gradual absorption by the mining companies of these explored deposits and the result has been a large increase in the supply of available ore. This increase was due primarily to the demand during the war.

The present producing capacity of the Lake Superior district is between eighty and ninety million tons per year, while the consuming capacity is from fifty to sixty million tons. Where producing capacity is in the hands of consuming interests, the amount of ore produced from the mines will be regulated by the requirements of the individual consumers. Very few consuming interests who own reserves are willing to sell their ore on the open market, on account of the necessity of conserving ore reserves to protect their requirements for blast furnaces and steel plants. It is generally believed by those who are familiar with the iron ore situation that within five years there will he a radical change and that the' open market ore developed at the present time will not be sufficient to supply the requirements. When this time arrives there will be an increase in the explorations now being carried on.

*Mining Geologist

The question then arises "What are the prospects for the discovery of large additional tonnages of high grade ore?"

On the Mesabi range there seems to be little chance for the development of additional reserves of high grade ore. On the west end of the range there are possibilities for the development of further commercial deposits of wash ore, although the presence of banded taconite in the district makes the concentration much more difficult than that of the ores which are being washed on the west end of the Mesabi at the present time. These deposits will require probably in addition to the present system of washing, a more complicated process of jigging which will add materially to the cost of producing' this ore.

The Cuyuna range offers excellent opportunities for further development of ore reserves, but the character of some of the iron ore developed on this range is such that it is not attractive at the present time. Most of the ore is high in phosphorus, and there are small prospects of the development of large tonnages of low phosphorous ores. There are developed probably at the present time twenty million tons of high phosphorus ore which is not merchantable, but upon the depletion of the reserves of that ore in the Iron River and Crystal Falls districts, this ore will undoubtedly come into the market. Further exploration on the Cuyuna range will no doubt materially increase these high phosphorus reserves. In addition to these there is a considerable quantity of manganiferous iron ore developed, and there are some possibilities for further development of this character of ore.

On the Vermilion range, exploration work has been carried on intermittently for the past twenty years with the hope of finding new deposits of high grade ore. Although this work has not been particularly systematic, a large territory has been covered, and the results have been uniformly negative. From the information at hand at the present time, it would seem that there are very poor prospects for the development of further deposits of commercial ore.

On the Gogebic range active- development has been carried on during the past fifteen years. This range is partly located in Wisconsin, and partly in Michigan, and work has been carried on throughout the entire district. The westernmost producing mine at the present time is the Montreal. A very extensive campaign of exploration has been carried on west of the Montreal mine during the past five years, but no commercial bodies of ore have been developed, and the prospects are not encouraging for the development of extensive high grade ore bodies. There is a gradual change of the iron formation west of the Montreal mine which has made it less susceptible to enrichment, and it is my opinion that this part of the range is not particularly promising. From the Montreal mine east to the Wakefield mine, the whole range has been thoroughly explored and is almost entirely included in present producing mines. The ore bodies in these mines will undoubtedly be extended, in depth, but there is no new territory to be explored in this part of the range. East of the City of Wakefield, exploration has been carried on intermittently during the past ten years with more or less indifferent success. The slate bands in the iron formation have materially thickened and the formation as a whole seems more slaty than it does further west, and for this reason, the formation does not appear to be so susceptible to concentration. The prospects for the development of further large ore bodies on the east end of the Gogebic range are not good.

The Crystal Falls and Iron River districts may be considered as a unit. There is a large territory unexplored in this district which offers excellent chances for the further development of high phosphorus ores. The demand for this character of ore is limited, and development work will not be carried on until there is a greater demand for this grade. With the exception of the Cuyuna range, this district offers the best chances for exploration in the Lake Superior district. However, it cannot be denied that the most promising territory has already been explored, and it is difficult to see where further deposits at all equal to the present ones can be found.

The Old Menominee range has been explored intermittently for the past twenty years with very discouraging results. Additional ore bodies have been found contiguous to operating mines, but no new properties have been developed during this period, and it is my opinion that this range offers poor chances for the development of new mines.

The Marquette range probably offers the greatest opportunity for the discovery of additional reserves of low phosphorous ore of any of the Lake Superior ranges. However, the property is closely held by large operating companies, and it will only be developed as further ore reserves are required by these companies. The extreme

western part of the range, including the north and south limb and the Republic trough, does not offer good chances for the discovery of large bodies of high grade ore. The iron formation has been altered into magnetite grunerite schist and hard ore jasper, and this formation is not suitable for the development of high grade soft ore bodies. Small deposits of hard ore may be found, but an extensive drilling campaign carried on during the past three or four years has failed to reveal such deposits.

In addition to the present developed iron ore deposits in Michigan and Wisconsin, there are large areas of Huronian rocks which, offer chances for the discovery of new iron ore ranges. Some of these areas in which iron formation is known to exist are the Marenisco range, the Turtle range, the Manitowish range, the Vieux Desert district, the Canover district, a large area in Wisconsin south of the Gogebic range, the Calumet trough, the Felch syncline, the Sturgeon River trough, and the areas of iron formation surrounding the Republic and Crystal Falls Archaen Elipses. Some scattered exploration has been done in all of these districts, but the results to date have not been encouraging; in most cases, the character of the iron formation is such that concentration of merchantable ore bodies can not be expected. There are areas of Huronian rocks north of the Iron River district and northwest of the Crystal Falls district which are only slightly explored and which, in my opinion, are well worthy of further exploration. There is a known trend of iron formation extending from the west end of the Old Menominee range to the City of Escanaba, but this formation is covered by an overlap of Cambrian sediments which makes exploration work difficult and which would make the mining of any commercial ore bodies expensive.

From the above general outline of the exploration and development which have been carried on in the various ranges of the Lake Superior district in the past, it would appear that, as a whole, the chances are not good for the development of new ranges or extensive new deposits of ore in the present known ranges. Development of ore bodies will be more expensive in the future than in the past, and will require much more careful and scientific effort. The easy chances have been exhausted, and successful exploration in the Lake Superior district in the future will be the result of intensive scientific effort.

During the past fifteen years there has been a great change in the methods of exploration in the Lake Superior district. Prior to that time, the work was carried on in a more or less hit or miss fashion, and consisted largely in extending known productive belts. At the present time all of the geological aids which science has devised are necessary to successful exploration.

The first and most important question to be answered before an exploration is begun in a certain district is "What is the character of the iron formation?" Experience in exploration of the iron formation of the Lake Superior district has indicated that a certain character of formation is necessary before the concentration of high grade ore bodies can be expected. On the Michigan ranges this is commonly called the soft ore formation. It means an oxidized iron formation sufficiently porous to permit the ready circulation of meteoric waters which leach out the silica and produce the concentration of iron ore. There are many iron formations which have been altered and metamorphosed by igneous intrusion, or by severe folding, which are so dense and hard that oxidation cannot proceed in them. These are the magnetite grunerite schists and the hard ore formations of the western Marquette range, and of the Republic and Crystal Falls ovals, the banded magnetite of the western end of the Gogebic range, the taconites of the east end of the Mesabi range, and the hard jaspilite of the Vermilion range. In general, the only ore bodies which may be expected in these formations are the primary ores probably deposited when these formations were laid down. As a rule, these ore bodies are small and of doubtful commercial value, and difficult to discover.

After the finding of iron formation of such character as to permit secondary concentration, the next problem for the explorer is to locate a structural condition favorable to the concentration of ore. The following are some of these structural conditions.

1st. The folding of the formation so as to produce a trough with the footwall acting as an impervious basement. This condition localizes and increases the activity of the circulation of surface waters.

2nd. The intersection of a dike with the footwall of the iron formation or with an impervious layer in the iron formation. This intersection also forms a trough localizing the circulation of meteoric waters.

3rd. The intersection of two dikes producing a trough with the same effect as above.

4th. The intersection of a fault plane with the footwall or an impervious layer in the iron formation. The fault plane in this case acts as a dike and localizes the circulation between it and the footwall.

5th. The intersection of a hard resistent iron formation by a fault or system of faults resulting in its breaking up and forming of a ready channel for the circulation of water.

Practically all concentrations of soft ore in the Lake Superior district have resulted from one or more of the above structural renditions. Accordingly, the problem of the explorer is to locate points where such structural conditions exist.

Where there are surface outcrops of the iron formation or associated rocks, an aerial geologic map should be made preliminary to exploration. It has been found in practically all of the Lake Superior ranges that either the iron formation itself or the footwall or hanging wall rocks are magnetic. A careful magnetic survey will frequently not only show the position and trend of the formation but it will also indicate the presence of structural conditions favorable to ore concentration. Folding and faulting and

the presence of igneous intrusions are very frequently indicated by careful magnetic work. Such preliminary aerial geology and magnetic surveys are comparatively inexpensive, and frequently save thousands of dollars in diamond drilling or underground exploration. If the overburden is light, test pitting or stand piping to ledge is an inexpensive and valuable aid. By means of test pits along a given known horizon the presence of folds or other favorable structural conditions can frequently be shown.

After all of these preliminaries have been completed, there are two methods of continuing exploration. They are diamond drilling or exploration by shaft sinking and underground development. On account of the relatively great cost and slowness of shaft sinking, except in special cases, diamond drill exploration in recent years has practically superseded this former method. Where information from adjoining properties indicates the presence of ore or structural conditions favorable for it, shaft sinking and underground development may be warranted, but as a general rule, diamond drilling is preferable.

Much has been published concerning methods of drilling and sampling, and it will not be necessary in this article to go into great detail on this subject. There are, however, a few important points which are worthy of mention. They are:

1st. The angle of holes most useful in exploring various structures.

2nd. A discussion of the deviation of drill holes, and the methods of determining, preventing, and allowing for same.

3rd. Methods of insuring accurate sampling.

4th. Methods of recording and filing drill records.

Under the first heading, I would say that, as a general rule, vertical drill holes are preferable to angle holes in almost any structure. Usually vertical holes hold their direction much better than inclined ones, and can be more accurately located to strike a given point in the formation. In almost all cases of secondary concentration, the ore bodies lie in troughs as previously outlined. It will readily be seen that inclined holes are apt to cut over or under the trough, but vertical holes within the area of the trough must cut through it. Although ore bodies usually occur in troughs, they frequently form tabular masses rising to considerable heights along the footwall or along a dike or fault plane. In such a case, inclined holes may be warranted, although vertical holes can usually be used advantageously. On the Gogebic range inclined drilling with the formation has been successfully used to determine the position of dikes intersecting it. These inclined holes have very little use in the development of ore, because ore encountered by them may be only narrow seams interbedded in the formation. Where diamond drilling is used underground to extend the outline of known ore bodies, or to explore for new ones, horizontal drilling is frequently used. Where the general position of the ore is known, any inclination of the hole best suited to prove up the extent or width of the ore body is warranted.

