lake mine, as the old shaft and the old engine house equipment were considered obsolete. This second hoisting engine built for this shaft consisted of two 20"x42" double cylinder non-compound non-condensing Corliss engines and two clutch-driven drums 7 ft. in diameter x 4-ft. face. This hoist was in operation for many years, and did the work from a greater depth and hoisted heavier loads at higher speeds than the large compound hoist that was installed in 1890.

Referring again to the cross compound engine with the 12 ft. drums, I will say that great pains were taken with the foundation for this hoist. It was given more than usual attention by the master mechanic and also by Mr. Mills. I happened to be in Houghton at that time installing the first compound Corliss engine for the Peninsula Electric Light and Power Company. Mr. Mills came into the engine house at Houghton one day and told me that he was looking for suitable sand for building the foundation for their hoisting engine. He thought that stamp sands would make an ideal mixture for concrete. Seemingly, they did not have a gravel deposit near Ishpeming in which Mr. Mills had sufficient confidence for concrete. Whether the stamp sand was shipped from Houghton or not I don't know.

In referring to the fact that non-compound non-condensing compressors and other inefficient engines were installed by The Cleveland Iron Mining Company in the early years covered by the foregoing outline, I do not wish to cast any aspersions on either the judgment or the ability of the men who determined these things, nor, the defects be laid to their lack of technical training, as after I came to Chicago in 1886, several large powerhouses were planned and laid out by technically trained men, and the engines all over the city that were used for driving the cable cars that had practically a constant load and a 24-hour service, were single cylinder non-condensing engines. I say "constant load" because the company had a number of these engines that were cut into and out of service during the day to suit the traffic requirements. Some of these engines were located so short a distance from the Chicago River and Lake Michigan, that water for condensing could be had at a nominal expense, but nevertheless these technical experts decided against it. In 1903 when the low prices prevailing on account of the then existing panic were taken advantage of by Charles T. Yerkes, and four or five large electrical street car powerhouses were built, each of which contained from 20,000 to 30,000 h.p., one of the best-known engineering firms of those days was employed to design and lay out these power plants. They installed cross-compound Corliss engines, but all of them except one ran non-condensing.

I am referring to this so as to show that those grand men in charge of The Cleveland-Cliffs Iron Company, such as J. C. Morse, D. H. Bacon, Duncan Gilchrist, and other men whose names I have forgotten, must not be held responsible by anyone on the ground that they lacked technical training, as the ones who had it were even more short-sighted.

A BRIEF DESCRIPTION OF THE DISTILLATION OF HARDWOOD AS PRACTICED BY THE CLEVELAND-CLIFFS IRON COMPANY, MARQUETTE, MICHIGAN.

BY E. J. HUDSON, MARQUETTE, MICH.*

Wood alcohol, acetic acid, wood tar and allied compounds are products of what is known as the "dry or destructive distillation of wood," which consists, in, the heating of wood in a closed vessel in the absence of air. Under these conditions the wood, is hot burned, but is decomposed into various condensable and non-condensable gases, which when cooled, form a liquid known as pyroligneous acid, containing the products previously mentioned. The residue is charcoal.

The presence of acetic acid and methyl alcohol in pyroligneous acid was discovered in about 1835. Previous to that time wood was distilled in a crude way for the production of tar, which was used in the leather industry.

The first successful wood distillation plant for the production of alcohol and acetic acid was established at Milbourne, N. Y., in about 1850, by a Scotchman by the name of Turnbull, who brought the equipment and workmen; from Scotland. The works are known today as the Scotch works and the original workmen gradually scattered to other factories in the United States so that from this one factory the industry grew very gradually to its present proportions.

*Superintendent Furnace Dept., Cleveland-Cliffs Iron Co.

This plant and others which followed, produced a crude grade of acetate of lime, which is a combination of ordinary lime and acetic acid. They also produced a crude alcohol, which on account of its poor quality did not find a ready sale. About 1865 a Mr. Pollock, a chemist of New York, began refining wood alcohol in a small way and improvements were gradually made in the refining process and a considerable demand created. In 1921 there were ninety active factories in the United States, located as follows:

Thirty-five in Pennsylvania, seventeen in New York, twelve in Michigan, four in Louisiana, three each in Alabama, Florida, Georgia, New Jersey and Wisconsin; two each in Mississippi and North Carolina; one each in Kentucky, Tennessee and West Virginia.

These plants at the present time are distilling about 3,500 cords of hardwood daily. The production of alcohol in 1919 was 17,000,000 gallons, and in 1921 8,000,000 gallons. The production of acetate of lime in 1919 was 184,000,000 pounds, and in 1921 62,000,000 pounds. The value of these products in 1919 was $32,625,000, and in 1921 $9,258,000, a decrease of approximately 71 per cent.

A large number of the plants in this country are of small capacity and produce what are known as primary products; charcoal, acetate of lime, tar and crude wood alcohol. A large portion of the crude alcohol produced in the United States is refined in a Central Refining plant at Buffalo, N. Y.

Owing to- increased cost of wood, fuel and labor and to increasing competition and decreasing prices, a large number of wood distillation plants were forced to adopt methods for decreasing the cost and increasing their income by the installation of more efficient apparatus and by converting the primary products into the more valuable derived products, such as the production of formaldehyde from wood alcohol, acetone and acetic acid from acetate of lime and creosote oil from tar, etc.

The Cleveland-Cliffs Iron company, was the first concern to make in conjunction with, a wood distillation plant, formaldehyde, acetone, acetic acid, chemically pure creosote and creosote oils for use in the mining industry.

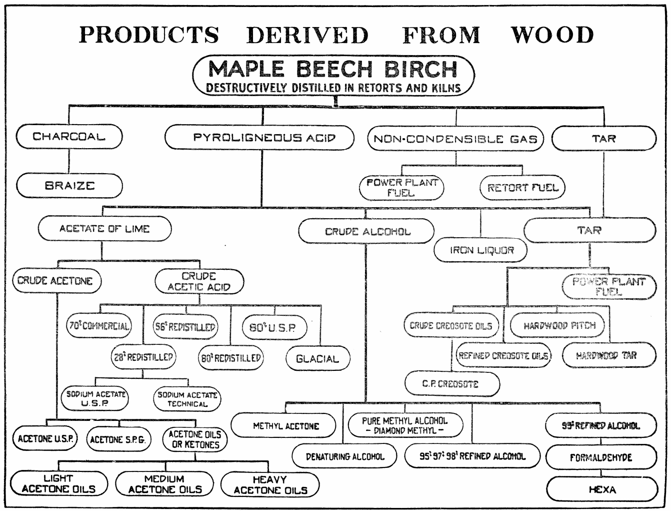
Wood consists of cellulose lignin and water; seasoned wood contains 40% of carbon, 4.8% of hydrogen, 34.2% of oxygen, 20% of water and 1% of ash.

A cord of seasoned wood containing 20 per cent of water, weighs about 4,000 pounds. When destructively distilled there is obtained from one cord of wood, 1,000 pounds of charcoal, 1,000 pounds of non-condensable gas and 2,000 pounds, of liquid products, or 250 gallons, which is known as pyroligneous acid, which contains a large number of products, as follows:

Formic Acid	Di Methyl Acetal
Acetic Acid	Methylal
Propionic Acid	Methyl Acetate
Butyric Acid	Allyl Acetate
Valeric Acid	Pyro Catechin
Caproic Acid	Pyro Xanthin
Crotonic Acid	Methyl Amine
Angelic Acid	Benzol
Methyl Alcohol	Cumol
Allyl Alcohol	Cymol
Acetaldehyde	Retene
Furfural	Chrysene
Methyl Furfurol	Paraffine
Acetone	Creosote
Methyl Ethyl Ketone	Creosote Compounds
Ethyl Propyl Ketone	

One thousand pounds of non-condensable gas is equivalent to about 10,000 cubic feet and contains approximately 40 per cent of carbon monoxide, which is combustible. The gas from one cord of wood contains 1,000,000 B. T. U.'s and is equivalent to about 100 pounds of coal. The gas is used for fuel, usually for firing the retorts.

Pyroligneous acid contains a total of three to four per cent of methyl alcohol, acetone and methyl acetate, seven to eight per cent of acetic acid and eighty per cent of water. In order to separate and refine these products, it is necessary, first to separate volatile substances from the tar and oils in solution, second to separate the acids from the alcohols and oils and finally to eliminate the water from all of the products. As it is necessary to handle about 80 per cent of water, which is a worthless product, it can readily be seen that economical methods of distillation and evaporation are necessary.



The Cleveland-Cliffs Iron Company erected a plant for the destructive distillation of wood at Gladstone, Michigan, in 1895. The wood was carbonized in bee-hive kilns and a considerable proportion of the apparatus for refining alcohol was constructed of wood. In 1901 a fifty-cord retort plant was constructed at Gladstone. The retorts have a capacity of five cords each and were known as Jumbo retorts, for the reason that previous to that time, retorts with a capacity of three-quarters of a cord were in general use. In the new refining plant the wooden apparatus was replaced with apparatus of copper and steel.

The Marquette plant was built in 1903. Kilns were used until 1915, when a retort plant with a capacity of 200 cords daily was erected. This plant consisted of twenty retorts, each with a capacity of ten cords.

The Marquette refining plant was destroyed by an explosion January 29, 1918, and a new refining plant was completed in 1919. This plant is modern in every respect and is considered to be the finest of its kind in the world.

It is an interesting fact that various parts of copper apparatus have recently been replaced with wooden apparatus which was discarded at the Gladstone plant over twenty years ago. This is due to the fact that the copper which was purchased during the war was of very inferior quality. Apparatus which should have a life from three to five years was corroded beyond: repair in three months.

Other plants were erected at Marquette for the manufacture of formaldehyde, acetone, acetic acid, pure creosote, creosote oils and sulphuric acid.

The wood carbonized at the Marquette plant consists of maple, beech and birch. Green logs 16 feet in length are delivered to the wood mill which is located near the distillation plant. The preparation of the wood in the mill consists of the following operations:

1. Sawing logs into 4-foot lengths.
2. Splitting the 4-foot lengths into “cordwood.”
3. Cutting the “cordwood” into blocks 12 inches long.

The blocks are then conveyed to a hopper which delivers the wood by gravity to the retort buggies, which are rectangular boxes with flat iron “slats” spaced 2 inches apart on the ends, sides and bottoms, mounted on trucks. Each buggy has a capacity of 2½ cords of wood.

The wood distillation plant consists of three units, the drying ovens, the retorts and the coolers.

The drying ovens are used for removing water from green wood before it is charged into the retorts for distillation and consist of long rectangular brick chambers, each with a capacity of twelve buggies of wood.

The ovens are heated with the waste heat from the retorts, which is forced into the ovens by means of fans. The wood remains in the ovens 72 hours. At the end of this period it has lost about 20 per cent of water and is in the same condition as wood which has been air-dried for one year. One oven is provided for each retort.

The wood is charged directly from the ovens into the retorts which are rectangular, air-tight, steel chambers entirely enclosed in a brick setting and are fired or heated externally, each retort having two fire boxes or ovens, one at each end. The heat from the fire boxes passes between the walls of the retort and the brick setting, then over the top of the retort to the stack. Each retort is provided with two outlets on the side which are connected with a condenser or cooler. The vapors and gas from the wood pass through the cooler, which is surrounded by running water and are condensed to a liquid, which as previously stated, is known as pyroligneous acid. After the retorts are charged with wood they are heated rapidly during, the first eight hours at the end of which period the .temperature inside the retort is about 275 degrees centigrade. It is a curious fact that when this temperature is reached, the wood, instead of absorbing heat, gives off large quantities of heat, which is usually sufficient to complete the carbonization, of the wood during the balance of the twenty-four hour period, which is required to complete the operation. Each retort has a capacity of four buggies of wood-or ten cords. The coolers are steel chambers of the same size, shape and capacity as the retorts and three, coolers are provided for each; retort.

The charcoal which remains in the buggies after the distillation of, the wood is, completed is charged directly, from the retorts into, the coolers where it remains for 72 hours, when it is sufficiently, cooled to be used in. the charcoal iron blast furnace. A standard gauge track passes through the drying ovens, retorts and coolers; the loaded buggies are charged into the dryers and.

retorts by a steam locomotive and the charcoal is removed from the coolers, and transported to the furnace, by an electric locomotive.