Under the second heading: The extent of the deviation of drill holes has been fully realized only in recent years. This has been largely due to the perfecting of apparatus for testing the direction and inclination of the holes. Formerly a drill hole started in a given direction on surface was supposed to continue in this direction to the bottom, and many mistakes in the location and extent of the ore bodies have been made on account of insufficient knowledge concerning the deviation of the holes. In doing accurate exploration work, it is necessary to carefully test the drill hole both for inclination and for direction. These tests should be made at regular intervals and as the drilling proceeds, for in many cases the deviation is so great as to destroy completely the usefulness of a hole. In non-magnetic formations, by the use of the Maas compass, a very accurate survey of the drill holes can be made.

In order to intelligently locate drill holes on surface, it is necessary for the explorer to know the probabilities as to their deviation. Experience on the various ranges and in various formations gives a fairly accurate idea of what deviation may be expected. In steeply inclined formations with alternate bands of hard and soft material such as the ordinary ferruginous cherts of the iron formation, vertical holes may be deflected with the formation and follow clown in a single bed. It is well to incline the hole slightly toward the dip of the formation to prevent this sliding off of the drill hole slightly toward the formation. In flat lying formations of the same character a vertical hole or an inclined one drilled at a less angle than normal to the formation will have a tendency to rise with the formation. After one or two holes have been drilled, the amount of deviation can be determined and clue allowance made for it in the location of other holes. The condition of the diamond drill equipment, and the method of drilling, have an important bearing upon the deviation of the hole. Worn core barrels and rods have a tendency to increase the deviation. Crowding the drilling and using excessive pressure also increases this tendency. As it is important to keep a hole straight, the use of two new core barrels which are stiffer than the rods, and the use of light pressure, aid materially in keeping the drilling in position.

Where a drill hole is being sunk in material of uniform composition, such as quartzite or dike, deflection is not serious. In many cases where deep drill holes are to be sunk, it is well to try to locate such holes in this material as far as possible in order to keep them straight.

The third and most important consideration is the sampling. The ultimate purpose of all diamond drill work is the location of commercial bodies of ore, and if the greatest care in accurate sampling is not used, reliable information will not be secured. In the first place, all such drilling should be under the careful supervision of a competent engineer or geologist, in order to insure that

all the proper precautions are taken. In the second place, an effort should be made to secure as large a percentage of core as possible, in order that the core samples may be used to check the sludge samples and detect any errors. A means only recently used for securing a large percentage of core is the use of a double tube core barrel. This prevents the grinding up of core and not only increases the core recovery, but decreases the wear on diamonds.

The only known method of getting absolutely accurate sludge samples is to carry the casing down continuously with the drilling. Where the ore outcrops at ledge, this method is universally pursued, and there can be no contamination in the sludge samples, in deeper drilling, this procedure is not practical, as the time required for carrying down the casing continuously would make the cost prohibitive. If the ore is fairly hard in texture, it has been found that if the casing is carried down to the point at which the ore is encountered, an accurate sample can be secured by drilling through the ore without casing. After passing through the ore the casing should again be carried down to the bottom so that the samples below the ore will not be contaminated by the softer ore above. In case the ore body is quite soft, the casing should be carried down at frequent intervals, as indicated by the condition of the hole, and the character of the ore.

The sludge samples from the drilling are collected either in barrels or in properly constructed sludge boxes with numerous compartments for settling. In the case of barrels, all the water for a five foot sample is run into the barrels and allowed to settle. The water is then syphoned off and the sludge sample collected from the bottom of the barrels. In the case of the sludge boxes, all of the water from the five foot sample is run through the sludge box and the sludge is collected in the bottom of the box. It has been found that settling in a sludge box will collect practically all of the sludge, and that an accurate sample can be secured without the use of barrels.

In case the presence of sulphur in the form of gypsum is suspected in an ore, the sludge samples cannot be relied upon to give an accurate analysis of the sulphur. The use of the double tube core barrel in this case is very important because it will secure a large recovery of core, and the core can be run for sulphur. Another method which can be used if good core recovery is not secured is the sampling of the water before and after entering the drill hole, and the measuring of the quantity of water used in drilling a five foot sample. The difference in the sulphur content of the two samples, multiplied by the quantity of water used, will give the amount of sulphur dissolved from this five foot sample. From this can be calculated the percentage of sulphur.

After the sludge samples are collected, care should be taken that they are not burned in drying. The usual method of drying is on a fire near the drill shanty, and if these samples are over-heated in such a fire, combined moisture and carbon dioxide may be driven off. The proper method is to use a steam drying apparatus.

A fourth consideration in drilling is recording and filing of data. A great deal of drilling has been done in the Lake Superior district, accurate records of which have been entirely lost. This has been due to improper methods of classifying, recording, and filing drill records and cores. When the cost of drilling is considered, it is almost unbelievable that carelessness in these respects should have destroyed the information secured from thousands of feet of drilling. As the cores from drilling are secured, a competent geologist should he called upon to accurately classify them before they have been disturbed or sampled. After they have been properly classified, the ore in the core should be sampled and representative pieces should be filed for future reference. The most convenient method of sampling core is by splitting it. The E. J. Longyear Manufacturing Company, of Marquette, Michigan, manufactures a very satisfactory core splitting device. By this method an accurate sample of the core can be secured and half of the core still left for filing.

The proper recording of diamond drill data is also very important. These records should show the location and elevation of the drill hole, the inclination and direction at regular intervals, the size at different depths, the size of the casing used to different depths, the amount of core recovered for each run or each five feet of drilling, the analyses of the core, the analyses of the sludge, and a section plotted to a convenient scale showing the geologic formations encountered, the clip of the formation cut at various points, and any other geologic data which can be obtained.

EXTRACTS FROM THE PROCEEDINGS OF THE
LAKE SUPERIOR MINING SECTION, NATIONAL SAFETY COUNCIL

HELD IN

HIBBING, MINNESOTA,

AUGUST 25 AND 26, 1925.

(Published by arrangements with the officers of the Safety Council.)

COMMITTEE IN CHARGE OF CONFERENCE.

William Conibear, Chairman	Cleveland-Cliffs Iron Co., Ishpeming, Mich.
Durant Barclay	Oliver Iron Mining Co., Coleraine, Minn.
Sid J. Sicotte	Pickands, Mather & Co., Hibbing, Minn.
A. C. Borgeson	Shenango Furnace Co., Chisholm, Minn.
B. A. Middlemiss	Oliver Iron Mining Co., Hibbing, Minn.

LIST OF THE LAKE SUPERIOR SAFETY CONFERENCES.

No.	Place.	Date.	Chairman.
1.	Houghton	April 23-25, 1919	Byron O. Pickard
2.	Duluth	June 19-20, 1919	Byron O. Pickard
3.	Duluth	June 24-25, 1920	Richard V. Ageton
4.	Duluth	October 26-27, 1923	George Martinson
5.	Duluth	August 28-29, 1923	George Martinson
6.	Ironwood	August 12-13, 1924	William Conibear
7.	Hibbing	August 25-26, 1925	William Conibear

OPENING ADDRESS.

By Frank O. Botsford, District Manager, Pickands, Mather & Co., Hibbing, Minn.

Gentlemen of the Lake Superior Mining Section of the National Safety Council:

The holding of your Conference here means, I believe, more to this mining community than you realize. The presence in Hibbing of practically all the Safety Engineers in the Lake Superior District will without doubt stimulate and increase the interest of not only the mine employees but of all the people in the community in safety work. We welcome you to Hibbing, not only for the pleasure it gives us to meet you all, but also because of the benefits we expect to receive from this Conference.

Your organization was conceived by a number of men who were interested in the promotion of safety. The result of several informal discussions was the holding of a meeting at Houghton, Michigan, in the spring of 1919. Two months later a second meeting was held in Duluth and the organization was completed. The first meetings were attended by about 25 men; the meeting held last year was attended by 122 men, indicating a healthy growth in the number of those interested in safety work.

The original idea of the yearly Conference was to provide an opportunity for Safety Engineers to meet and exchange thoughts on the subject they are most interested in. All the meetings from 1919 to 1923 inclusive were held in Duluth. Beginning in 1924 the Conference was held in Ironwood and this year in Hibbing, both cities being mining centers. This change in a meeting place from Duluth to mining towns is the result of the desire on your part to extend somewhat the field of the Conference. The meetings held in Duluth were, to a large extent, limited to Safety Engineers and a few mining officials. It was thought that a larger number of mine employees could attend the Conference if they were held in mining centers with the result that safety work would be forwarded by spreading the gospel to a larger number. The meeting at Ironwood was very successful from this standpoint as it was attended by many mining men who would have been unable to attend a meeting held in Duluth. I believe that by holding the Conference in mining towns, which permits the largest possible number of mine employees to attend, cannot fail to give the safety movement a shove forward.

The idea that safety work was of great enough importance to warrant the creation of Safety Departments by the iron mining companies of Lake Superior was born about 1911 or 12. As I look back to those days I can see that our first efforts to further the promotion of safety were very crude. We had never given the question much thought; we believed that our mines were as safe as anyone could reasonably expect them to be; we felt that we were taking every precaution to insure the safety of all employees. We see today, after years of thinking and analyzing from a safety standpoint, that many conditions that we believed to be safe then were actually hazardous to a high degree. This clearer vision was not developed by any change in our ideas as to the value of human life, but was brought about by the thinking along safety lines by Safety Engineers, mine operators, and by the men themselves. The power of thought is unlimited and when a large number of men are thinking on one subject the dark corners become bright. They see more, they see more accurately. Where before we saw the obvious now we see all sides and even beyond the object or condition viewed, and discover the hidden danger which would not have been visible to us if we had depended on our eyesight alone. It is the thinking of many men that is responsible for the great progress in safety work, and our future advancement will depend entirely on how clearly we think.

After the safety departments were created, committees were appointed to discuss the problem of safety and decide on the methods to adopt to make the mines safer. In most cases it was decided that the best method was to formulate what we called safety rules. We worked hard making rules to govern the surface man, the open pit man, and the Underground man. The rules were printed in many languages and bound in small books. Every possible ‘dangerous situation was covered by a rule beginning with “Do” or “Don’t.” It was Do this or that, or Don’t do this or that. We were determined to cut out accidents and, like the average American, we thought the best and easiest way was to make a law or a rule against accidents. We even had penalties attached to put teeth in the rules.

We soon discovered that our rules did not reduce accidents any more than sumptuary laws passed by legislatures make the people any better. There is a

contrary streak in most of us, and a rule or law that makes no appeal to our reason is apt to make very little impression on us. There are a lot of busy people in this country of ours today who would like to lay down rules of conduct for all of us; they, of course, setting themselves up to be the judges of what is proper for us. I am afraid that the average mine employee, when he received the book of rules in those days, felt that we were going too far with our "Do's and Don't's." Getting injured was a personal matter with him and it was his own business anyway. Further, hadn't he always taken care of himself, and he guessed he could continue to do so without following a lot of Do and Don't handed to him by the boss. Our miners in the pioneer days of safety could not see the need of safety rules and for this reason refused to accept them and abide by them.

When the majority of the people in a state see the need of a law, the law is promptly enacted and it is very easily enforced. When, however, a law is enacted because of the demand from an active minority, as so many thousand statutes have been in our different states, and if the law does not appeal to the majority as being needed, then the law soon becomes inactive. We have a good illustration of this in the so-called Blue Laws on the statute books of many states.

Our first efforts were wrong. Before writing our rules we should have sold the idea of safety to the men. We should have stimulated in the men the desire for a few rules to insure safe operations. We attempted to force the idea of safety on the man without taking into consideration his thought, or better, his lack of thought on the subject. We now obtain real results by trying to instill into the individual the germ of the safety idea which, if properly nourished, leads the man to think about safety. All of us are inclined to resist the didactic Do or Don't on any proposition. We learn only by the development of ideas within ourselves.

We can guard thoroughly each piece of equipment, fence off all dangerous places. We can make rules covering every conceivable hazard, and accidents will continue to occur with distressing regularity. I thoroughly believe that progress in the prevention of accidents can only be made by getting the individual to think safety. If I had to choose between having a mine well guarded but manned with a crew that was indifferent to safety, or having a mine entirely unguarded but operated with a crew who were thinking safety, I would choose the latter, because in my opinion there would be less accidents among the men who were thinking safety. I believe, therefore, the future progress of safety work, the further reduction of disability days, can only be accomplished by sowing the seed of the safety idea in the individual, carefully nurturing the seed until it has sprouted into a strong, healthy demand within him for a desire always to work and play in a safe way.

I cannot speak too highly of the interest in safety work and the initiative displayed by the men who are responsible for these Conferences. A yearly Conference like this quickens the interest in safety work, it is productive of new ideas, and I think we can truthfully say that each meeting advances the work a little further towards the goal you are striving for, that is, the entire elimination of accidents in the mines.

The work the Safety Engineer is doing is very important because it deals with the welfare of all the men connected with the industry. The more clearly you think, the more energy you display, means more lives saved and the gradual reduction of pain and suffering. It is meetings of this kind that help you to see more plainly, to think more clearly; that revive and stimulate your interest and cause you to strive for still greater results in the elimination and prevention of accidents. I hope you will continue to hold these Conferences each year.

We welcome you to Hibbing and hope your stay here will be an enjoyable one. Our underground and open pit mines are open to you and while you are here we are entirely at your service.

MINE VENTILATION—MARQUETTE RANGE.

By C. W. Nicolson, Mining Engineer, The Cleveland-Cliffs Iron Company, Ishpeming, Michigan.

The purpose of mine ventilation is fourfold—to maintain good health and consequently safety, to maintain a high efficiency of work, to decrease the decay of timbers, and to control air currents in case of mine fire. Probably all men here present realize the necessity of an adequate supply of fresh air underground, but at the risk of being tiresome I am going to speak briefly of the air conditions encountered in mines and their effect upon the human system.

Air in heavily-timbered iron mines, especially in those using a crushing system of mining, is found to differ from normal surface air in several respects—a high degree of saturation, the presence of more or less carbon dioxide, and a decrease in the percentage of oxygen. The dry-bulb temperatures rarely, if ever, equal summer temperatures on surface, but the greater humidity frequently gives wet-bulb temperatures such as are rarely encountered above ground

The presence of CO_2 in low percentages has no ill effect on men, as it is not until 6% to 8% is reached that poisonous symptoms appear and as much as 25% has to be present to cause danger to life. However, 1% will cause deep and heavy breathing and with more than 3% breathing becomes so heavy as to be distressing and steady work is not possible. Therefore, CO_2 in low percentages, while not at all dangerous, makes for inefficiency.

A decrease in the oxygen of several per cent has no ill-effect on man, as the concentration or partial pressure of oxygen in high altitudes is lower than is usually found in mines. However, a decrease in the oxygen content causes a man to reach that depth of breathing which is distressing sooner on doing muscular work and

consequently makes for inefficiency. The influence of oxygen on combustion and life will be appreciated from the following:

With air containing 17% of oxygen, a candle flame is extinguished.

With air containing 15% of oxygen, breathing is distressing.

With air containing 12% to 13% of oxygen, an acetylene flame is extinguished.

With air containing 12% of oxygen, breathing is very difficult.

With air containing 10% of oxygen, there is great danger to life.

With air containing 7½% of oxygen, death occurs.

In heavily-timbered iron mines experience has shown that an increase in the presence of CO_2 is almost invariably accompanied by a corresponding decrease in the percentage of oxygen and the combination of the two produces a distressing effect sooner than either one singly. The increase of CO_2 and decrease of oxygen are caused by the exhalations of men, by the burning of lights and by the oxidation of timbers, of which the last is by far the most important.

There is no doubt that the problem of temperature is as important from a mine ventilation standpoint as the dilution of gases, and will become more formidable as deeper ore-bodies are worked. Of the causes of heating of mine air, the atmospheric condition on surface and the rise of temperature due to compression of the air descending the shaft are overcome, as far as the mines of the Marquette Range are concerned, by the low rock temperatures and the presence of large quantities of water falling, through the air. As a result, the temperature of the downcast air entering the mine workings is nearly constant throughout the year and seldom exceeds 60° F. The air in the mine and particularly in the working places is warmed by the heat given off by men, lamps and machinery, by the oxidation of the timbers and by the heat produced by crushing, of which the last two are the most important.

In conjunction with the problem of temperature is that of humidity, which prevents evaporation and therefore cooling and affects the working capacity of men. The heat of the body is disposed of by radiation, convection and evaporation. In a saturated atmosphere there can be no evaporation of perspiration, and so the body temperature rises to the detriment of the working efficiency of the miner. No matter how much he perspires, he cannot become cooled. A high wet-bulb temperature does not injure the health of the worker—it only affects his working capacity and increases his discomfort. In still air, without working, 88° is the maximum wet-bulb temperature at which a man feels comfortable, even with a minimum of clothing. The dry-bulb does not matter much—an air temperature of 1300 with a wet-bulb of 88° has no more effect on the body-temperature than if both bulbs registered 88°. About 80° wet-bulb is the limit for hard manual work, but continuous hard work all clay is impossible at 78° wet-bulb. The remedies for such conditions are a reduction of the percentage of humidity, a reduction of the temperature and the production of a current of air over the body of the worker.

The effect of these various conditions having been briefly discussed, it might be well to decide upon the constituents of a working atmosphere which it is practicable to maintain and which will make for efficiency. These I would place as follows: Oxygen, not less than 20%; CO_2, not more than 0.5%; wet-bulb temperature, not over 70°; humidity, not over 90%. The quantity of air per man per minute entering the mine will be whatever is necessary to provide the above constituents and the velocity of air through the actual working place should be sufficient to produce a cooling effect. Having thus stated the problems of mine atmosphere, we may now discuss the conditions as found in the mines of the Marquette Range and the methods which have been adopted to improve them.

The predominant characteristic of mine air on the Marquette Range is complete, or almost complete, saturation. Tests made at practically all the mines of the range showed from 95% to 100% humidity of the air at the bottom of the downcast shaft and from 98% to 100% in the air entering the upcast. This condition exists at all times during the year.

The rock temperatures are very low as compared to mines in other districts. Unfortunately, records of such rock temperatures are very fragmentary, practically all readings having been taken in the air in the rock drifts. However, as the air in most of these drifts has very little movement and as the water, which should be of about the same temperature as the rock, drops through it, these air temperatures may approximate the rock temperatures. The following readings were taken in four different mines:

Sea Level Elevation.	Temperature.
600	50°
500	51
300	54
100	54
-200	57
-400	60
-1000	63

This shows an increase of 1° for every 123 feet of depth.

The temperatures in the sub-levels vary greatly, depending on the amount of timber, the rate of crushing and the amount of ventilation. Wet-bulb temperatures, which are practically the same as dry-bulb, range from 60° to 87°, though the latter figure is seldom reached. However, in some mines, before mechanical ventilation was installed, 70° to 75° wet-bulb was not uncommon.

The temperature in any mine is practically constant throughout the year, but increases with depth and with crushing.

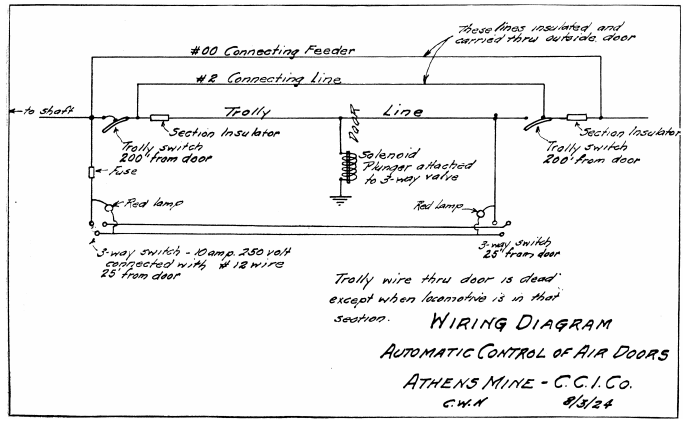
The chemical composition of the air varies in different mines, depending on the amount of timber, the rate of crushing and the amount of air entering the mine, which in turn depends on the depth of the workings, the number and elevation of the openings to surface, and the surface temperature.

Carbon dioxide is being continuously produced by oxidation and crushing of the timber, and can be diluted only by an adequate supply of pure air. It is evident that the natural ventilation will be much better in a shallow mine with numerous openings to surface than in a deep one with two, or in an extreme case, with only one opening. Practically all the Marquette Range mines are at least 1000' deep and many are much deeper.

In one large mine, in which the air supplied by natural ventilation has always been considered to be perfectly satisfactory, and in which the efficiency is high, tests have shown the presence of from 1% to 1.5% CO_2 and from 18.5% to 20.0% oxygen. It is doubtful whether any large soft ore mine on this range will show less than 1%. This is not of itself particularly objectionable but is an indication that in the near future natural ventilation will no longer be adequate and that fans must eventually be installed.