From a 200-cord plant there is obtained approximately 50,000 to 60,000 gallons of pyroligneous acid daily. This acid is pumped to a battery of wooden storage tanks where tar, which amounts to fifteen to twenty gallons per cord of wood, settles by gravity to the bottom of the tanks and is drawn off. This tar is the raw material for the manufacture of creosote, creosote oils and pitch. The pyroligneous acid still contains tar and oil in solution and the first operation in the refining process is to separate the soluble tar and oil from the acetic acid, alcohol and other products, contained in the acid. This is done by fractional distillation in multiple effect vacuum evaporators.

The next step in the process is to remove the acids. This is done by adding slacked lime to the pyroligneous acid. The lime which is an alkali, combines with the acids and forms acetate of lime. This material is soluble in water; and the next step is to separate the alcohol, acetone, etc., from the acetate of lime. This is accomplished by means of what is known as continuous fractional distillation, which consists in feeding a refining column with the neutralized liquor continuously and removing the volatile products or distillate and acetate of lime solution from the column continuously.

The distillate contains wood alcohol, acetone, methyl acetate and allyl alcohol and is known as “crude 80 per cent wood alcohol,” and contains approximately 16 per cent of acetone, 3 per cent of methyl acetate and about 3 per cent of allyl alcohol, and 18 per cent of water. The crude alcohol, when treated chemically and redistilled, gives a product testing about 95 per cent, and is the 95 per cent alcohol which is on the market. In our process we separate the alcohol from the other products and produce pure alcohol and a mixture of acetone, methyl acetate and alcohol, which is known to the trade as “Methyl Acetone.”

From the bottom of the continuous column is obtained the acetate of lime solution. This solution is treated in a triple effect evaporator, which distills off the greater percentage of the water and there is obtained from the evaporator an acetate of lime solution, containing about 25 per cent of acetate of lime. This is fed continuously into a pan in which a steam heated cast iron drum rotates. The drum packs up a thin film of the acetate of lime solution and in less than one revolution of the drum, the bulk of the water is evaporated and the acetate of lime in the form of paste which adheres tot the drum and which contains about 25 per cent of water, is scraped off by means of steel knives. The acetate of lime is now in a mushy condition and is fed continuously upon canvas belts which travel over steam coils. This operation removes all the water except 5 per cent to 6 per cent and the product obtained from the belts is known as 80 per cent acetate of lime.

The Marquette plant is now distilling about 6,600 cords of wood and producing 50,000 gallons of alcohol and 1,000,000 pounds of acetate of lime monthly. The yield of alcohol and methyl acetone varies from seven to eight gallons per cord of wood and the acetate of lime from 160 to 180 pounds per cord. The yields depend largely upon the kind and quality of the wood distilled.

The commercial product, known as 95 per cent refined wood alcohol, contains a small percentage of allyl alcohol which is very toxic and is the cause of blindness of men who work with an impure grade of alcohol, or who drink liquor adulterated with wood alcohol. In our process the allyl alcohol is separated and sold to the Musterole Company for use in the manufacture of artificial mustard oil, which is the principal ingredient in Musterole ointment. No matter how carefully our workmen handle this product, they invariably get conjunctivitis, “sore eyes,” which however, disappears in a day or two. We have not had a case of total blindness during” the past twenty-two years.

The refining process used at a large percentage of the wood distillation plants is an intermittent or discontinuous process, which requires a large number of units. The refining process used at the Marquette plant is a continuous process; the pyroligneous acid is fed continuously into the evaporators and pure alcohol, methyl acetone, and acetate of lime are produced continuously twenty-four hours per day, every day in the year.

The Cleveland-Cliffs Iron Company was a pioneer in this country in the use of multiple effect evaporators and continuous columns for wood distillation purposes. The primary products of the destructive distillation of wood are alcohol, acetate of lime, tar and charcoal, and the derived products are:

Formaldehyde—This product is made from pure alcohol by partial oxidation or by burning the alcohol with a limited quantity of air or oxygen. It is a gas and the commercial product is a 40 per cent solution of gas in water. It is used as a disinfectant and germacide for embalming purposes, for treating seed grain and potatoes to prevent smut, and for the manufacture of a medicinal chemical known as Hexamethylenetetramine. Wheat and potato crops are increased not less than 10 per cent when the seed is treated with Formaldehyde.

Acetone—This product is made by the destructive distillation of acetate of lime, in retorts similar to the retorts used for the destructive distillation of wood. In addition to acetone, there is produced in this process a porous carbonate of lime, which has some value as a fertilizer. Chemically pure acetone is used as a solvent for fats, resins and camphors, in dyeing and varnish industries, in the manufacture of smokeless powders, as an absorbent for acetylene gas and for the manufacture of chloroform.

Acetic Acid—This product is made by treating acetate of lime with sulphuric acid. The sulphuric acid combines with the lime, forming sulphate of calcium or plaster of paris and the acetic acid is set free and removed from the mixture by distillation under a vacuum. There are a number of grades of acetic acid, ranging from 28 per cent to 99½ percent, which is known as glacial acetic acid. This acid has the property of freezing at about 60 degrees Fahrenheit. The various grades of acetic acid are used in the manufacture of pigments, white lead, in printing and dyeing of textiles, for medicinal purposes, as a caustic, in the manufacture of medicinal chemicals, such as acetanilide and asperin. It is also used, when diluted to about 4 per cent, as vinegar.

Creosote and Creosote Oils—These products are produced by the distillation of the tar, separated from the pyroligneous acid. Cast iron stills heated with direct fire are used; for this purpose . Various grades are produced as follows: Chemically pure creosote, which is used for medicinal purposes; wood creosote flotation oils, which are used for separating minerals, by what is known as the flotation process; heavy creosote oil, used in the preparation of metal paints; hardwood pitch used by the electrical companies for coating transformers, and by the rubber industry, in the manufacture of automobile tires.

Iron Liquor—This is produced by treating pyroligneous acid with iron fillings or turnings and is used in dyeing khaki cloth and in the manufacture of printers ink rollers.

Sodium Acetate—This is produced by treating pyroligneous acid with soda ash and is used as a diuretic, in the textile industry and in the manufacture of acetic anhydride.

Pure Wood Alcohol—Pure wood alcohol is essential for the production of a large number of dyes and is also used as a solvent; it is used in the manufacture of medicinal and photographic chemicals and in the manufacture of formaldehyde.

Methyl Acetone—This is used in the manufacture of paint and varnish removers, as a solvent for nitrocellulose .and gums and in the manufacture of gas mantles and belting cements. Large quantities were used during the war for dissolving the dope used for coating aeroplane wings.

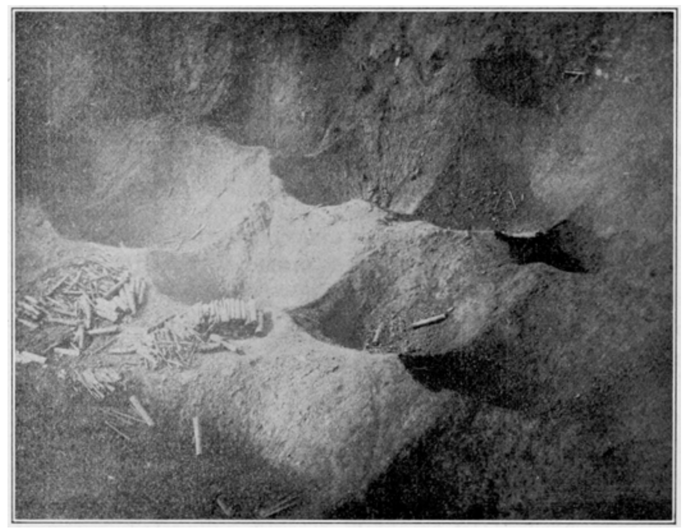
The Marquette plant requires a boiler plant of 4,000 horsepower and 9,000,000 gallons of water daily.

WHY DO WE NEED A CLASSIFICATION OF METHODS OF MINING?

BY, F. W. SPERR, HOUGHTON, MICH.*

This question: can be broadly answered by the broad assertion that every subject needs a classification for intelligent treatment and scientific discussion. The object of such treatment and discussion is the promotion of the development of knowledge, the stimulation of progress, and the increase of human welfare.

A classification is an orderly arrangement in classes according to some common characters or properties: it is the division and subdivision of things of the same general name into ultimate classes in which, the individuals possess common properties or characters.



ARCH CHUTES—MILLING PIT AT EVELETH, MINN.

The top of an arch that may be 20 ft. to 30 ft. above a haulage level. The arch is perforated with mills. The mills are funneled at the top and have loading chutes at the bottom. The ridges between the mills are called hogbacks.

Classees are natural or artificial; natural, when founded on natural relations or resemblances; artificial, when formed arbitrarily, for want of a complete knowledge of natural or actual relations.

Classifications of methods of .mining have been too artificial. What we desire to make, and what we need, is a most perfectly natural classification; and, to get this, all interested persons must contribute their quotas of knowledge, if the venture is to be successful.

A method is a definite procedure employed by an operative, under his control, for the achievement of his purpose.

Mining is removing useful material from its natural position in the earth.

A mine is a place where useful material is being removed from its natural position in the earth. If the material is a fluid, the place is called a well after the flow is under control.

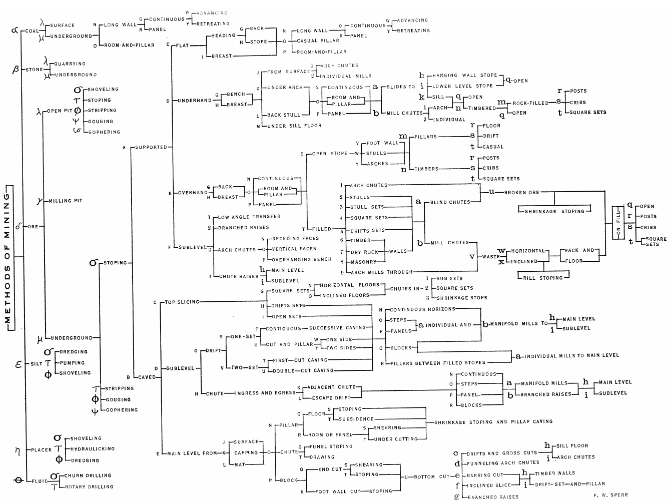
*Professor, Michigan College of Mines.

With the above definitions in mind we may proceed to work out a classification of Methods of Mining. Such a classification can always be presented most compactly and clearly in the form of a chart; and we are herewith presenting the results of our labors, thus far, in such form, together with the bases for the classifications.

It will be observed that the subject of Underground Ore Mining has been carried out in the most complete detail; and this is not finished. Much yet remains to be done to' make the classification perfect and complete.

Following the chart and based upon it, is a classification of the illustrations of methods of mining which have been published in our Proceedings, together with incidental remarks on some of the papers.

Following the tabulated classification of illustrations, we have illustrations of methods indexed according* to the chart.

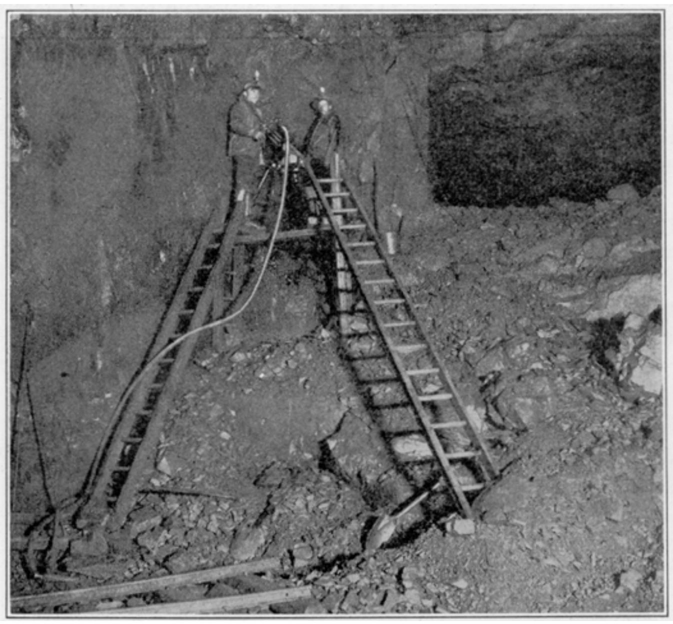


BASES OF CLASSIFICATIONS.