In another large mine the air, which has in former years been satisfactory, now contains from 2% to 3% CO_2 and 17% to 18% oxygen, a condition which is already having a decided effect upon efficiency. As an example of what occurs in extreme conditions, I may cite the case of the Gwinn Mine, which was formerly connected to the Francis Mine by a long drift, in which a fan was handling 40,000 cu. ft. of air per minute. When the Francis Mine was worked out and abandoned, a dam was placed in the connecting drift and the Francis was allowed to fill with water. The only opening to the Gwinn Mine was then a vertical four-compartment shaft 1300' deep. No mining has been done there for some time but timbermen are kept at work maintaining the drifts and raises. During the winter, the men experienced no difficulty in breathing, though in the stagnant air the timber rotted rapidly. With the coming of warm weather last June, the air rapidly became so poor that work was almost impossible. Analysis showed the presence of 13% oxygen and 5% CO_2, with a wet-bulb temperature of 57 to 59. How much further this deterioration of the air might have gone, had not steps been taken immediately to remedy it, cannot be said definitely, though theoretically there is no reason why there should not have been an entire replacement of oxygen by carbon dioxide. It is interesting to note that the timbermen stayed in this atmosphere from six to eight hours a day without any ill effects, though the amount of work they were able to do was very small. A line of twelve-inch ventube was put down the shaft and through this 2000 cu. ft. per minute of fresh air was supplied to the men placing a large fan on the bottom level and building doors. The shaft will be divided into two air-tight compartments by means of gunite, in a manner similar to that employed at the Athens Mine, as will be described later.

Such are the general air conditions existing in the mines of this range. Complete installations for mechanical ventilation have been completed at two mines, which will be briefly described, as examples of what may be done towards remedying poor conditions.



The installation at the Lake Mine in Ishpeming was described by L. Eaton in the 1922 volume of Proceedings of the Lake Superior Mining Institute. As this is not here available, I shall summarize the conditions and results. This mine, while comparatively shallow, being only 573' to the bottom level, had extensive working's and had been in continuous operation for 26 years, during which time a large amount of timber had been placed underground, practically all of which remained in the mat. The oxidation of this timber by crushing and rotting produced much heat and considerable carbon dioxide. There was but one shaft, a second outlet being provided by a raise, too small to serve as an efficient airway. Analysis of the air showed—humidity, 95% to 100%; temperature 70° to 80° wet-bulb—carbon dioxide 1.0% to 2.6%. As under such conditions the efficiency of the men was low, a new air-shaft, 5x10 inside, was raised to surface and a fan, with a capacity of 45,000 cu. ft. per minute against three inches of water gauge, was placed underground near the up-cast shaft, the air being drawn down through the new shaft. Doors were installed to control the flow of air and various new drifts and raises driven. The results obtained were very satisfactory. About 56,000 cu. ft. of air per minute was circulated through the mine, the humidity was reduced from 100% to 96%, the wet-bulb temperature from 76° to 65° and the carbon dioxide from 2% to 0.25%.

The design of the fan station, doors and door control is fully described in Mr. Eaton's paper and will not be repeated here.

This is a good example of mechanical ventilation of a shallow mine with two shafts. An installation under entirely different conditions has been completed at the Athens Mine in Negaunee. The shaft, which is 2400' deep to the bottom level, is connected to the Negaunee shaft to the North 1000' below surface. However, as the Athens workings lie to the South of the Athens shaft and

the Negaunee workings to the North of Negaunee shaft, it is not feasible to attempt any ventilation between the two shafts. Prior to the curtailment in 1921 the ventilation of the Athens Mine was entirely by natural means and was adequate, as the mine was new and there was comparatively little timber underground and very little crushing effect had yet been experienced. During the following summer, while the mine was operating but four hours per day, the air became poor and analyses showed an average of 17% oxygen and 3% carbon dioxide on the main levels, with a wet-bulb temperature of 60° and humidity of 100%. In some of the sub-levels, the wet-bulb temperature was 75° and the air analysis: —oxygen 16%, CO_2 4%. In one place a wet-bulb temperature of 87° was encountered, where hot gases came down from the mat. As the Negaunee Mine to the North was ventilated by natural means and the ventilating pressure was comparatively low, no attempt could be made to make use of Negaunee shaft in connection with the Athens Mine ventilation, lest by so doing the ventilating current of Negaunee Mine should be destroyed. As the upper workings of the Athens Mine are 1800' from surface and as the bulk of the work was being done 2200' from surface, it was not practical to provide any other opening. The remaining alternative was to use the Athens shaft, both for upcast and downcast air. A fan with a capacity of 40,000 cu. ft. per minute against three inches of water gauge was placed on the 10th or bottom level near the shaft and doors were built on the various levels so that the air passed down the cage compartment through the fan and in on the 10th level; thence through raises to the various working levels above and out to the shaft on the top level where it was discharged into the skip compartment and so to surface. All visible cracks in the plank partition between the cage and skip compartments were closed but in spite of this the air leaked through the partition and very little fresh air was induced from surface. It was evident that this partition must be made, absolutely air tight, which was done by applying a coat of gunite throughout the entire length, as described in the 1923 volume of the Proceedings of the Lake Superior Mining Institute. The quality of the air was then satisfactory but the quantity delivered by the fan was only 25,000 cu. ft. per minute. To remedy this, several raises were put up in various parts of the mine, a discharge chimney constructed for the fan and all door frames covered with gunite to reduce leakage. At the present time the fan is delivering 46,000 c.f.m. against a water gauge of 1 4/5", as compared to a delivery of 25,000 c.f.m. against three inches of water gauge a year ago. There is no trace of carbon dioxide in the air discharged from the fan and in the discharge air entering the skip roads on the top level, the average percentage is .25. As both shaft and mine are wet the air is practically saturated at all times but the temperature is low, being from 58° to 63° at all points on the main levels during all seasons.

As it is not feasible to attempt to pass the primary ventilating' current through the sub-levels, small fans with five horsepower motors have been placed on the main levels and flexible canvas piping carried up into the sub-levels where it is split so as to carry a line into every working place. In this manner sub-levels which formerly had a wet-bulb temperature of 75° have now been reduced to 68° with a relative humidity of 90% and the percentage of carbon dioxide is not over 0.3.

Both for efficiency in ventilation and for protection in case of fire the mine has been divided into two air splits, the main air current passing in on the 10th or bottom level being divided so that half of it ventilates the 9th and 8th levels and is discharged into the shaft through the South crosscut on the 6th level; the rest of the air passes from the 10th level directly to the North crosscut on the 6th, ventilates workings on the 6th and 4th levels and is discharged to the shaft on the 4th level, which is the top level. In this manner the ventilating resistence has been reduced as the velocity on any level except the 10th is only half of what it would be were the full current passed through that level, and in case of a fire in either split, the other one can still be ventilated without fear of smoke or gas.

To control the flow of air, it was necessary to place doors on all the levels. As any such construction on a main haulage level is dangerous, every effort has been made to reduce the hazard. Two doors on each level provide an air lock through which the trains may pass without leakage of air. These doors, which are practically the same a those used in the Lake Mine, are opened by pneumatic cylinders, the valves of which have heretofore been actuated from a distance of 200' by wires and levers. Some trouble has been experienced due to the failure of the motorman to throw the lever, and the consequent failure of the door to open. An automatic method of owning these doors is now being installed, a section insulator and a trolley switch being placed in the trolley wire, 200' on either side of the door, the current being carried around by an insulated connecting line. The line between these section insulators is then dead except when the motor has closed the trolley switch. A connection is made near the door from the trolley wire to a solenoid, the plunger of which is connected to a three-way valve in the air line leading to the pneumatic cylinder. When the locomotive reaches a point 200' from the door, the trolley switch is automatically closed, thus energizing the solenoid, which opens the air valve and causes the door to open. At a point 200' on the other side of the door the locomotive trolley opens the second trolley switch, thus de-energizing the solenoid and closing the three-way valve, the door being then closed by counter weight. As some of these doors are located near curves and the lever which operated the valve by means of wires was located around the curve out of sight of the doors, there was always danger that some person might close the door as the train was passing through. With the new method of electrical control this is no longer possible, as no one would attempt to close the trolley switch by hand. For the use of men walking on the level who wish to open the door, small three-way switches have been installed some 25' on either side of the door, by closing which the solenoid is energized and

the door opened. At all future installations, a small door will be placed in the frame beside the large door, the small door serving for men who are walking and the the large door for the motor trains. As a further precaution, red and green electric lights have been installed at both sides of the doors and also around the curves near the doors. The connections for these lights are so arranged that the red lights remain on until the door is fully opened, at which time the reds are turned off and the greens turned on. A movement of the door of a half inch will switch off the greens and switch on the reds.

Great care has been taken during all this work to provide against any fire hazard, all electrical installations being thoroughly insulated and all wood and timber near any fan being coated with gunite. All door frames have been gunited and the doors themselves covered on both sides with Toncan metal.

To provide a method of cutting off circulation throughout the mine, a fire door has been built on each level near the shaft, the door itself being made of steel and the door frame of timber with a coating of gunite. These doors are held open by a latch, to which is attached a small air cylinder. All these air cylinders are connected to an air line in the shaft which extends from the collar to the bottom level and valves have been placed at the collar and at each level so that the opening of any one valve will actuate all air cylinders and permit all the fire doors to be closed by the counter weights which are attached to them.

This system of fire doors is not peculiar to the Athens Mine but has been installed at all mines on the Marquette Range. A complete description of these doors appears in the 1923 volume of the Proceedings of the Lake Superior Mining Institute.

In conclusion, it might be well to emphasize the conditions which make for good or bad ventilation in the mines of the Marquette Range. These mines are all moderately deep—from 1000' to 2500'—they contain large quantities of timber and are subject to a heavy crushing action, which causes a rapid production of heat and carbon dioxide; the air is practically always saturated with water vapor. On the other hand, they possess one unusual and very favorable condition—namely, low rock temperatures. A cooling effect can be produced in the working places only by a reduction of the relative humidity or by a reduction of temperature; of these, the former is almost impossible but the later is comparatively simple.

UNDERGROUND HAULAGE.

By Anton Tancig, Mechanical Superintendent, The Shenango Furnace Co., Chisholm, Minn.

In presenting the subject of Underground Haulage for consideration by the Lake Superior Branch of the National Safety Council assembled here today, I am aware of the two-fold interest it contains for those present. First, it must be of interest to Safety Engineers to have this matter discussed because of its association with any program of safety, and second, because the wide awake operator realizes that 100 per cent safety means maximum efficiency—efficiency in haulage plus conservation in man power.

The suggestions contained herein are based on practice and observation, giving due consideration in any recommendations to the fact that underground haulage is a non-productive expense, and as such, it must be kept at as low a figure as is consistent with good practice.