α β δ ε η θ	Classes of materials.
λ γ $\varkappa$	Position of material.
σ τ ϕ ψ ω	Operations.
A and B	Fundamental divisions of stoping methods.
C, D, E, F	According to character, form, and position of orebody, and character of enclosing rock.
G, H, I	Method of attack for control of ground.
I, K, L, M	According to outline and range of action.
N, O, P, Q, R	According to form and outline of mass under attack.
S, T, U, V, W, Y	Method and order of procedure as required for controlling and handling the ground.
1, 2, 3, 4, 5, 6, 7, 8, 9	Character and manner of support of ore passes.
a, b	According to number of ore passes in a unit area.
c, d, e, f, g	Preparation for initial movement of material.
h, i, k	Disposition of broken material.
m, n, q	Variety of supports.
r, s, t	Character of supports.
u, v	Variety of filling material.
w, x	Form of filling.

ILLUSTRATIONS OF METHODS OF MINING PUBLISHED IN PROCEEDINGS OF THE LAKE SUPERIOR MINING INSTITUTE.

Vol.	Authors	Pages		Chart Classification of Illustrations with Incidental remarks on Papers
		Paper	Illustration	
1898	E. F. Brown	40-45	Folders	B E K P Q T R U c h
1906	A. N. Wold		Opp. 111	A E G N T 7 b v w q
XV	P. S. Williams	179-187	180, 183	
			185, 186	B D G S T (or S U W or V T or V U) O a h
			188	A E G N T l u q
			189	A D G K N b 2
			190	A F 3 P
				(When this paper was written Sub-level Caving had not been clearly distinguished from Top Slicing.)
XVI	Floyd L. Burr	144-155	147, 151	A E G O T 4 b v w q
				(In the text are given B C I R a and other unclassified methods of removing pillars.)
	Fred C. Roberts	218-221	219, 220	
			221, 224	B E K P Q S and R U c i
			222	A F 3 P
	E. B. Wilson	227-238	229	Milling Pit.
			231	Open Pit.
	W. A. McEachern	239-243	240, 241 & 242	B C H N b h
XVIII	Willard Bayliss	133-154	138	B C I N b h, B C H N b h, & B C G N 2
	E. D. M'Neil		140-141	B C I N b h
	J. S. Lutes		148 & Folder	Open Pit Shoveling.
	Missabe Iron Range Committee		152	Milling Pit.
XIX	J. P. Hodgson	100-115	103	A E G O T 4 b v w t
			105	A E G N T 5 b v x q
			108	B C ? O a h
	H. T. Hulst	131-141	132	A E G N T l u q
	G. R. Jackson		134	B E K O S
	W. A. Siebenthal		135	A D G K N b 2
	Marquette Range Committee		137	A E G N T 5 a u q & A E G N T 5 b u q
				(In the discussion which followed the presentation of these papers. there was some discussion of Mr. Hulst's paper following the remark of Mr. Graff given at the bottom of page 138 and preceding the remark given at the top of page 139. The latter remark was part of the discussion of Mr. Hulst's paper; but, as it now stands, it appears to refer to Mr. Graff's remark to which it does not apply.)
XX	O. E. Olson	54-64	56, 57	B D G V T O a h
	O. M. Schaus		59, 61	B D H K O a l
	Frank Blackwell		62	A F 3 P
	Gogebic Range Committee			
	Edwin Higgins	88-102	92, 94	
			96, 98	A C G & H & I O
XXI	W. C. Gordon	9-23	15,17,19	B D G S U W N b h
	A. J. Myers	25-28	26	B E K P Q T R U c h
	C. H. Baxter	29-32	30,31,32	B C I R a
	F. J. Smith	46-49	48	A F 3 N
	M. E. Richards	52-55	54, 55	A F 3 P
	F. W. Sperr	205-211	207, 209	A F 2



A D G K N or O a k q

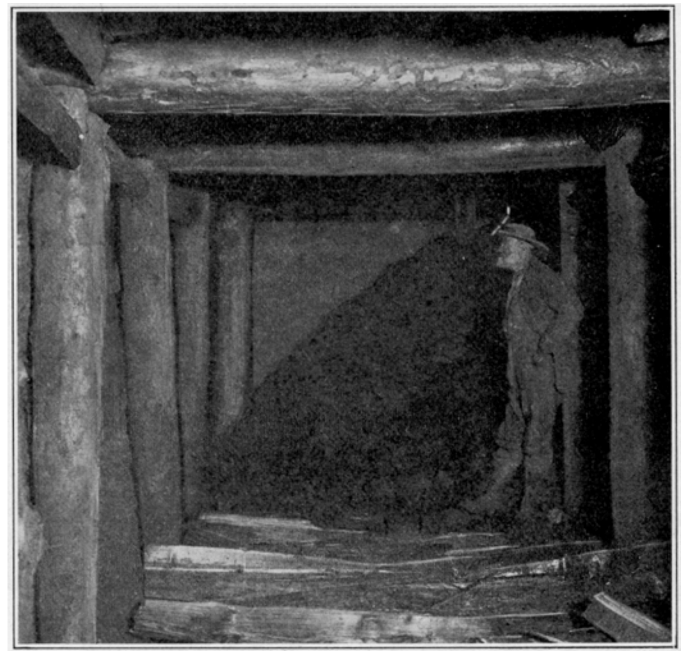
This completes the list of illustrations of methods of mining that have been published in the Proceeding's to date. Many excellent unillustrated descriptions of methods of mining have been published which might also be classified and tabulated in the same manner. Moreover, many of the illustrated papers describe methods that are not illustrated; and I wish to call special attention to the paper prepared by the Missabe Iron Range Committee, in respect to the classification of methods of mining in use an that Range. The Committee gives the three general methods as:

1. UNDERGROUND MINING.
2. OPEN PIT MINING.
3. MILLING PIT MINING.

These are the three general methods of ore mining given on our chart.

Under the head of Underground Mining this Committee gives the Top-Slicing or Caving method of mining, which is their Caving Method. On some other Range some other caving method will be known as "The Caving Method," and we try to show on the chart that there are several caving methods, legitimately and properly so-called. Under Top-Slicing the Committee gives Drift Slicing, Square Set Slicing, and Prop Slicing which is a peculiar method to be adapted locally wherever the proper conditions for it may he found.

There are two distinctly different methods of drift slicing, the one with the use of sets of ordinary drift height, the other with sets 10 ft. to 12 ft. high or even higher." It was my first thought to distinguish these as low sets and high sets, but then it seemed as though it would be more indicative to distinguish them as Drift Sets and Open Sets, letting the name of the four initial sets of the high set system give the name to the system.



B C H O a h

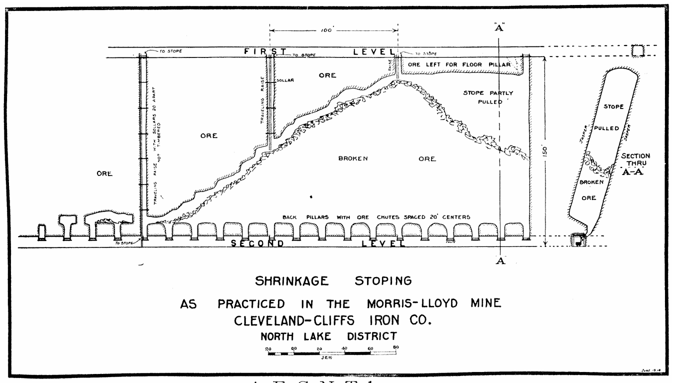
What has gone before bears largely on the benefit of a classification of methods of mining to the readers of papers, but I believe a far more important benefit may come to the writers of papers. Our best writers on methods of mining are usually busy men, and I believe it will be of great assistance to them to have a topical outline of their subject ready at hand.

The following are illustrations of Methods of Mining which have been published in the Proceedings since 1914. All earlier publications of illustrations, as well as those to follow, and also all methods discussed and published by the Institute, can be arranged according to the Chart, and published in Proceedings to follow Vol. XXII.

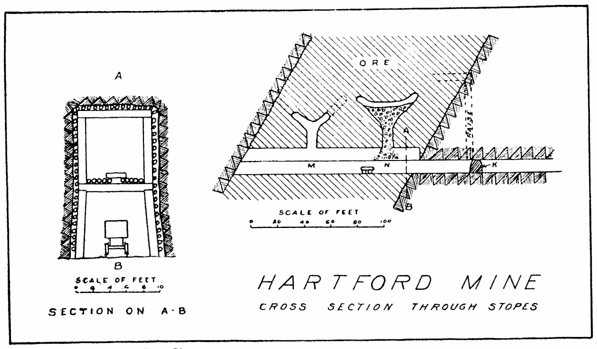
DISCUSSION.

QUESTION:—What is the difference between the Milling Pit Method and the Underhand Stoping from Surface Method?

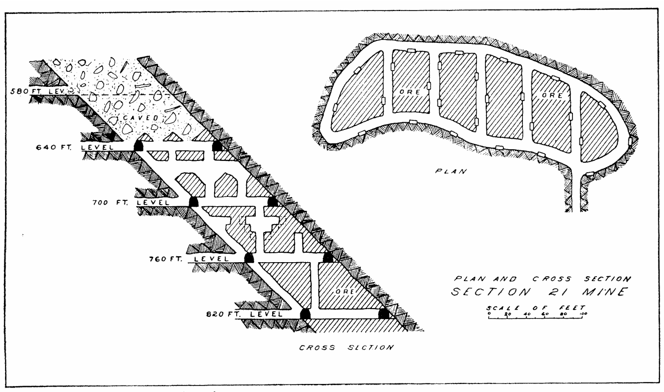
MR. SPERR:—The Milling Pit Method applies where the ore occurs in lenticular shaped masses, or in bodies of more or less equal dimensions, and where the excavation resembles a pit. Underhand Stoping from Surface applies where the orebody is narrow, long and deep, and where the excavation does not resmble a pit.



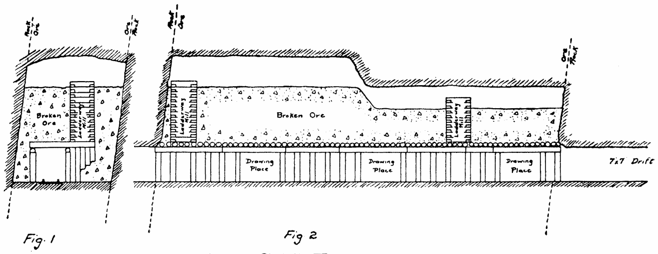
A E G N T 1 u q



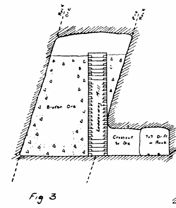
B E K O S
CHUTE CAVING TO MAIN LEVEL



A DG K N b 2
UNDERHAND STOPING



A E G N T 5 a u q



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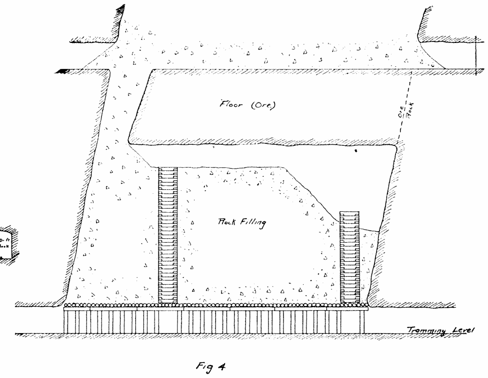
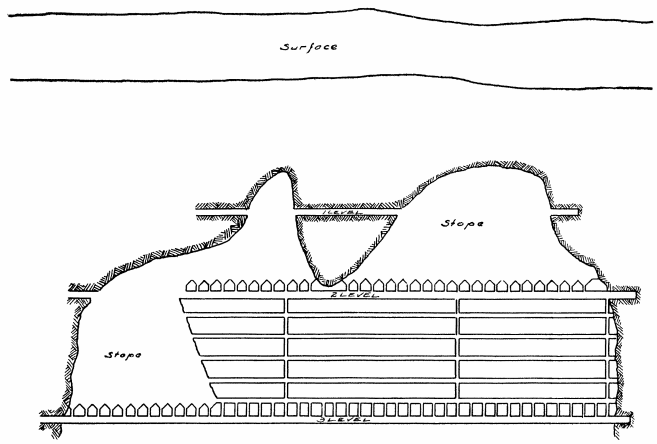