It is not the intention in this paper to criticise, other than constructively, any of the schemes or systems now in use, also what criticisms are made are only general, because we all know that there are mines far advanced in the line of safety and efficiency. So we must recognize the fact that some operators have to meet their haulage problems with the material and skill available, therefore it seems to me that everyone concerned is entitled to credit for what has been done.

It is a strange fact, but true nevertheless, that underground haulage has progressed but little over what it was twenty years ago. Of course some minor changes have been made here and there. While mules as motive power have been superseded by the electric locomotive, we still use very narrow gauge tracks of light steel supported by an occasional tie. On such tracks we use small capacity top heavy cars having a short wheel base and it seems almost impossible for us to discard the link and pin coupler in favor of the safer automatic coupler.

It is perfectly safe to state that many sets of roller bearing trucks have been installed to make cars run easier on poor tracks when all that was needed was a little attention to tracks. Our underground haulage problem doesn't require any engineering research, we already know that the railroads use the plainest kind of journals and bearings but the very best kind of a road bed, so it seems to me that we should at least try to« profit by their practice.

When installing an underground haulage system, the tracks should be considered first, and because they receive a minimum of attention after having been installed, they should be much more rugged than surface tracks for a similar duty. A fault commonly found with most underground tracks is the light steel, poor ties poorly spaced and inattention to joints. As an illustration, 30-pound steel is too light for 6-ton locomotives hauling trains of three ton capacity cars, that is the gable bottom cars weighing better than 4,000 pounds each. Such rails not only spring, producing a hill and valley effect, but they retain very poor alignment, all of which is a detriment to safe and economical operation.

You will also find that the distance from the top of such light rails to the joint bolt is too short, and the least wear on the wheel or ball of the rail causes the wheel flange to

strike the bolt head or nut, which action of course loosens them. Incidentally, this condition has been known to cause derailments. It has been found that 50 pound steel gives the best results when using the equipment just mentioned, it permits the trains to run at higher speeds without side rocking or bumping up and down, and, as far as the track itself was concerned, the derailment hazard was entirely eliminated.

The 50 pound rail compared to the 30 pound rail, not only makes a better track, but provides a 25 per cent increase in the width of the ball of the rail. This of course increases the wearing surface of the wheel treads, so naturally this extra width insures a longer life to both wheels and rails besides being a benefit to locomotive traction. Some further benefits to be had through the use of the heavier steel, are the greater distances between the ball of the rail and joint bolts, the base of the rail is wider and the webb of the rail contains enough metal to allow the use of compression bonds. This feature is important because a lot of trouble and expense has resulted from trying to bond very light steel. It doesn't matter what type of bond is used on light steel, the lack of sufficient metal together with the inevitable looose joint, soon makes it worse than useless. To get an inexpensive bond installation that will last the life of the mine, use heavy rails that come drilled for bonds which are easily installed.

In addition to using heavy steel, make the grades as easy as the ground will permit and by all means let us get away from the narrow gauge tracks in new installation. Standardize on one or two curves and see that they are put in with rail benders. Having standard curves, simplifies the purchase and installation of frogs and switches. It is a mistake to use home made frogs and switches, better results are obtained through the purchase of properly designed and manufactured material. This is said with all due respect to the average mine shop mechanic, because he hasn't the time, training not material to successfully compete with manufacturing specialists. In the matter of switch stands or rather throws, we again insist on using the home made article which is hard to reach, inefficient and unsafe. If the Safety Engineers would study the operation of parallel throw switch stands, they would soon urge their adoption as being the safest for underground use. It isn't necessary to go any further into the matter of tracks except to emphasise the necessity of observing the fundamentals of track laying if you want good safe tracks.

The next important item in our haulage system is the underground main level car, and while every operator has his own ideas about the kind of car his conditions will permit him to use, there are several points to be considered before buying and they apply to any type. We must get away from the link and pin couplers, in fact Safety Engineers should always condemn them and urge the use of automatic couplers because they are quicker, they eliminate excessive train slack and most important of all is that they are the safest couplers to use. Use the longest wheel base consistent with your minimum curve, because this will shorten the over-hang of the car, eliminating jack-knife derailments and you will find that the car will run much easier. Use well designed cast iron wheels having chilled treads and flanges, preferably wheels having a slight taper to the tread, such wheels are the easiest running because the chilled flange and tread reduce the friction between the wheel and rail, especially on curves.

For a journal I would suggest using an axle of liberal size, fairly hard, running in a brass or babbitt bearing and lubricated with oil. The journal box should be so designed that the wool waste in the oil cellar can be renewed without taking the car apart. In other words, duplicate as near as possible the car journal and bearing used by the railroads because they are easy running and can be repaired in any mine shop. From the standpoint of efficiency, we should use larger cars or at least cars having the same capacity as the skips because this will mean fewer car trips and easier checking.

I have seen a number of special safety features that may be worth mentioning at this time, because they may be applicable to conditions confronting some of the Safety Engineers present. While in one of the modern coal mines recently, I noticed that the tracks were not in the center of the drift but were laid to one side, providing a man-way on the other side. This eliminated the necessity of walking on the track and made unnecessary the use of red lights on the end car. These man-ways were marked appropriately and the scheme seemed to be very successful.

Another matter of interest to me was the employment of wide awake capable men to look after the cars and tracks. Usually this job is given to employees too old to be good miners or to any one that happens to be handy at the time. Very few men are hired because they are good track and car men.

Some of the mines have congested traffic conditions at certain times of the shift that can be made less dangerous through the use of automatic block signals. A lot of confusion and some accidents result because the motorman forgets to pull the red light switch against some other train. An automatic switch operated by the trolley or motor wheels will eliminate the human element from this safety feature besidse effectively controlling the traffic at all times.

The foregoing suggestions have been mentioned to show some of the possibilities for improving the main artery of an underground mine. It may not be within the province of the Safety Engineer to recommend changes for the sake of efficiency, but when better efficiency means greater safety, then it is their business and should receive their attention and have proper recommendations.

It is possible that some of you won't agree with all that has been outlined, having in mind, no doubt, the possibility of excessive first cost. As a matter of fact, actual installations show that the additional cost is small

and the results quickly justify the extra care and expenditure necessary to make a good installation, besides there is this difference—the first cost of any haulage system whether good or passable, safe or unsafe, is a capital account, but the operating and maintenance expense is a charge against costs. A good, smooth running haulage system will cause the fewest delays and accidents, is the cheapest to operate, likewise it gives the bosses more time to devote to the miners or productive labor.

There is one fact in connection with this subject that should be emphasized, that is the inseparables of efficiency and safety. This should always be kept in mind, but more especially today, when it is more imperative than ever before to obtain low operating costs. With a first-class system it will be possible to haul the same tonnage with fewer trains, this will not only reduce the hauling cost, but will reduce the accident hazard by virtue of employing fewer men. In the final analysis, the haulage system that produces the lowest cost per unit of production, is one that is so well designed and installed that it is the safest to operate.

SAFE PRACTICE IN UNDERGROUND TRANSPORT.

By Lucien Eaton, Superintendent, The Cleveland-Cliffs Iron Mining Co., Ishpeming, Mich.

In presenting this paper on Underground Transportation at this meeting my object is primarily to start a discussion which will bring out the latest developments in practice and the latest devices for prevention of accidents in this part of the operation of mines. As many papers have been written on this subject in recent years my treatment of it is of necessity more in the nature of a review than a presentation of new facts. Most of the articles written on the subject of underground transportation have dealt with main-level haulage, and comparatively little has been written m regard to sub-level tramming. As sub-level tramming and hand ramming are decreasing yearly in importance through the use of mechanical methods of moving the ore into the chutes or cars, or through changes to mining methods that allow more movement of ore by gravity, main-level haulage is correspondingly increasing in importance. Furthermore the use of animals as motive-power and of rope-haulage is also on the wane, so that the subject has gradually been narrowed to locomotive haulage.

HAND TRAMMING.

In a previous paper I discussed the problem of accidents in underground transportation, and in touching on the subject of hand tramming and sub-level tramming, which may be classed together as far as accidents are concerned, I take the liberty of quoting from this paper as follows:

"The accidents which occur in this kind of transportation are rather frequent and hard to prevent, but are rarely serious. They consist mostly of strained backs, hernia, minor injuries to hands and arms and occasional injuries to head and feet. Strained backs and hernias cannot be prevented, but contributory causes can be decreased by using roller-bearing cars that are easily dumped. Injuries to hands and arms have various causes. When two men are shoveling into the same care one man sometimes strikes the other with his shovel or with a piece of ore. In loading coarse ore men often get their fingers jammed between a heavy chunk and the top of the car. Two of the commonest kinds of accidents to hands are getting the hand jammed between the side or top of the car and the timber in the drift in heavy ground, especially in going around a corner, or in catching the fingers between the car-body and the truck after dumping.

"Guards on top of the car are effective against contact with timbers or chutes above the cars, but no successful side-guards have, to my knowledge, been devised. Blocks properly placed on the truck four inches or more in front of the rear of the car-body prevent pinching of fingers after dumping. Men also occasionally bump their heads, or slip on the rail, or pull the car over their feet, but these accidents are due to carelessness, and cannot be prevented. Occasional accidents also occur, especially where large cars are used, from men being squeezed between cars or between a car and the side of the drift. These accidents are often serious and sometimes fatal, and, being usually due to carelessness, are very difficult to prevent."

With the exception of the injuries to hands and feet and those received in the act of loading most of the accidents in hand-tramming are likely to occur also when locomotive haulage is used, and the means for their prevention will be discussed under that head.

LOCOMOTIVE HAULAGE.

Locomotives for underground use are of four types:

(1) Compressed air locomotives.

(2) Gasoline locomotives.

(3) Electric trolley locomotives.

(4) Electric storage-battery locomotives.

Compressed air locomotives have been very successful in many instances, and have some advantages under difficult operating conditions, especially on dirty and wet tracks and adverse grades. Maintenance is high and operating efficiency from a power standpoint is low, and they are not growing in favor. There are relatively few installations in this country.

Gasoline locomotives give off objectionable fumes, which vitiate the atmosphere and are often dangerous.

Their maintenance cost is high and they are unreliable in service, except under very favorable conditions.

Electric trolley locomotives are very widely used, especially for long hauls, and their size and speed have been increased enormously in the past few years. The desire for large units to haul long trains at high rates of speed has been responsible for many of the accidents that have occurred. In most cases, and especially in coal mines, the weight of the locomotive determines the size of rail that should be used, and, unless the size of the rail is increased, when a larger locomotive is put in service, derailments are apt to be frequent. I understand that a controller has recently been perfected by which one man is enabled to operate two locomotives in tandem. With such a controller two six-ton locomotives have the same tractive effort as one twelve-ton locomotive, and the danger of derailment through over-loading the track is reduced. Furthermore most of the time used in hauling cars is spent at the terminals, picking up loads and leaving empties, and vice versa, and it seems to me that in many cases the speed of the trains on main hauls could be reduced and safety consequently increased without loss of capacity, if better terminal facilities were provided. This idea has been borne out in practice in my own experience, for I have found little difference in capacity between trolley locomotives with a speed of eight miles an hour and storage-battery locomotives with a speed of three and a half miles per hour.

Storage-battery locomotives have increased rapidly in popularity in the past few years, and in many places they have displaced trolley locomotives. Their greater flexibility in operation, and the ease with which they can be moved from one level to another are strong points in their favor, and in timbered drifts that crush badly, where the high cost of maintenance of trolley wires and the danger of fire almost prohibit the use of trolley locomotives, they are in a class by themselves. On account of their lower voltage and slower speed and the absence of a bare trolley-wire they are also safer in operation.

The difficulties that arose from the change from hand-tramming and animal haulage to locomotive haulage, that has occurred in the past ten years, and the use of larger equipment have started a movement for improving and standardizing construction and operation of locomotives, tracks and cars, and the American Mining Congress through its Standardization Division has made available much useful information on these subjects. The recommendations of the Underground Transportation committees, and particularly those of the Coal Mining Branch, are well worth studying, and, if adapted to metal mining and put in practice, would go a long way in reducing the number, of accidents that occur in this part of the operation.

Changes in car design and capacity are constantly being made, larger and larger equipment being the rule. End-dump cars were succeeded by gable-bottomed or saddle-back cars, and these in turn are being displaced by solid-bodied cars of the rocker-clump or rotary-clump type. This is an advance from the standpoint of safety, efficiency and economy. There is less spill along the track with fewer derailments and fewer men exposed to danger when cleaning track, speed of dumping is increased, and both maintenance and cost of operation are reduced. There has also been a change to outside journals instead of outside wheels, which is a distinct improvement on account of reduction in the frequency of derailments.

If statistics were compiled, showing the number of accidents and fatalities per thousand men employed in locomotive haulage underground in the Lake Superior District, I think that the accident rate would be astonishingly large, and would show that this part of the mining operation is one of the most hazardous. This fact has, I think, been largely overlooked on account of the relatively small number of men engaged in this kind of work.

Accidents on main haulage ways constitute from ten to twelve per cent of those occurring underground, and of these about ninety per cent happen to men operating trains and ten per cent to men walking through or working in the haulage drifts. In order to start a discussion, I have made a rough classification of the various kinds of haulage accidents and a brief statement of the means used or recommended to prevent them, drawing freely from the information given in papers on this subject published in the proceedings of this Council in the past four years.

Causes of Accidents.

Accidents to men filling cars at chutes are probably the most frequent, especially those caused by pieces of ore or rock falling on hands or arms or rolling over the car onto the feet. The use of finger-chutes in hard ore prevents most of these, and handles properly placed on the backs of the stopper-boards also help. Care in placing the stopper-boards, when the chute is hung up, will do the most good in the soft ore mines.

Accidents of this kind were so frequent at the mine of the New Jersey Zinc Co., at Franklin, N. J., that a rule was put into effect there several years ago, forbidding chute men to stand in front of the chute when barring. They are required to stand at one side out of the line of flying chunks. This practice makes harder work for the chute men, but has reduced the number of accidents.

One of the most frequent causes of injury is derailment. Aside from danger of personal injury derailments are expensive both in cost of repairs and in loss of product from delay. Their prevention is therefore worthy of much attention. The first requisite in preventing derailments is to have a good track. The track should be carefully laid with sufficiently heavy rails (40 lb. rail for 6-ton locomotives), with angle-bar splices at every joint. Joints should be bonded on trolley installations, and a clearance of half an inch should be left between the ends of the rails at every joint to prevent buckling. Ties

should be closely spaced, and tie-plates used on tracks of long life. Special attention should be paid to ballast and drainage, which are too often neglected in our mines. Cast steel or manganese steel frogs with flanges or plate frogs with guardrails should be always used. In laying switches great care should be used to prevent "bunching," which causes side-sway in the train, and all frogs and switches that are to be out of use for six months or more should be taken up. Changes in the size of the rails should be avoided, not only because of the bump that is given where the change in size occurs, but also because wheels that have been grooved through wear on a narrow rail will jump easily off a wider one. Tracks should be kept clean, and timber and other material should not be allowed to lie along the drift.

Next in importance to the track is the condition of the rolling-stock. Wheels on both cars and locomotives should be frequently inspected, and grooved, flat, badly worn or wobbly wheels should be replaced. Outside journals with free-running axles are to be preferred to tight axles and loose, outside wheels. The wheel-base should be at least one-third of the length of the car, and should be greater than the track-gauge. On heavy cars springs between the axle and the truck help to prevent derailments from small obstructions on the track, and reduce the danger of broken axles, but often increase body-sway. Couplers should be so designed that cars ride smoothly without crowding when being pushed around a curve. Leaky doors should be avoided, and, if rocker-dump cars are used, their catches should be so designed that they cannot be jounced out of place, while the train is in motion, and allow the car-body to overturn. Locomotives should have a clearance of at least 3½ inches above the rail, and should have wheels and wheel-base suitable for the shortest radius curve that they have to go around. Sharp curves should be avoided, especially on main line tracks. A jack and a set of re-railers should be provided for every locomotive.

Collisions with other trains can he avoided by proper routing and by use of block signals. When more than one locomotive is in operation on one level and trains are hauled back and forth through a cross-cut between the vein and the shaft, a block signal should be used at the end of this cross-cut. This is usually a switch that is thrown by the trolley-wheel in passing, and shows a red light when the cross-cut is occupied and a green one when it is clear. The same signal should be used in other sections of the mine, where more than one locomotive is being used.

Collisions with ventilation doors often occur, and sometimes inflict serious injuries. Automatic doors that are opened by the weight of the wheels on the track are not efficient on the higher-pressure air-currents, and mechanically operated doors, opened by compressed-air or hydraulic cylinders and closed by counter-weights give better service. Every door of this kind should be equipped with automatic switches, which will show a green light, when the door is fully opened, and a red light at all other times.

On all tracks leading to the shaft, where there is a chance for the locomotive or a car to go into the shaft, a spring derailing switch, that will have to be held open by hand to permit passage, should be provided. Collisions and accidents of all kinds are less likely to occur if all haulage-ways are thoroughly lighted.

Automatic couplers should be used on all cars that are hauled in trains. The standard half-size coupler made by the American Steel Foundries is very satisfactory. It is six inches deep at the end, and used to be constructed with a six-inch jaw. When so constructed cars sometimes become uncoupled by one coupler riding over the other, when passing over a bump in the track, but the jaw has recently been deepened to nine inches, and such accidents are now almost impossible. Coupler-shanks should be long enough to keep the corners of the cars from coming together on a curve, and the couplers should, be protected from falling dirt that may get into the mechanism. Accidents often happen to brakemen who insist on holding the locking-pin in their hands, when coupling cars, but such accidents are entirely unnecessary, because the couplers work automatically when properly opened. Couplers should be inspected frequently, and when worn should be promptly changed, and the worn coupler sent to the shop for repair. This system gives better results than putting in new parts on an old coupler underground. Most repairs are easily made in the blacksmith shop, and the couplers have a long life.

Most material moved by the train should be carried on special trucks or in the cars. It is bad practice to carry loose material on top of the cars, and there is often danger of striking the trolley-wire in lifting something out of a car. Dynamite should have its special car with an enclosed insulated body, and timber should be carried on timber-trucks. It is often convenient to carry drill-steel, tools, etc., in small quantities on the locomotive, and this is very hard to prevent, unless the top of the locomotive is arched or rounded so that nothing will stay on it. A better practice perhaps is to provide a strong cover and side-stakes along the sides so that a small amount of material can be carried without danger of its falling off.

There is always danger of coming in contact with charged electric wires. Storage-battery locomotives have the advantage here, as their voltage is usually about eighty, and they have no trolley-wire. There is, however, danger of burns from ignition of gas when the battery is charging, and of acid-burns, when lead batteries are used. Battery trays should be insulated from the boxes. In trolley installations the wire should be at least six feet above the track, and should be protected by an inverted wooden trough not over six inches wide inside at all plats and at all chutes. The wiring should be divided into sections of 1,000 to 2,000 feet, and each section provided with a knifeswitch in a box that can be locked with the switch either open or shut. By this arrangement an electrician working on a dead section

can be sure that no one will turn the current on, while he is working.

The voltage most often used on trolley circuits is 240 to 250 volts at the locomotive with 250 to 275 volts at the generator. A voltage greater than 300 at the generator should not be permitted.

When a locomotive is not in use, if it is a trolley locomotive, the trolley-pole should always be removed from the wire, and in any case the main switch should be opened. Accidents have occurred from neglect of these precautions by the starting of the locomotive, when the current was turned on.

The most frequent and usually the most serious injuries to men who are working in the haulage drift or walking through it are caused by their being struck by a moving train. The two best ways to prevent this kind of accident are to have the drift well lighted and to provide a good pathway along the side with sufficient clearance for the train to pass safely. This can easily be done in 8x8 drifts in rock, if the track is laid a little off center. If this is not possible, "refuges" should be provided every three hundred feet (the Oliver Iron Mining Co. places them at 100-foot intervals), the drift being widened at these points enough to accommodate several men. These places should be marked by green lights or by being white-washed, and should be kept clear of rubbish at all times.

All locomotives are provided with head-lights, but most of them have grids over the lenses, which catch dirt and prevent proper cleaning of the lens. Lenses of the bulls-eye type are to be preferred. Every locomotive should also be provided with a warning signal—either a bell or a horn. I do not favor automatic horns or bells that sound all the time the locomotive is in motion, as the men soon become used to the noise, and do not pay as much attention to it as they would to an intermittent signal.

When trains are pushed ahead of the locomotive there should be a tail-light on the rear-end to serve as a warning to men in the drift. Various kinds are in use, but the most satisfactory in my experience is a large carbide lamp with a red reflector. This is better than a lamp with a red lens, because it is almost impossible to keep the lenses from breaking. The taillight should also be used when the locomotive is ahead, not only to prevent a rear-end collision, but also to give the brakeman assurance at the end of the trip that he has not lost any cars on the way.

Serious and fatal accidents to men walking beside the track have occurred from trains breaking in two. After the first part of the train had passed, the men stepped out on the track, and were struck by the moving cars that had broken away. Longer jaws on the automatic couplers have practically eliminted this danger. A man is sometimes injured when carrying tools on his shoulder, by having them come in contact with the trolley-wire. Such accidents usually occur to new hands, who are not familiar with trolley installations, and are rare at mines where the labor turn-over is small. The practice of carrying tools on the shoulder in drifts where there are trolley-wires should be prohibited.