A T G N T 5 b u q



A F 3 P

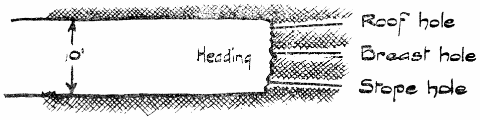


Fig. a

A C I O

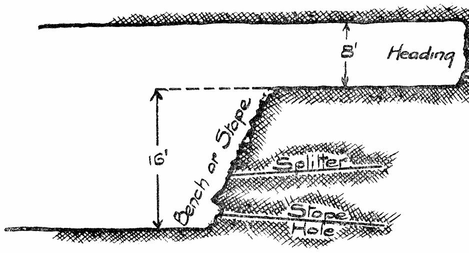


Fig. b

A C G O

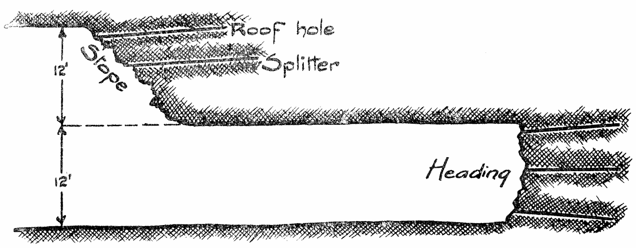


Fig. e

SKETCH 3. METHODS OF CARRYING FACE

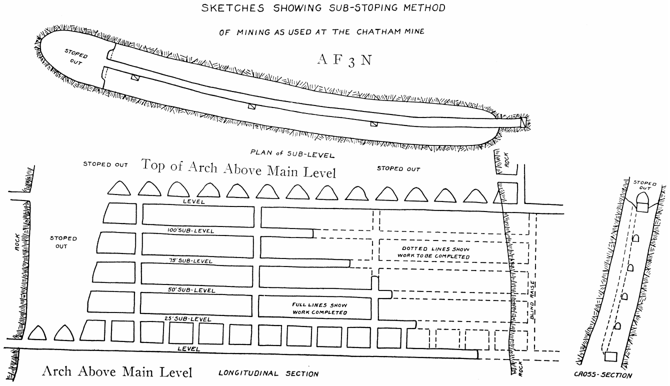
A C H O

L. S. M. I. Vol. XX, p. 96

SUBLEVEL STOPING TO TOP OF ARCH WITH RECEDING STOPE FACES

SKETCHES SHOWING SUB-STOPING METHOD OF MINING AS USED AT THE CHATHAM MINE

A F 3 N



(Sublevel caving with alternate ore pillar and one- set undercut, caving from end and drawing from both sides of undercut. Locally, the sublevels for stoping are called stopes; and only the ventilating and supply drift which is driven half way between main levels, connecting the raises, is called the sub-level.)

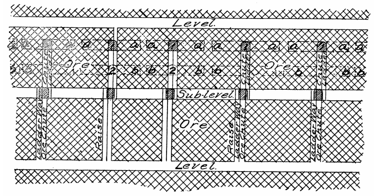


Fig. 1. Longitudinal Section of Orebody Between Two Levels—Showing how preparations for mining are made. Mining will begin in the drifts (a) at the top of each raise, and at the end of each drift farthest from the raise. When the slice of ore above the floor of drifts (1) is mined out the miners begin at (2) in the raise and work as in the slice above. The process is repeated until the level below is reached.

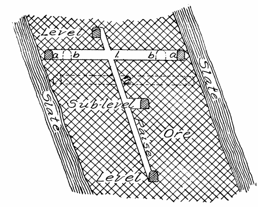


Fig. 2. Cross-Section of Orebody Between Two Levels—Showing how preparations for mining are made. Mining will begin in the ends of drifts (a) farthest from crosscut (1). When the ore about drift (a) is mined drift (b) will be opened and the ore mined from around it, and like drifts opened until all the ore above the floor of crosscut (1) is mined. Crosscut (2) is then opened and mined in like manner. The process is repeated until the level below is reached.

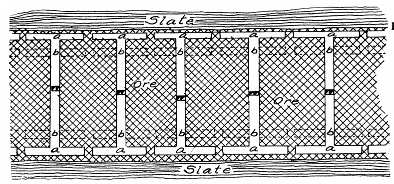


Fig. 3. Horizontal Section Through the Orebody at the Base of a Slice of Ore to Be Removed—Showing how the ore is to be mined. When the ore about drift (a) is mined drift (b) will be driven and the ore about it mined, and the process repeated until the ore back to the raise is removed, after which the whole operation is repeated about sixteen feet below.

B D G S U Y N b h

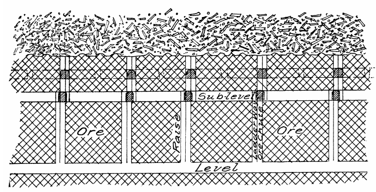


Fig. 4. Longitudinal Section of Orebody—This is the same sections as shown in Fig. 1, but the ore about the main level above, and, also, that about sublevel (1) has been mined. Above the ore is a thick covering of lagging and other waste.

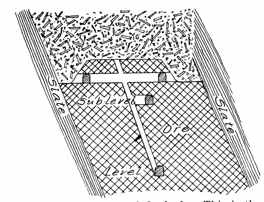
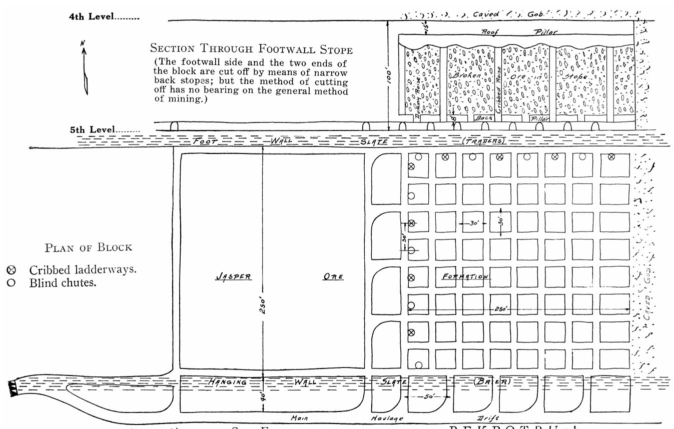


Fig. 5. Cross-Section of Orebody—This is the same section as is shown in Fig. (2), but the ore about the upper level, and that about sub-level (1) has been mined, as has also a part of that about sub-level (2).

From METHODS OF MINING AT THE CHAPIN MINE,

presented to convention of Lake Superior Mining Institute at Birmingham, Alabama, March 13-15, 1917. By W. C. GORDON, Geologist, Oliver Iron Mining Co., Iron Mountain, Mich.



BLOCK CAVING TO SILL FLOOR

B E K P Q T R U c h

CO-OPERATIVE EFFORT IN THE STUDY OF MINING METHODS.

(Discussion of the Paper of C. F. Jackson, page 24.)

BY F. W. SPERR, HOUGHTON, MICH.

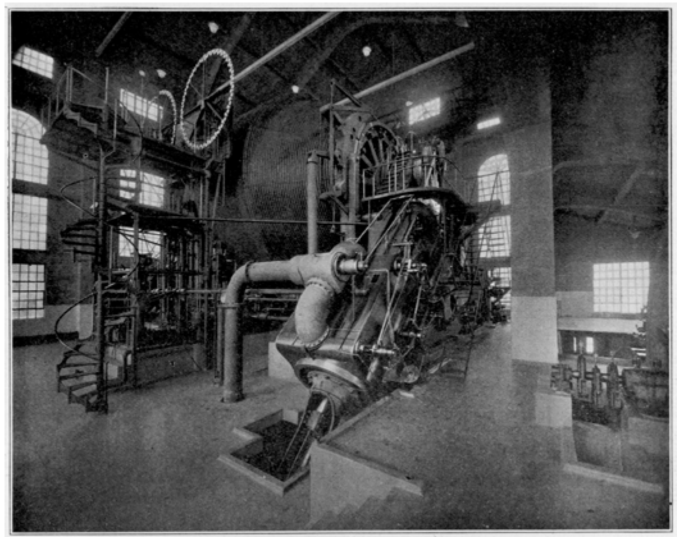
MR. SPERR:—I should be pleased to offer a few remarks on Mr. Jackson's paper. I would say that it seems to me as though the topical outline given in this paper should be of great assistance to any one in undertaking to write a paper on any mining subject. In his outline under Methods of Ore Mining, however, I am not in full accord with Mr. Jackson's views. I doubt whether it is either feasible or wise to try to build a complete classification of Methods of Ore Mining using this as a basis. Its most vital defect appears to me to be the separation of top slicing from caving methods. Top slicing has been recognized as a caving method in all of our mining. literature, and in the Proceedings of this Institute, beginning with those of the Inaugural Meeting in 1893. I think Shrinkage Stopes should go with Filled Stopes, for they are certainly filled during the operation of mining. Combined Methods will probably have to be placed under a separate classification as indicated in Mr. Jackson's chart, because there will be found an almost infinite variety of them. As to Sublevel Stopes, they are not Filled Stopes, nor even Overhand Stopes. They are as much Underhand as Overhand, or even more. It would be very arbitrary to class them as Overhand. An overhand stope is one in which the excavating is performed mainly above the feet of the miner; an underhand stope is one in which the excavating is performed mainly below the feet of the miner,

NORDBERG COMPOUND STEAM HOISTING ENGINE, QUINCY MINING COMPANY, NO. 2 SHAFT, HANCOCK, MICHIGAN.

This consists of a large compound condensing hoist with its condensing equipment,—the largest hoist in the world. It has a winding capacity of 10,000 feet of 1⅝-inch rope reaching dawn an incline shaft to a vertical depth of 6,600 feet. When winding the rope down the second cone of the drum, it has a capacity of 13,300 feet reaching to a vertical depth of 8,600 feet. The hoist operates in balance, raising a load of 20,000 pounds of rock per trip and designed for a rope speed of 3,200 feet per minute.

It is a cross compound engine having two high pressure and two low pressure Corliss cylinders. Each cylinder is arranged on an individual frame and with its crosshead, connecting rod and piston rods, forms an engine, each engine being arranged to drive the drum shaft above it. These engines are mounted on a triangular frame at the apex of which the main drum shaft is located. Each engine is set at 45° of the vertical and so arranged that two low pressure cylinders are connected to one crank pin while both high pressure cylinders are connected to the other crank pin. The low pressure pistons are supported by the crosshead and tail guides. The low pressure and high pressure cylinders are provided with separate throttle valves, the high pressure having a balanced poppet type value, while the low pressure, a rocking valve. Between each high pressure and low pressure cylinder is located a reheating receiver, the pressure in which is controlled at will by the operator.

The drum is of the cylindro-conical type which is so familiar in the Lake Superior copper district. There being eight impulses per revolution, together with the great mass of the drum, which weighs 516,000 pounds without the shaft, eliminates practically all pulsation in the rope. The drum is built up of forty-eight sections securely bolted together and thoroughly trussed within. This arrangement prevents all deflection of the drum shaft.



NORDBERG COMPOUND STEAM HOISTING ENGINE, QUINCY MINING COMPANY, NO. 2 SHAFT, HANCOCK, MICHIGAN

The hoist is fully protected by an improved gaiety stop, whereby the throttle valve is automatically closed as the skip approaches the landing. In case of overwinding, the brakes are applied automatically, and the control is. so arranged that the hoist cannot be started in the wrong direction by the operator. Overspeed is prevented by a speed governor which controls the cut-off cams of the valve gear. The arrangement is so made that the proper dash pots can be hooked up by throwing the reverse mechanism over and back.

At each end of the drum is a set of improved Nordberg type brakes, 16 feet in diameter, each one actuated by an oil cylinder which takes its oil from a loaded accumulator. The oil cylinders are controlled by special poppet valves, one controlling the lift and the other the drop of the piston and so arranged that both valves cannot be opened at the same time. The reverse mechanism and the throttle are handled in the same way. All this gearing is operated by floating lever mechanism and is under full control of the operator.

The total weight of the engine with the condensing equipment is 1,765,000 pounds. The engine covers a floor space of 60 feet by 54 feet and stands 60 feet high from the bottom of foundation to the top of the drum. The foundation under the hoist and condensing equipment contains 3,000 yards of concrete.

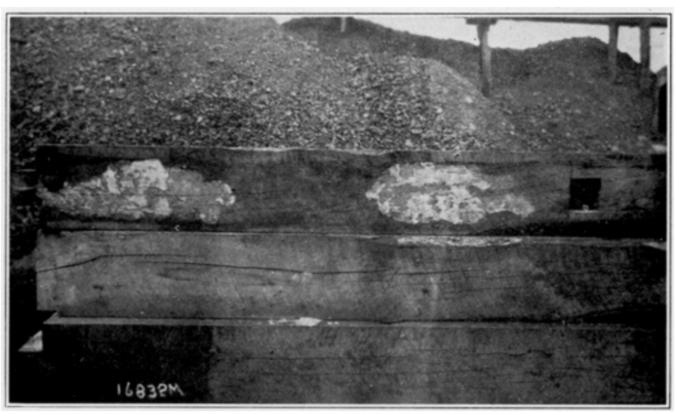
Below are some of the leading dimensions:

Drum diameter	30 ft.
Steam cylinders	32"-60"x66"
Main bearings	28"x54"
Crank pins	15x15½" diameter
Crosshead pins	8"x12"
Piston Rod,—High pressure	6" diameter
Piston Rod,—Low pressure	10" diameter
Weight of skip	10,000 lbs.
Weight of 10,000 ft. of 1⅝" rope	41,500 lbs.
Time required for one trip of 10,000 ft.	4 Min., 8 Sec.

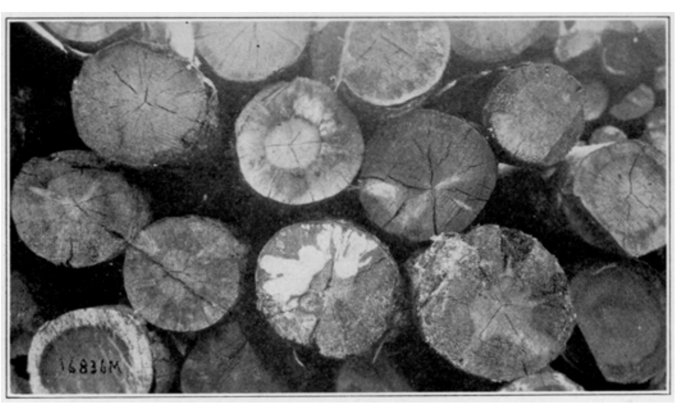
The condensing equipment is made to take care of 1,460 lbs. of steam per trip of 10,000 ft.

The dry air pump is set tandem with the steam cylinder, while the circulating pumps are located below the floor set vertically and driven through a rocker arm from the piston rod of the dry air pump.

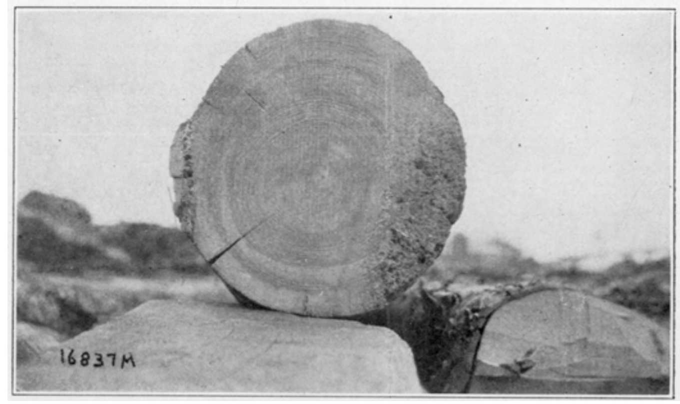
The hoist exhausts into a large steam drum 8 ft. in diameter and 17 ft. long from which the exhaust steam passes to the air pumps. The steam cylinder is 14"x36" and the dry air pump cylinder, 22"x36". The two circulating pumps are each 24"x12", being single acting.



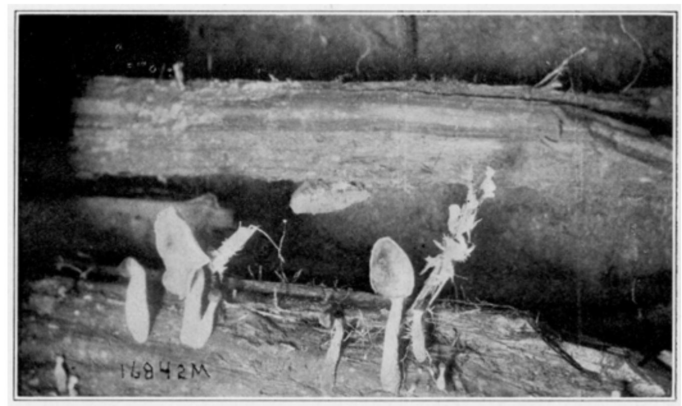
TIMBERS VERY MUCH WEAKENED BY DECAY DUE TO IMPROPER STORAGE. PROBABLY HALF THEIR VALUE GONE BEFORE THEY ARE PUT INTO SERVICE



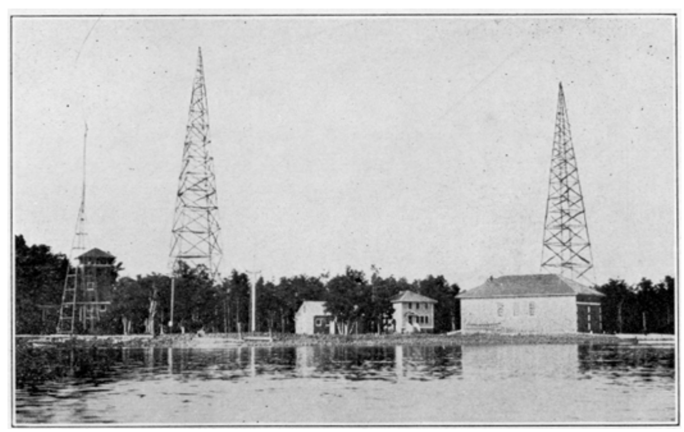
TIMBERS HELD TOO LONG IN STORAGE UNDER BAD CONDITIONS. DECAY IS MAKING RAPID PROGRESS.



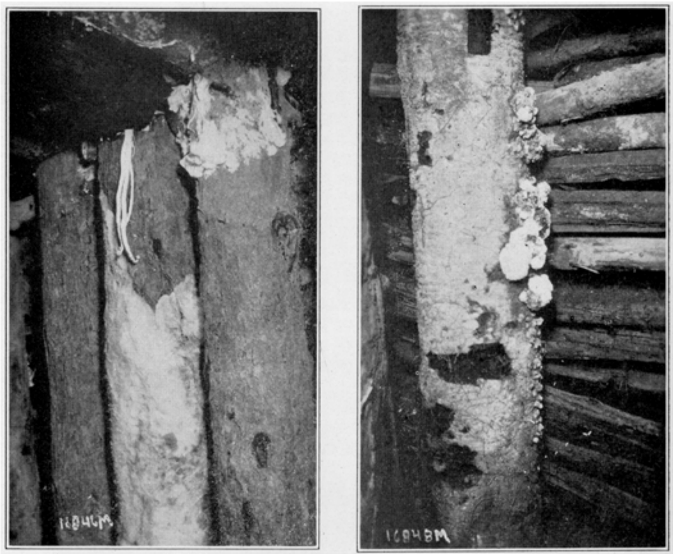
THIS WAS A GOOD POST UNTIL ONE SIDE BECAME HALF-ROTTED BY BAD STORAGE CONDITIONS.



THE LUXURIANT FUNGUS GROWTH ON THESE TIMBERS PROBABLY STATED IN THE STORAGE PILE.



EAGLE HARBOR, MICHIGAN, GOV'T RADIO STATION



THE LUXURIANT FUNGUS GROWTH ON THESE TIMBERS PROBABLY STARTED IN THE STORAGE PILE.

MINING METHODS IN THE MINEVILLE (N. Y.) DISTRICT.

BY EARL C. HENRY,* MINEVILLE, N. Y.

Description of Geology and Mining Methods of an Adirondack Iron Mine, With Recoveries, Costs, Etc.

Magnetic iron ore was mined in Essex County, N. Y., during the American Revolution; Benedict Arnold is said to have mined ore near Port Henry to secure iron for chains and spikes for the Lake Champlain fleet. Details regarding the operations prior to 1804 are not easily obtained but work on a commercial scale appears to have been started about 1838. The Witherbee, Sherman & Co. was established in 1849. The property of the district is held in fee almost entirely by the mining companies.

The Mineville iron-ore district, as well as the entire Adirondack region, belongs to the pre-Cambrian complex. The readily identified rocks consist of gabbro, anorthosite, syenite, and granite, and are classed as igneous, eruptive, and intrusive. In addition, there is a great variety of gneisses, rocks with a variable mineral composition but all more or less distinctly foliated. The Grenville series are the oldest rocks in the district; this series consists of graphitic white limestones, graphitic sandstones, and quartzites and gneisses with or without graphite.

The orebodies occur in the gneissic rocks and are comformable to the structure of the rocks. The typical occurrence of the ore in this district is in lenticular bodies with a parallel pitch to the southwest; this structure is best exemplified in the New Bed mine. The Harmony and Old Bed orebodies are faulted by two sets of diabase dikes, one set having a southwest strike and the other an east-west strike. The ores occurring in the acid gneissic rocks are non-titaniferous. The ores occurring in the gabbros and anorthosites are high in titanium: these deposits are irregular, have no structural relation with one another, and are unquestionably of igneous origin. The origin of the gneissic rocks and the ores therein contained is not settled; both the sedimentary theory of ore concentration and the igneous theory of magmatic segregation have been advanced.

*Witherbee, Sherman & Co,

The iron mineral in all the orebodies is crystalline magnetite; some very perfect and large specimens have been obtained. The gangue is siliceous in all the ores and the phosphorus varies from 1.50 to 0.04 per cent in the crude in the different ores. In the Old Bed mine, the gradation from pure ore to wall rock is sharp; while in the Harmony and New Bed mines, the gradation is gradual. The district is overlain with glacial drift. The Harmony orebody does not outcrop; it was found by magnetic needle observations.

Mineville is situated 6 miles northwest of Port Henry, which is the shipping point for the ores, by rail on the Delaware & Hudson railroad or by water through New York state barge canal and down the Hudson River. Lake Champlain is 100 ft. above sea level and is referred to as datum. The ground rises steeply to the 500ft. contour and this extends upward in a broad valley to Mineville; the mines are about on the 1300ft. contour. The general valley is closed, except for this southeastern entrance, by the Adirondack foot hills on the west and north. Bald Peak and spurs on the east, and Bulwagga Mountain on the south. The Lake Champlain & Moriah railroad serves the mines and in 6 miles of track gains 1200 ft. in elevation. The climate is similar to other districts in the northern states, with a moderate rainfall. The water supply is ample for all purposes and some water-power stations are located in the district. Lumbering has been an important industry. The lumber and some of the timber used in the operations are supplied locally; coal is shipped into the district.

The labor supply is made up of Americans, Poles, Italians, Spaniards, Hungarians, and Austrians. They are efficient mine workmen. The district is not unionized.

The diamond drill is the only machine used by the Witherbee, Sherman & Co. in exploring outcrops of unknown extent, to determine the extent of an operating orebody, or to feel out an orebody in advance of a proposed slope.

Magnetic iron orebodies of the non-titaniferous type are fairly regular. They are strictly conformable to the schistosity or gneissic structure of their hosts; formal spacing of diamond-drill holes is thus a matter of secondary importance. Dip, strike, and pitch are the controlling factors. Care is taken to locate a drill hole well within the side lines, which have been fairly well determined in the operated mine, and strictly on the strike line. So well established is the lenticular character of the greater number of magnetic iron mines that mathematical spacing by means of coordinates would lead to disastrous conclusions; the greater number of holes located on this principle would be barren, even a large lens or series of lenses might be cut only once or twice in a dozen holes.

Determining Size and Estimating Value of Orebodies.

Witherbee, Sherman & Co. has stressed the importance of core recovery; even in rock, 100 per cent core is insisted upon within reason. As a result, 100 per cent core in the ore horizon is the rule. The ore horizon is divided, by eye, into rich, lean, and very lean sections; each section of the core is split and the iron and phosphorus percentages determined. The completed analysis section may then read, for example,

1.5 ft., iron 47.5 per cent., phosphorus 0.55 per cent.
3.0 ft., iron 35.0 per cent., phosphorus 0.70 per cent.
2.0 ft., iron 20.0 per cent., phosphorus 0.48 per cent.
10.0 ft., iron 45.0 per cent., phosphorus 0.50 per cent.
16.6 ft.

The general average, on a foot basis is 16.6 ft. ore with an average iron content of 40.4 per cent.

To provide against possible loss of core, sludge samples have been taken. Experience shows that the sludge runs about five units in excess of iron in core; for example, the sludge from the foregoing would show about 45 per cent iron against 40.4 per cent shown by the core. The entire core, including the split ore, is carefully stored in racks in a core house.