The suggestions made above for prevention of accidents, will, if followed out, reduce the number of injuries to employees, but the greatest improvement in conditions can be brought about only by constant effort in educating the men to the end that they will themselves appreciate and guard against the dangers of their occupation.

In closing I wish to make acknowledgment to Messrs. B. W. Shove, H. L. Reese, C. D. Woodward, G. F. MacWilliams, A. F. Brosky, A. J. Hoskin, G. M. Gillette and J. W. Reed and to the Standardization Division of the American Mining Congress for information and suggestions taken from their articles.

DISCUSSION.

CHAIRMAN CONIBEAR: I think you will agree with me that the two speakers have covered this subject very thoroughly. However, we have a few minutes at our disposal for discussion. Has anybody a question to ask or additional information to give us?

MR. HULST: In the case of a bad derailment where automatic couplers are used, do you have a separate link and pin to connect with them to get a car back on the track?

MR. EATON: No; we usually carry a chain along that they can hitch on, but we haven't had a link and pin that I know of for some time. You can take the jaw out and use a link in there if you want to. The usual practice has been to take the chain and just throw a loop around the head of the coupler and another one to hitch onto the other car and pull them that way, but in recent years we haven't had very much trouble with that. We had a little at first. I think the best thing is to keep the tracks in shape. I think we all have neglected the ballasting and drainage of our tracks, particularly drainage. I don't believe there is a mine that has water in it, where you can't find places in the track, when a train goes over, you will see the water squeeze out from under the ties.

CHAIRMAN CONIBEAR: Several delegates are interested in storage battery locomotives. Will you please tell us about your experience with them?

MR. EATON: I am a comparatively new user of them. We have had them in use about three years. The copper country has a great many. We have found them very satisfactory in service and from an operating standpoint they are just as economical as the trolley locomotive. In fact, our cost has been about a cent a ton less with the storage battery locomotives than with the trollies, but that has been largely clue to the fact that they were working more nearly to full capacity. We put in storage battery locomotives and took away some of the traffic from the trolley locomotives, and that, of course, reduced their efficiency, but on an even basis, including depreciation on the battery, the cost of operation between the two is so close that there is no choice; and I

have found them very satisfactory in service and from the safety standpoint. We use Edison batteries almost entirely, and I am a strong booster for Edison batteries. They cost more, but they last longer, and they are very easy to take care of.

I have various types of locomotives, from four tons down to a ton and a quarter; the last one is a boys' size locomotive, but it does a man's work. The price of these small locomotives is being worked down to where you can buy them cheaply. We paid $1,000 for the chassis on that locomotive, and the battery cost $700, and that is comparatively cheap, and, if you can replace one gang of trammers with that type of locomotive, you can pay for it in a year.

MR. MARTINSON: Mr. Eaton, in your paper you mentioned a condition that everybody would like to have; that is running always with the pole as it should be on the locomotive. In some places that is almost impossible to do. Have you ever had any experience with the use of these so-called dynamo trolley poles?

MR. EATON: I will say that the pantograph trolley is a fine thing, if you keep your trolley wire perfectly straight, but it doesn't give satisfactory service where your trolley wire is wobbly. I used them on one locomotive, where there should have been no trouble from crooked trolley wires, for three or four years. It worked very well but the men preferred the pole-trolley, because they had less trouble with it jumping off the wire.

ALL ACCIDENTS, LAKE SUPERIOR MINING INDUSTRY 1911-1923, INCLUSIVE.

By William Conibear, Safety Inspector, The Cleveland-Cliffs Iron Co., Ishpeming, Michigan.

In 1911 a number of Lake Superior mine operators decided that in order to reduce accidents it was essential to provide safer working conditions and that employees should he shown that their safety was a prime and fundamental consideration. With this object in view, safety departments were organized and campaigns for the reduction of accidents were inaugurated. Interest in this phase of mining has increased since 1911, and today practically all operators, recognizing their responsibility for the prevention of injuries and accidental deaths, are concentrating their best effort on plans for the elimination of the hazards of the industry. No longer is the economic phase of mining regarded as paramount. Equal in importance has become the slogan "Safety First."

Accidents statistics for the entire Lake Superior mining district, prior to 1911, are not available, and we cannot therefore accurately guage the measure of success that has been obtained in recent years in accident prevention. We know that the industry, from its early stage until 1911, sustained many fatalities annually and that the average annual rate for the entire period was too high to compare favorably with the low rates that were maintained by the metal and coal mines of European countries. I have, however, the figures for the iron mines in Michigan covering the ten years from 1901 to 1910, when 152,430 men were employed and 716 men were killed, which resulted in an average fatality rate of 4.69 per thousand men. I do not think that this rate is too high to be representative of all the Lake Superior mines for that period. For instance, in support of this supposition, the mines of St. Louis County, Minnesota, for the three years from 1906 to 1908 employed 41,686 men and lost 231 men by accidents, which gave a fatality rate of 5.54 per thousand men.

The mines of the Lake Superior district from 1911 to 1923, inclusive employed 563,134 men and reported 1,742 men killed. The fatality rate therefore was 3.09 per thousand. This is 17 per cent less than the rate for the metal mines and 23 per cent less than the rate for the coal mines in the United States, as reported for the same period. If the average fatality rate, which occurred at the iron mines of Michigan from 1901 to 1910, had prevailed throughout the entire district from 1911 to 1923, we would have sustained an additional loss of 899 men.

The value of this conservation of life cannot be measured in dollars and cents—it is inestimable. It is this evidence, however, that proves that accident prevention is possible. While it is a slow process, we may reasonably expect that our record in the future will be better than that of the past. The fatality record that has characterized the mines of Dickinson County, Michigan, since 1900, justifies this expectancy. An average annual fatality-rate of 2.63 per thousand from 1901 to 1911 was reduced to 1.65 from 1912 to 1924. If all the iron and copper mines of Lake Superior had had an equally low rate since 1911, 805 lives would have been conserved, in addition to the number that was actually recorded as saved from accidental death. As our fatality rate is now annually higher than that which prevailed in Dickinson County twenty-four years ago, we have no other conclusion to draw than that a lower accident record is possible. Nine hundred and twenty-nine lives compared to 2,621 lives are the figures that may be used to estimate the minimum and maximum liability in loss of life represented by the operation of our mines from 1911 to 1923. In other words, a loss of 70 men annually compared to a loss of 200 men is a possible reduction in the number of mine fatalities if we believe sincerely in accident prevention and work efficiently and consistently to promote higher standards of safety.

I have divided the time from 1911 to 1923, inclusive, into two periods, and have compared them to show the progress made in recent years in reducing accidents. Figures for 1924 are not yet available.

Table IV gives in parallel columns the death rate per thousand men employed underground, open pit and

surface, or surface, for the iron and copper mines of this district. I shall not review these rates in detail but invite attention to those that are of particular interest.

The average fatality rate for all mines of the district during the second period (1917-1923) was 15½ per cent less than the rate for the first period (1911-1916), based on the number of men employed. All metal mines in the United States show a reduction of 12 ⅔ per cent. Underground mining in Minnesota and the open pit and surface operations of the iron mines in Michigan had higher rates in the second period but all other rates show a downward trend. The average rates for the iron and copper mines in Michigan and the iron mines in Minnesota were very close, being 2.82, 2.84 and 2.85 respectively. As these mines extend over a large area and employ annually thousands of men, the similarity of the average fatality rates for the seven years indicates that there has been a united effort on the part of all operators to reduce accidents. The iron mines in Wisconsin sustained no fatalities by surface work during the second period, and a fatality rate of 2.77 for underground was thereby reduced to an average rate of 2.07, the lowest record for both periods. The rates for underground at the iron and copper mines of Michigan were the highest both periods, but the reductions that were made the second period, together with low surface rates due to the employment of many men at less hazardous work, gave average rates that were on a par with the rate established by the Minnesota mines for the entire period.

I stated at one of our Safety Conferences that underground mining was more dangerous than open pit mining, and a number of the delegates from Minnesota took exception to the statement. But if accident statistics are a criterion of the hazards of an industry, they point to this conclusion. In the deep iron mines of Michigan, there are more difficulties to combat in accident prevention than are to be found in the shallow mines of Minnesota, and for the same reason, the deeper mines of the Copper Country are more hazardous than Michigan's iron mines. A review of the principal causes of accidents substantiates these deductions.

Falls of ground, shaft work, cars and steam shovels, and explosives were charged with 75 per cent of the fatalities that occurred from 1919 to 1923 at the metal mines in Michigan. The same causes, in different ratios, accounted for 67 per cent of Minnesota's total. Fatalities by falls of ground were 10 per cent higher in Michigan than in Minnesota and shaft accidents 13 per cent higher. On the other hand, the rate for cars and steam shovels in Minnesota was 16 per cent higher than the rate in Michigan, which indicates one of the main causes of accidents in open pit mining. The rates for explosives are about the same, approximately 7 per cent in Michigan and 6 per cent in Minnesota.

Tables III and V give the statistics of injuries that I have been able to collect. The average annual rate for the metal mines of Michigan and Minnesota since 1911 was 232 injuries per thousand men. This is slightly higher than the average rate for all the United States metal mines. Minnesota mines had a reduction of 30 per cent the second period in the number of injuries reported, whereas the iron and copper mines of Michigan had a reduction of only 13 per cent.

The number of injuries that are being reported every year are many and should command the same serious consideration that is being given to the fatalities. Often the margin between a slight or serious injury or a fatality, is so narrow that we are forced to admit that chance plays no inconsiderable part in the fate of man, but frequent repetitions of accidents by like causes are signs pointing to the hazards that must be studied if we are to be more successful in preventing accidents.