The method of estimating tonnage as the result of diamond drilling is comparatively simple in the orebodies of this company. The horizontal working face of one mine is, at right angles to the axis, 1,850 ft. The average thickness of the ore and the percentage of iron is determined. Three drill holes were located at an average distance of 738 ft. in advance of working faces. The average thickness of the face working, of the ore shown in the drill holes, is the average thickness. This multiplied by the horizontal area gives the cubic feet of ore. Dip is disregarded, or allowed for possible errors. The tonnage will, of course, vary with the percentage of iron; if the cores show no diminution in thickness from working face, 500 or 1,000 ft. in advance of drilling is reckoned as probable ore.

Mining Methods Employed.

Witherbee, Sherman & Co. operate the following underground mines. Old Bed, Harmony, New Bed, and Smith. The ore is magnetite, averaging from 30 to 50 per cent iron and varying in phosphorus. The hanging wall is hard granitic gneiss and the footwall is hornblende gneiss. The orebodies are inclined, dipping to the southwest at an angle varying from 10 to 60 deg. The ore varies and is mined in thicknesses from 4 to 70 ft. Underhand stoping is used and pillars of ore are left to support the roof. Not attempt is made to sort out the rock. All the broken material is sent to the mill. Timber is used only for tracks, stairways, and pocket faces.

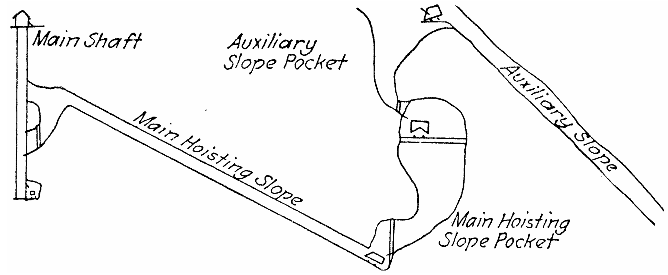


Fig. 1—Ideal Section Showing Relation Between Units

The Old Bed, Harmony and Smith mine workings are reached by a shaft while the New Bed is served by a tunnel. Each mine has a main hoisting slope, equipped with a large storage pocket at the bottom, in which all the ore in the mine is collected. From this pocket a haulage road is driven in the footwall and pockets made where necessary to serve the auxiliary slope. The ore bodies are faulted by dikes, so the auxiliary slopes are placed in the most advantageous locations to serve the faulted sections of the orebody. The main hoisting slope delivers the ore to a large pocket at the foot of the shaft, from which it is hoisted to the surface and delivered to the mill bin. At the New Bed mine, the main slope delivers the ore to a bin on the main tunnel level, whence it is transferred to the mill bin by electric locomotives.

The drilling and blasting in each slope is supervised by a slope boss. Drilling is done by one-man hammer drills of both the wet and dry types. The light hammer drills are used in stoping and are run dry in the well-ventilated stopes, ⅞-in. hexagonal hollow drill steel being used. The heavier water hammer drills are used in the drifts, sinks and small headings, 1¼-in. round hollow steel being used. Cross bits are used on all drills. In the drifts, the wedge or V cut round is used. In the stopes, a bench is advanced in the heading and the ore is stoped by the underhand method from this bench; 25 per cent gelatin powder is used for both blasting and block holing.

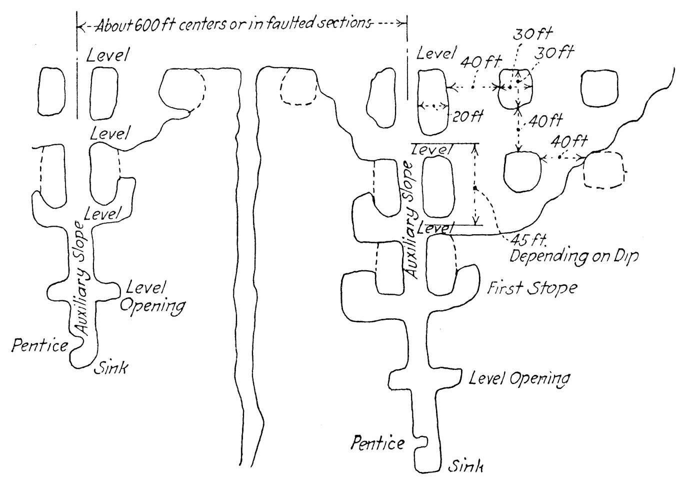


Fig. 2—Sketch of Method of Mining

Mine sampling, in the strict sense of the word, is seldom done. The crude ore, sent to the mill, is sampled daily by passing a pan every half hour through the stream of ore after it has been crushed to 4 in. Inspection of working faces gives a close approximation of the grade.

In the Harmony mine, six Type O Thew shovels are being used to good advantage; three Myers-Whaley shovels are operated in the Old Bed mine.

Trolley-type electric haulage motors are used in all the mines. The main haulage roads are equipped with 7-ton locomotives having two G.E. HM819 motors and 3-ton locomotives having two G.E. HM826 motors. The short hauls and tramming from the electric shovels is done by a locomotive built in the company's shops and equipped with a G.E. 96 motor. A 54 cu. ft. gable-bottom car is used throughout. The haulage tracks are 36-in. gage and are laid with 45-lb. rails. The hand tram cars are of the end dump type and have a capacity of 1½ tons; these tracks are 36-in. gage and laid with 30-lb. rails.

Underground storage pockets of from 500 to 1,500 tons capacity are provided at the head of each auxiliary slope and at the foot of the main hoisting slope. Skips operating in the auxiliary slopes dump the ore into the pocket, from which it is drawn into gable-bottom cars and transported to the main hoisting-slope pocket. From this pocket, the ore is drawn off into a measuring chute, holding a skip load, and delivered to the main slope skip by gates operated by air lifts.

The surface hoists are manufactured by Wellman-Seaver-Morgan Co.; they are of the double-drum, double-clutch and brake type and are equipped with 500-h.p. motors. The main slope hoists underground are 600-h.p. Nordberg; design with double drum, double clutch, and brake and are equipped with two 300-h.p. motors. The auxiliary slopes are equipped with Nordberg 300-h.p. double-drum, double-clutch, and brake type hoists with two 150-h.p. motors. These slopes are also equipped with 52 and 75-h.p. Lidgerwood single-drum clutched hoists. The power supplied is twenty-five cycle, three-phase, 440-volt. The electric repeat-signal system is used. The surface cages have a capacity of twenty men and the underground cages, twenty-eight men. The cage in the vertical shaft is equipped with safety catches and the Lilly safety controller is used on the hoists operating the man cages. The surface skips have a capacity of 3½ tons and the main slope skips, 7 tons. The rope is 1⅛-in. plow-steel, regular-lay. The surface and main hoisting slope skips are operated in balance and the auxiliary slope skips out of balance. The hoisting speeds are: For surface hoists 800 ft. per min., main slope hoists 1200 ft. per min., and auxiliary slope hoists 600 ft. per min.

Electric pumps are used in all the mines with air pumps held in reserve. The capacities vary from too to 4.00 gal. per min. The mines are comparatively dry.

The following types of air compressors are in use:

Nordberg 5600 cu. ft., operated by steam.
Nordberg 2500 cu. ft., operated by electricity.
Ingersoll Rand 2500 cu. ft., operated by electricity.
Ingersoll Rand 1200 cu. ft., operated by electricity.
Ingersoll Rand 600 cu. ft., operated by electricity.
Ingersoll Rand 300 cu. ft., operated by electricity.

The ventilation is natural. The mine workings are connected to the outcrop pits and the circulation of the air is controlled by drifts and doors.

The mine is lighted by no-volt, a.c, lighting circuit; the main stations are illuminated by flood lighting. The individual miners use carbide lamps.

A Stromberg-Carlson telephone system connects the various slopes and underground hoist stations to the mine central. The mine central is connected to the surface telephone system.

The following records of production are the results obtained for year 1921, operating at 60 per cent of capacity. The long ton of 2240 lb. is used. All labor is employed by the day, except in stoping, drifting, and tramming; the stoping contract is figured by the ton, the drifting contract by the foot advance, and the tramming contract by the car.

	Tons Per Man Per Hour	Man Hours Per Ton
Stoping	4.6	0.217
Development	3.3	0.303
All underground labor	0.74	1.35
Total organization	0.43	2.33

The classification of labor for the total organization is as follows:

	Per Cent		Per Cent
Mines	58.1	Surface construction	3.5
Mills	13.4	Laboratory and testing plant	0.6
Electrical repairmen	1.3	Engineering	1.0
Foundry and shops	6.7	Office	3.0
Power plants	4.2	Hospital	0.6
Supply department	1.2	Watchmen	0.1
General surface	6.3		

The labor turnover for the year was 130 per cent; this, however, does not mean that all new men were employed, it includes the men who drew their time and were away for over three days before returning to work. The total labor costs are 58 per cent of the total cost of production.

The following results were obtained from explosives during the year:

Operating	1.40	tons ore per pound of powder
Development	0.57	tons ore per pound of powder
Total operating and developing	1.10	tons ore per pound of powder

To place the ore in the head house requires 9.5 kw.-hr., which is distributed as follows: Mining (compressed air) 2.84 kw.-hr.; haulage, 0.56 kw.-hr.; hoisting, 5.30 kw.-hr.; pumping, 0.40 kw-hr.; lighting, 0.40 kw.-hr.

The total cost of supplies used, expressed in per cent of the total, is:

	Per Cent		Per Cent
Explosives	31.0	Lumber	4.6
Oils	0.6	Tools	0.7
Pack and waste	0.2	Electrical supplies	5.0
Power	24.6	Air hose	0.2
Iron and steel	9.8	Wire rope	2.6
Castings	3.1	Miscellaneous	8.9
Bolts, nuts and washers	5.9	Shop supplies	1.5
Pipe and fittings	0.9		

Supplies cost 42 per cent of the total cost of production.

SAFETY AND WELFARE MEASURES.

The safety program is organized through the general safety first committee, which is composed of the heads of departments with the general manager acting as chairman. Each month, one of these members and men selected from the several departments act as a surface safety first committee and inspect the plant. The mines safety first committee is organized in a similar manner; both of these committees report to the general safety first committee. A prize is offered to the best safety first suggestion proposed by an employee during the month and a reward is made for all suggestions accepted.

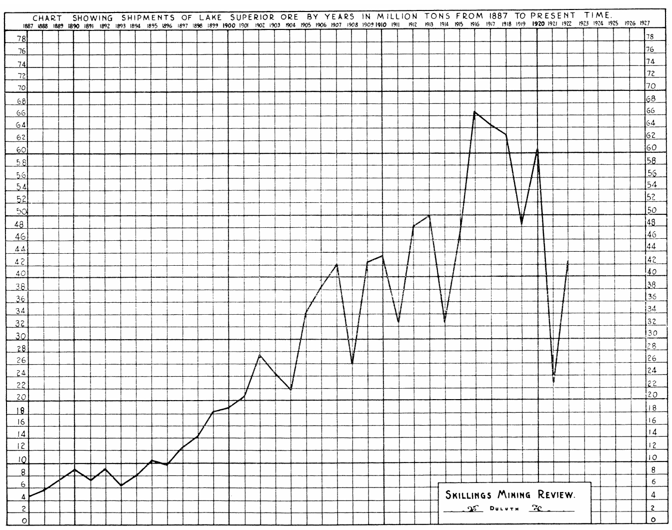


CHART SHOWING SHIPMENTS OF LAKE SUPERIOR ORES BY YEARS IN MILLION TONS FOR 1887 TO 1922, INCLUSIVE.
(By Courtesy of Skillings' Mining Review, December 9, 1922)

The welfare work is carried on by the community committee, which consists of one representative from each of the two companies operating in this district and one for the community. This committee employs a director, who has charge of all welfare work. The activities are numerous; they consist, in part, of an entertainment program at the community building, band organizations, visiting nursing, sanitation, garbage disposal, sidewalk improvements, Fourth of July and Labor Day celebrations, community fair, and athletic activities. The director and community committee also take an active interest in all matters pertaining to the welfare of the employees and the community.

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BIOGRAPHICAL

GEORGE BREWER.

A native of Cornwall, England, born July 23, 1842, in the parish of St. Teath.

As a boy he was called upon to help in the support of his mother, on the death of his father, working in the mines for seven years. He emigrated to America in 1866 working at the Bruce mine, Ontario, Canada.

He came to the United States in 1869, first going to Ishpeming for three years and then to the Jackson mine in Negaunee. He later had charge of the South Jackson mine for ten years. He spent one year at the Peninsular mine, Houghton, Michigan, returning as captain of the Rolling Mill mine, Negaunee, until the spring of 1885.

In June, 1885, as mining captain he opened the Aurora mine, Ironwood, Michigan. He remained at the mine as captain and superintendent for many years resigning his position to enter the furniture business with his son Fred. He later disposed of this business and became mine inspector far Gogebic County.

In 1912 he retired from that position.

Throughout his life he was interested in the civic and social welfare of the communities in which he lived and waged many battles against the immorality of the early days on the Gogebic range. He was always a loyal American citizen.

His death occurred Tuesday, December 15th, 1920.

EDMUND D. BRIGHAM.

Born in Dunkirk, N. Y., December 29, 1856. Removed when a child to Chicago, in 1864, and from there to Sharon, Wisconsin, where he received his education, in the public schools and the Sharon Academy. At the age of 16 he went to upper Michigan as a telegraph operator for the Tilden Iron Mine & Furnace Co.

From December, 1873, until November, 1874, he worked as train dispatcher for the C. M. & St. P. Railway at Western Union Junction and Racine, Wis. In 1874 he entered the service of the Chicago & Northwestern Railway at Ishpeming. In 1880 he became traveling freight agent, and then chief clerk of the general freight department at Chicago. Later he was division freight agent and general freight agent, and in 1910 was made assistant freight traffic manager, which position he held at his death on March 5th, 1921.

Mr. Brigham's early experience in upper Michigan brought him in touch with the production and shipment of iron ores and one of his principal activities as assistant freight traffic manager was the direction of such freight movement.

During the railroad administration he was district manager at Duluth, Minnesota, later returning to take charge of the distribution of coal in the same capacity.

He was a courteous gentleman to all and was very widely known and admired by most of the operators in the mining region.

AUGUSTUS C. BROWN.

Augustus C. Brown was born in Washington County, New York, February 10th, 1833, and died in Marinette, Wisconsin, June 1, 1890. He was of Scotch-Irish extraction, his people having emigrated to this country in pre-Revolutionary times.

He received a common school education in New York State and came to Wisconsin in 1853 engaging in the lumber business with Daniel Wells, Jr., of Milwaukee, and Jessie Spaulding, of Chicago, and for a number of years managed the Menominee River Lumber Co. He later bought an interest in the N. Ludington Co. and continued as the managing head of that company until 1877, when his attention was attracted to the new and rich discoveries of iron ore on the Menominee range. Jointly with J. J. Hagerman and J. H. Van Dyke and others, he formed the Menominee Mining Co. which company developed practically all of the large mines which have been operated on the eastern end of the Menominee range.

Mr. Brown became agent or general manager of the company and continued to be connected with the same until 1887, at which time the company concluded the disposition of most of its mines and wound up its business.

During a portion of the same period he was also largely interested in the development of the Cripple Creek mining district in Colorado, and, in connection with J. J. Hagerman and others, financed and built a large portion of the Colorado & Midland Railway. Mr. Brown was also largely interested in banking and was president of the Stevenson National Bank of his home city and director in Milwaukee and Chicago institutions.

He was married in 1861 to Miss Parmeglia A. Gould, bv which marriage were born one daughter and three sons, all of whom survived him.

ALEXANDER M. COW.

Born December 16th, 1861, at Dixon, Illinois. Early in his life, his parents moved to Evansville, Indiana, and later in 1879 to Washington, Pa., where he entered Washington and Jefferson College in the Class of 1881. Leaving that school he entered Ohio State University and graduated in 1883 as a mechanical engineer.

He was employed by the Perm Railway mechanical department from 1884 to 1888; by the Allegheny County Lighting company from 1888 to 1892; as consulting engineer and superintendent of erection in rolling mills in the Pittsburgh district from 1892 to 1895; in the experimenting department of the G. H. Westinghouse Electric & Manufacturing Co. from 1895 to 1903. Much of this work in the latter company was in the investigation of gas producers, one type of which he patented.

He later experimented with a copper furnace, the explosion of which burned him terribly. In 1905 he left Pittsburgh and came to Duluth as assistant chief mechanical engineer, of the Oliver Iron Mining Co. During his employment with this company he developed many unusual mechanical devices, especially giving attention to the design of stripping cars, steam shovels and other mining machinery. He patented several useful improvements in the machines used in mining operations, among which are the following:

Log washer improvement, 1911; log washer improvement, 1919; water cooler, 1920; nine patents on improvements to stripping cars and several on steam shovel dippers.

In all eighteen patents were allowed him, indicating how versatile he was and how clearly he could think out a mechanical problem.

Lie was a genial companion, a kind and true friend, a devoted father and husband and an interested and stalwart citizen. He died March 8, 1922.

JAMES D. IRELAND.

James Duane Ireland was born in 1878 and died December 6, 192.1, at Cleveland, Ohio. He was a graduate of Yale, 1900. He held degrees of mining and mechanical engineering from the Massachusetts Institute of Technology, receiving same in 1902 and 1903. After completing his studies he was employed at Camp Bird mine, Colorado, and later on at various points in Arizona, Colorado and Mexico. In 1907 he accepted a position as mining engineer with M. A. Hanna & Co., of Cleveland, working in the Lake Superior district. In 1908 Mr. Ireland was appointed general manager of the iron ore properties of this company, holding this position until 1917, when he was made a member of the firm of M. A. Hanna & Co. with headquarters at Cleveland.

While operating in the Lake Superior district, Mr. Ireland was among the first to recognize the advantages of using electrical power and adopted a policy of practically complete electrification of iron mines operated by his company. He was the first operator in the Lake Superior district to successfully dry iron ores, and built the first mill in the same district, using jigs for the concentration of banded ores. He was also the first operator in the Lake Superior district to adopt the use of an all electric shovel, and use this type equipment with dragline attachment in, such a way as to overcast the spoil from the first cut in open pit stripping operations and then re-cast this material so as to make room for depositing the spoil of the second cut.

After locating in Cleveland in 1917, Mr. Ireland devoted a large portion of his time to the complete electrification of fourteen collieries, involving the construction of three central power stations, each having a capacity of 15,000 kilowatts and one 2,000 kilowatts. As a part of this construction work the boilers in the power stations were so designed and constructed as to make possible the use of pulverized anthracite slush, formerly considered a waste product from the anthracite coal breakers. This was. the first time this system of firing was developed into a commercial success.

Mr. Ireland was an unusual combination! of expert geologist, mechanical and electrical engineer, with a very keen understanding of finance and business conditions. He was a splendid executive and his unfailing courtesy and reputation for square dealing were characteristic.

JOHN M. LONGYEAR.

John Munro Longyear was born in Lansing, Michigan, April 15, 1850, and died in Brookline, Massachusetts, May 28, 1922.

He was a son of judge John W. Longyear, who served two terms in the House of Representatives, in Washington, was a member of the Michigan constitutional convention of 1867, and later was named judge of the United States District Court for the Eastern District of Michigan.

Mr. Longyear received his early education in the public schools in Lansing and supplemented this by attending Olivet College, in Michigan, and Georgetown College, in the District of Columbia. When but fifteen years of age, he was compelled because of ill health to abandon his studies. In 1872 he became identified with the lumbering industry, in connection with which he did considerable exploring in the lower and upper peninsulas of Michigan. In 1873 he established his home in Marquette, Michigan, and made extensive investments in timber and mineral lands for himself and for others. In 1878 he was appointed agent of the Lake Superior Ship Canal, Railway & Iron Co., which was later succeeded by the Keweenaw Association, and he was connected with this organization until his death. In 1881 he published the first map of the Gogebic iron range, where he had large iron ore holdings. From 1903 to 1920 he was manager of the Michigan Land & Iron Co. He was also heavily interested on the Mesaba range, where he organized the Longyear-Mesaba Land & Iron Co.

The coal fields of the far north, in Spitsbergen, attracted Mr. Longyear and he went there and secured possession of a considerable acreage, organizing the Arctic Coal Co. to operate the mines. He was president of the company.

He took a keen interest in affairs in Marquette and in the Lake Superior district, serving as mayor of Marquette for several terms. He was the president of the Marquette County Historical society at the time of his death. For a number of years he served as a member of the board of control of the Michigan College of Mines.

He was survived by Mrs. Longyear, three daughters and two sons.

WILLIAM J. RICHARDS.

Born in Houghton County in 1862.

His parents, who were Cornish, came to the upper peninsula of Michigan at an early date. Mr. Richards' boyhood days were spent in Rockland and his education was acquired at the schools of that place.

He turned his attention to mining at an early day and after his apprenticeship at the copper mines, went to Silver Islet, Lake Superior. Leaving that point, lie returned to the copper mines and from there to the Minnesota mines at Tower. He worked there as a carpenter and later moved from tower and became mining captain about 1895 at the Auburn mine, near Virginia, Minnesota.

About 1896 he moved to Eveleth, Minnesota, becoming mining captain of the Fayal mine. He remained at the Fayal until 1900 and left there to take charge of the Spruce mine tinder Harry Roberts. In 1901 he left the Spruce mine and went to Crystal Falls, becoming manager of the properties for Corrigan & McKinney, and retired from that position in 1916 or 1917.

Mr. Richards led a very active life throughout all his career and was admired and respected by all who knew him. He had a particularly genial personality. In 1910 he became president of the Lake Superior Mining Institute.

He died January 19th, 1920.

JULIUS N. ST. CLAIR.

Julius N. St. Clair was born in Marquette, Michigan, in December, 1857. He died on July 5, 1912, from a stroke of apoplexy.

He was connected with the mining of iron ore from a very early date, being in the service of the Washington Iron Co. at what is now Humboldt, Marquette County, Michigan. Later he went to Ishpeming, at which place he married Sophie G. Rood. Somewhat later he became connected and part owner of the Deer Lake furnace situated on the Carp river, north of Ishpeming. He also was one of the stockholders in the West Republic mine at Republic, Michigan, being one of the St. Clair brothers, who developed that property. In 1904 he moved from Ishpeming to Duluth, having charge of the Jones & Laughlin office at that place, and was in their employ at the time of his death.

He was survived by his widow and four children.

EUGENE G. ST. CLAIR.

Eugene G. St. Clair was born at Strongsville, Cuyhoga County, Ohio, April 9, 1847; died from a stroke of apoplexy June 13, 1918, at the city of Duluth, Minn.

His first connection with iron ore mining was at the Washington mine, Humboldt, Marquette County, to which he went in 1867, remaining there until 1876; going to Ishpeming, Michigan, where he joined in the purchase of a general store which was run for a number of years. Shortly after reaching Ishpeming, he became connected with the Winthrop mine as part owner and director; later with the West Republic mine at Republic, Michigan. About 1894, he was with the Vega Iron Co. at Sparta, Minn. At a still later date was with the Fayal mine at Eveleth. Subsequently, at different dates, he was connected as officer and stockholder in the Cobalt region; Jones Step Process Co., at Iron Mountain, Michigan; with the Section 30 Mining Co. at Section 30, Minnesota, and was stockholder of the Section 30 Mercantile Co.

He was survived by his wife and three children.

JAMES R. THOMPSON.

Born at Racine, Wisconsin, on June 19th, 1865.

Mr. Thompson was educated at the public schools of Racine and after graduating at the high school entered the University of Wisconsin, from which institution he was graduated as a mining engineer.

Shortly after graduation, he became chief mining engineer at the Jackson mine, Negaunee, Michigan, and later was made chief engineer for the Iron Cliffs Co.'s Marquette range properties. He then went as chief engineer for the Lake Superior Iron Co. at Ishpeming under Supt. C. H. Hall.

In the early 90's he became superintendent of the Newport mine at Ironwood, Michigan, for the Schlesinger interests and developed that property to its present size.

Under his direction the machinery was installed that permitted the hoisting of 1,000,000 tons in a year from a single shaft from a depth of 2,000 feet, which was, a very remarkable performance.

In 1910 he became general manager of the American mine, becoming interested in the same with the M. A. Hanna Co. At this mine he installed an elaborate concentrating mill for the improvement of the lean ores in that property. About 1919 the orebody became smaller, so restricting the operations that the mine was closed. For this reason, he decided to convert the concentrating mill into one for the treatment or waste material from the Michigan Verde Antique marble quarry, using the product for stucco and roofing, and in this he was successful.

A man of strong personality and physique, he accomplished much for the development of the Fake Superior region in geology, mining machinery, deep mining and many appliances used in mining.

He will long be remembered by his many personal friends in this region.

He died August 7th, 1922.

JOHN H. VAN DYKE.

John H. Van Dyke was horn of Dutch and Scotch ancestry in Mercersburg, Franklin County, Pennsylvania, October 17, 1823; graduated at eighteen from Marshall College; immediately removed to Detroit, Michigan, and studied law with his brother, James A. Van Dyke, a prominent lawyer of that city; was admitted to the bar in 1846 and the same year located in Milwaukee, where he enjoyed prominence as a lawyer and success as a business man, being among the foremost in the educational, charitable and civil upbuilding of that city, where he died on the 9th of March, 1909.

The Milwaukee Iron Co. was established by Capt. E. B. Ward of Detroit, which company erected and operated blast furnaces and a rolling mill at Bay View, adjoining Milwaukee, and Mr. Van Dyke was at the outset chosen its vice president and counsel, and acted as such for a number of years.

The Milwaukee Iron Co. in 1872 sent the first exploring party of any considerable size into the territory afterwards known as the Menominee iron range, which explorations were under the direction of Dr. N. P. Hulst, and whose first work was on Section 10. T. 39, N. R. 29, and the so-called Breen mine.

In 1876 its explorations on the Menominee iron range passed to the Menominee Mining Co., in which J. J. Hagerman, John H. Van Dyke, Albert Conro, A. C. Brown and Dr. N. P. Hulst were the principal parties interested.

Much difficulty was encountered in persuading the eastern furnaces to favorably consider the use of the Menominee range ores, which were a fine soft hematite, and in marked contrast to the hard hematite ore of the Marquette range, but the high content of iron and low content of phosphorus attracted attention and soon produced a market.

Another and almost insurmountable difficulty which Mr. Van Dyke and his associates had to contend with was the endeavor to interest capitalists shortly after the panic of 1873, in the construction of a railroad into the wilderness to connect the new and undeveloped range with the Northwestern Railroad at Powers, but in 1877 this was accomplished at a cost of over $475,000, exclusive of equipment, and subsequently proved a most profitable venture.

The Menominee Mining Co. was successful in the discovery, and operation of many of the important mines in this district, viz:

The Vulcan mine was discovered in 1873 and developed in 1876 and its first shipment of ore made upon the completion of the railroad in 1877.

The Norway and Cyclops mines were discovered in 1878 and about 5,200 tons of ore shipped therefrom in that year.

The Chapin mine was discovered in 1879 and its first shipment of ore in 1880 amounted to 34,556 tons.

In addition to the above named enterprises, Mr. Van Dyke was active in the development of a number of other properties on the Menominee range, including the Quinnesec mine, the Florence mine and the Pewabic mine at Iron Mountain, and the construction of the hydraulic power plant at the Falls on the Menominee river.

It is an interesting fact that many of the men now prominent in mining circles in the iron ranges of Michigan and Minnesota had their early training in one or more of the mining companies in which Mr. Van Dyke was interested and active for a period of over thirty-six years, and who cherish a fond recollection of him as a just and generous friend, as well as one of the pioneers of the Menominee iron range.

WILLIAM J. WEST.

Born in Dodgeville, Wisconsin, in 1866.

He attended school in Dodgeville and graduated from the high school and later taught school for a time. In 1886 he went to the Vermilion range and was employed as a time keeper at the Soudan mine under Capt. Elisha Morcom.

Later he was a clerk in the office of the Minnesota Iron Co., remaining there until 1893 under Amos Shephard, who was then chief clerk.

From 1893 to 1895 he attended the University of Wisconsin and then returned to Duluth, taking a position as deputy clerk of the District Court, under John Owens, then clerk of the court.

In 1899 he became clerk at the Sparta mine for Pickands, Mather & Co. under C. H. Munger, superintendent, and in a few years was promoted to assistant mine superintendent.

About 1901 he became superintendent of the Sharon mine at Buhl and later when that property was taken by the Oliver Iron Mining Co. (in 1903) was superintendent o»f the Myers Hull-Rust and then assistant general superintendent.

He was made general superintendent of the Hibbing district in 1906 and remained in that position until April 1st, 1917, when he was made district manager, for the Oliver Iron Mining Co., at Virginia, Minnesota.

He remained in that position until his death on April 30th, 1922.

Mr. West, through his long connection with the mining industry, made and kept a very large number of friends and associates. He was fond of hunting and outdoor life and was always esteemed as a delightful companion and friend.

PAST OFFICERS.

PRESIDENTS.

Nelson P. Hulst 1893	James MacNaughton 1905
J. Parke Channing 1894	Thomas F. Cole 1906
John Duncan 1895	Murray M. Duncan 1908
William G. Mather 1896	D. E. Sutherland 1909
William Kelly 1898	William J. Richards 1910
Graham Pope 1900	F. W. Denton 1911
W. J. Olcott 1901	Pentecost Mitchell 1912
Walter Fitch 1902	W. H. Johnston 1913
George H. Abeel 1903	L. M. Hardenburgh 1914
O. C. Davidson 1904	C. E. Lawrence 1915

Charles T. Fairbairn 1917

(No meetings were held in 1897, 1899, 1907, 1916, 1918, 1919, 1920 and 1921.)

VICE PRESIDENTS.

1893.	John T. Jones F. P. Mills	J. Parke Channing	Graham Pope M. W. Burt
1894.	John T. Jones F. P. Mills	R. A. Parker	Graham Pope W. J. Olcott
1895.	F. McM. Stanton Geo. A. Newett	R. A. Parker	Per Larsson W. J. Olcott
1896.	F. McM. Stanton Geo. A. Newett	J. F. Armstrong	Per Larsson Geo. H. Abeel
1898.	E. F. Brown James B. Cooper	Edwin Ball	Walter Fitch Geo. H. Abeel
1900.	O. C. Davidson T. F. Cole	M. M. Duncan	J. H. McLean F. W. Denton
1901.	J. H. McLean M. M. Duncan	Nelson P. Hulst	F. W. Denton William Kelly
1902.	William Kelly Nelson P. Hulst	Fred Smith	H. F. Ellard Wm. H. Johnston
1903.	H. F. Ellard Fred Smith	James B. Cooper	Wm. H. Johnston John H. McLean
1904.	H. F. Ellard Wm. H. Johnston	Fred Smith	John H. McLean James B. Cooper
1905.	M. M. Duncan Fred M. Prescott	F. W. McNair	John H. McLean James B. Cooper
1906.	M. M. Duncan J. M. Longyear	Fred M. Prescott	F. W. McNair F. W. Denton
1908.	J. M. Longyear F. W. Denton	David T. Morgan	D. E. Sutherland Norman W. Haire
1909.	W. J. Richards Charles Trezona	D. T. Morgan	D. E. Sutherland Norman W. Haire
1910.	W. J. Richards John M. Bush	Frederick W. Sperr	Charles Trezona James H. Rough
1911.	E. D. Brigham John M. Bush	Frederick W. Sperr	C. H. Munger James H. Rough
1912.	E. D. Brigham Geo. H. Abeel	W. P. Chinn	C. H. Munger W. H. Jobe
1913.	Geo. H. Abeel Francis J. Webb	W. P. Chinn	A. D. Edwards W. H. Jobe
1914.	Francis J. Webb Charles T. Kruse	Luther C. Brewer	A. D. Edwards Charles E. Lawrence
1915.	G. L. Woodworth G. S. Barber	G. R. Jackson	F. E. Keese T. A. Flannigan
1917.	George L. Woodworth Grant S. Barber	Wm. D. Calverley	Frank E. Keese M. E. Richards

MANAGERS.

1893.		
John Duncan Walter Fitch	William Kelly	James MacNaughton Charles Munger
1894.		
Walter Fitch John Duncan	M. E. Wadsworth	C. M. Boss O. C. Davidson
1895.		
F. P. Mills Ed Ball	M. E. Wadsworth	C. M. Boss O. C. Davidson
1896.		
F. P. Mills Ed. Ball	C. H. Munger	Graham Pope William Kelly
1898.		
M. M. Duncan J. D. Gilchrist	T. F. Cole	Graham Pope O. C. Davidson
1900.		
E. F. Brown Ed. Ball	James B. Cooper	Walter Fitch George H. Abeel
1901.		
James B. Cooper James MacNaughton	(One Vacancy)	James Clancey J. L. Greatsinger
1902.		
James Clancey J. L. Greatsinger	Amos Shephard	Graham Pope T. F. Cole
1903.		
Graham Pope Amos Shephard	W. J. Richards	T. F. Cole John McDowell
1904.		
John McDowell Wm. J. Richards	Graham Pope	Thomas F. Cole Amos Shephard
1905.		
John C. Greenway John McDowell	William Kelly	H. B. Sturtevant Wm. J. Richards
1906.		
John C. Greenway Jas. R. Thompson	William Kelly	H. B. Sturtevant Felix A. Vogel
1908.		
James R. Thompson Felix A. Vogel	John C. Greenway	J. Ward Amberg Pentecost Mitchell
1909.		
F. E. Keese W. J. Uren	L. M. Hardenburg	J. Ward Amberg Pentecost Mitchell
1910.		
Frank E. Keese Charles E. Lawrence	William J. Uren	L. M. Hardenburg William J. West
1911.		
Charles E. Lawrence Peter W. Pascoe	J. B. Cooper	William J. West L. C. Brewer
1912.		
M. H. Godfrey Peter W. Pascoe	J. B. Cooper	J. E. Jopling L. C. Brewer
1913.		
M. H. Godfrey G. S. Barber	Wm. H. Johnston	J. E. Jopling C. H. Baxter
1914.		
G. S. Barber W. A. Siebenthal	*Stuart R. Elliott	C. H. Baxter J. S. Lutes

*To fill vacancy of Wm. H. Johnston, elected to presidency.

1915.		
F. H. Armstrong Henry Rowe	M. E. Richards	William Wearne Enoh Henderson
1917.		
F. H. Armstrong E. S. Grierson	Thomas Hoatson	William Wearne B. W. Batchelder

TREASURERS.

C. M. Boss 1893
A. C. Lane 1894
Geo. D. Swift 1895-1896
A. J. Yungbluth 1898-1900
Geo. H. Abeel 1901-1902
E. W. Hopkins .... 1903-....

SECRETARIES.

F. W. Denton 1893-1896
F. W. Denton and F. W. Sperr 1898
F. W. Sperr 1900
A. J. Yungbluth .... 1901-....

LIST OF PUBLICATIONS RECEIVED BY THE INSTITUTE.

The Institution of Mining and Metallurgy, Cleveland House, 225 City Road, London, E. C. 1.

American Institute Mining and Metallurgical Engineers, 29 W. 39th St., New York City.

American Society of Civil Engineers, 220 West 57th Street, New York City.

Massachusetts Institute of Technology, Boston, Mass.

Western Society of Engineers, 1734-41 Monadnock Block, Chicago.

The Mining Society of Nova Scotia, Halifax, N. S.

Canadian Mining Institute, Rooms 3 and 4, Windsor Hotel, Montreal.

Canadian Society of Civil Engineers, Montreal.

Institute of Mining Engineers, Neville Hall, Newcastle Upon-Tyne, England.

Chemical, Metallurgical and Mining Society of South Africa, Johannesburg, S. A.

American Mining Congress, Munsey Bldg., Washington, D. C.

State Bureau of Mines, Colorado, Denver, Colo.

Reports of the United States Geological Survey, Washington, D. C.

Geological Survey of Ohio State University, Columbus, O.

Geological Survey of New South Wales, Sydney, N. S. W.

Oklahoma Geological Survey, Norman, Okla.

University of Oregon, Library, Eugene, Oregon.

Case School of Applied Science, Department of Mining & Metallurgy, Cleveland, Ohio.

University of Illinois, Exchange Department, Urbana, Ill.

University of Missouri, Columbia, Mo.

University of Michigan, Ann Arbor, Mich.

University of Colorado, Boulder, Colo.

Columbia University, New York City, N. Y.

University of Pittsburgh, State Hall, Pittsburgh, Pa.

.Iowa State College, Ames, Iowa.

Engineering-Contracting, 355 Dearborn Street, Chicago, Ill.

The Excavating Engineer, 267 National Avenue, Milwaukee, Wis.

GENERAL INDEX.

Volumes I to XXI (1893-1917.)

(NOTE:—In addition to the Index by Volumes, which has been published in each number and which form is to be continued, there has been prepared a General Index which gives the title of each paper in italics and the name of the author in small capitals. This shows the volume, page and year.)