The economic loss that is involved annually by men being killed and injured is large and should be another incentive for promoting accident prevention work. If as many men were injured per thousand men employed in Wisconsin as were injured at the mines in Michigan and Minnesota a total of 10,064 men were injured annually at all mines from 1911 to 1923. The number killed average 130. Mr. W. W. Adams, chief statistician for the United States Bureau of Mines, reported recently that three-fourths of the injured workers at metal mines were between 20 and 45 years of age and that the average lost time in each temporary injury was 12.2 days. Assuming as a basis that the average age of men killed was 40 years, that each death represents an average loss in life expectency of 20 years, and that the average daily wage of Lake Superior mine workers is $5.00, the following computation is made:

Number of days labor lost annually because of injuries..	122,000
Amount of wages lost annually because of injuries....	$ 610,000
Number of days labor lost because of each fatality.....	6,000
Number of days labor lost because of 130 fatalities....	780,000
Amount of the wage loss occasioned by one year's fatalities	$3,900,000

Total wage loss occasioned by all accidents for each year $4,500,000. This is an economic loss sustained by the commonwealths of Michigan, Minnesota and Wisconsin. There is also an economic burden placed upon the employment where these accidents occur. Compensation payments for a year's accidents have been computed as follows:

Michigan—	
84 fatalities at $4,000	$ 336,000
6,267 injuries at $40.00	250,000
	$ 586,000
Minnesota—	
46 fatalities at $6,000	$ 276,000
3,573 injuries at $40.00	147,000
	$ 418,000
Wisconsin—	
3 fatalities at $5,000	$ 15,000
300 injuries at $40.00	12,000
	$ 27,000
Total Loss—	
Michigan	$ 586,000
Minnesota	418,000
Wisconsin	27,000
	$1,051,000

Michigan and Minnesota have always been in the lead among the metal mining states of the Union in the number of men employed in metal mining. Michigan first, Minnesota second, followed closely by Arizona and Montana. Total days labor performed, in round numbers, from 1911 to 1923, were 95,000,000 in Michigan; 60,000,000 in Minnesota; 60,000,000 in Arizona and 52,000,000 in Montana. The severe depression that has been experienced the past few years in the Copper Country has reduced very heavily the number of men employed there, but both Michigan and Minnesota will continue to employ for a long time many men in the mining industry.

From the statistical data submitted I draw the following conclusion. Accident prevention is not only possible but it is absolutely necessary. Investigation, education and invention are the factors that must be brought into force to stimulate and promote this most worthy work.

DISCUSSION.

MR. LOHNEIS: In listening to these reports of the various ranges. I think it brings us back to the old subject of unified reports and standardized reports on all accidents. I just wanted to ask if anything further has been clone by this body along those lines.

CHAIRMAN CONIBEAR: We went on record at our Conference last year as favoring the form used by the Bureau of Mines.

MR. LOHNEIS: I understand that that was done; in fact, I was present at the meeting when it was done; but has any move been made to see that the inspectors would do this?

CHAIRMAN CONIBEAR: What is the use if an inspector has the power to refuse to make an annual report if he fails to be reelected to office.

MR. LOHNEIS: Do you not think that if this body of men went on record and had some committee working on it that some thing might be obtained if it was taken up by the various legislatures?

MR. MARTINSON: I believe that if we want to make an honest and fair comparison that the time is ripe for this group to select someone to see if we can't get some uniformity in the reports required by the County Mine Inspectors in the states of Michigan, Wisconsin and Minnesota.

MR. KROGDAHL: What I think Mr. Lohneis is trying to get at is the result of these statistics are based on what the various operators report, but what do they report to the mine inspector or to the state.

CHAIRMAN CONIBEAR: They are required by law to report to the state all accidents.

MR. MARTINSON: As I understand it, the Bureau of Mines wants each accident reported, but I do not think all mining companies report them.

MR. GREGORY: The Bureau of Mines asks every operating company in the United States to submit all accidents yearly. Within the last year and a half it has been trying to get some more detailed information and it has asked all companies that will do so to submit individual reports on each accident.

MR. QUAYLE: Do you think that it is possible for every district to show a record comparable to Dickinson county? The mines there have been operating many years and they must be working under a mat that is especially strong. The mines on this range do not get a mat that will hold.

MR. EATON: I agree with the last speaker. You can't make comparison between any two districts and say they are the same any more than you can between any two men.

CHAIRMAN CONIBEAR: But the average annual fatality rates of all the districts are about the same.

MR. ———: We read very often about the great coal mine disaster. Of course, it is true that there is a vastly larger number of men working in coal mines than the Lake Superior mines, but, as I recall, we have had only four or five serious accidents in the Lake Superior district in recent years with a large loss of life. We have read of a great number of coal mine disasters where there has been a loss of 100 or 150 or more men, and on that basis your figures don't appear to be correct.

CHAIRMAN CONIBEAR: I haven't the exact figures in mind but I know accidents by falls of roof in coal mines are much higher than the number by gas and dust explosions. I think you will find that four times as many men are killed annually by falls of coal and rock as by explosions. When many men are killed in an explosion it commands attention, but we hear little about the many accidents which cause the loss of one or two lives.

MR. MARTINSON: No matter how pessimistic our Chairman may want us to feel about the reduction of fatalities, I believe that Mr. Smith's chart, showing the decreasing red line, beginning in 1905 and ending in 1924, justifies all the money that has ever been spent for safety in the entire Lake Superior District.

CHAIRMAN CONIBEAR: I have been contending this afternoon that we are making progress but that we have by no means reached the goal. We should not entertain the opinion or thought that our accident prevention work has been solved. I claim that we should aim to secure the record of Dickinson County.

MR. SMITH: If we could bring the rate any lower in St. Louis County we should do it. It seems to me that we have got it down so low I wish we could keep it there. We are going to have accidents and we get them in such peculiar ways that nobody is to blame. I don't know how to prevent them.

MR. HULST: I note in the first period you have used six years and in the second seven years.

CHAIRMAN CONIBEAR: I had 13 years to divide into two periods. I thought that from 1911 to 1916, six years, was a sufficient time to indicate a start in safety work, and that by including 1917 in the second period it would bring the average rate lower for that period, and therefore show more progress.

I will be glad to furnish the statistics for each year covered by my paper, giving the total number of shifts worked and the total number of men employed. I think you will find them accurate. They were taken from the reports of the U. S. Bureau of Mines, and if you can show a discrepancy in those reports, Mr. Adams, who compiles them, will be pleased to hear from you.

ACCIDENT STATISTICS, LAKE SUPERIOR MINES, 1911-1923 (INCLUSIVE)

TABLE I.
NUMBER OF MEN EMPLOYED.

	Minnesota (Iron)			Wisconsin (Iron)			Michigan (Iron)			Michigan (Copper)		
	Underground	Open Pit and Surface	Total	Underground	Open Pit and Surface	Total	Underground	Open Pit and Surface	Total	Underground	Surface	Total
1911-1916	49,206	54,730	103,936	7,091	2,781	9,872	64,007	27,633	91,640	60,445	24,447	84,892
1917-1923	40,868	63,059	103,927	5,038	1,707	6,745	65,240	31,772	97,012	42,813	22,297	65,110
Total			207,863			16,617			188,652			150,002
Total for all mines												563,134

TABLE II.
NUMBER OF MEN KILLED.

	Minnesota (Iron)			Wisconsin (Iron)			Michigan (Iron)			Michigan (Copper)		
	Underground	Open Pit and Surface	Total	Underground	Open Pit and Surface	Total	Underground	Open Pit and Surface	Total	Underground	Surface	Total
1911-1916	166	144	310	25	3	28	303	32	335	279	20	299
1917-1923	144	153	297	14	0	14	236	38	274	173	12	185
Total			607			42			609			484
Total for all mines												1,742

TABLE III.
NUMBER OF MEN INJURED.*

	Minnesota (Iron)	Michigan (Iron & Copper)
1911-1916	27,082	44,379
1917-1923	19,297	36,091
Total	46,379	80,470

*Information for Wisconsin mines not available

TABLE IV.
COMPARATIVE FATALITY RATES PER 1,000 MEN EMPLOYED.

Average Fatality Rate	Minnesota (Iron)			Wisconsin (Iron)			Michigan (Iron)			Michigan (Copper)				
	Underground	Open Pit and Surface	All Men	Underground	Open Pit and Surface	All Men	Underground	Open Pit and Surface	All Men	Underground	Surface	All Men	United States Metal Mines	United States Coal Mines
1911-1916	3.37	2.63	2.98	3.52	1.07	2.82	4.73	1.15	3.65	4.61	.81	3.40	3.95	3.89
1917-1923	3.52	2.42	2.85	2.77	0.00	2.07	3.61	1.19	2.82	4.04	.53	2.84	3.54	4.20
1911-1923	3.44	2.52	2.92	3.21	.66	2.52	4.17	1.04	3.22	4.38	.68	3.22	3.75	4.03

Average fatality rate for all Lake Superior mines, 1911-1923.....3.09

TABLE V.
COMPARATIVE INJURY RATE PER 1,000 MEN EMPLOYED.

	Minnesota (Iron)	Michigan (Iron & Copper)	U.S. Metal Mines
1911-1916	260	258	208
1917-1923	185	223	247
1911-1923	223	240	227

TABLE VI.
STATISTICS, DICKINSON COUNTY, MICH.

	Number of Men Employed	Number of Men Killed	Fatality Rate Per 1,000 Men Employed.
1901-1911	31,836	84	2.63
1912-1924	27,189	45	1.65
1901-1924	59,025	129	2.18

SOME SAFETY PRACTICES IN METAL MINES OF THE WEST.*

By F. C. Gregory, District Engineer, United States Bureau of Mines, Duluth, Minnesota.

The subject which has been assigned to me by the Chairman is of such large scope that I am going to limit it in territory to the mines in Arizona, California and Nevada, with whose practices I am more familiar. Even then it will be possible only briefly to describe the methods and practices which appeal to me as the most interesting. No attempt at comparison with the practices in the Lake Superior district will be attempted. The type of deposits and the mining methods are so varied that some of the practices described are not generally applicable.

Since the safety work is involved in every operation, the companies have attempted to use only those mining methods which are not only economical in the extraction of the ore but also are safe for the men. This has been the inspiration in the modification of old mining methods or the devising of new ones to meet special conditions. The tendency of late years has been for the construction of re-enforced concrete shafts and underground structures. This type of construction eliminates both the fire hazard, which is considerable, and also the chance of injury which is always present with the more temporary types of construction, especially in their maintenance. When it is practicable, separate shafts for handling the men are provided, a few being equipped with Otis elevator hoists.

*Published by permission of Director of U. S. Bureau of Mines.

Mechanical ventilation is general in the large copper mines and is gradually being adopted by the deep gold and silver mines. Such ventilation makes for safer and healthier mining especially where high temperatures or dusty conditions prevail. In general, the ventilation system is under the supervision of the safety department.

The form of the safety organization varies a great deal with the individual mines both in the personnel and in the authority which has been delegated to it. The extreme types vary from one in which a single safety inspector, who has authority to discharge anyone up to the Mine Foreman and who is responsible only to the General Manager of the company, carries on the work single handed, to elaborate organizations involving Foreman and Bosses' Committees, Workmen's Committees, and Safety Inspectors in its general organization, but without much authority to enforce its rules. The work of each of these types of safety organizations has been effective to about the same extent as the interest and effort put into the work. One of the special features which they employ in their work is the Safety Bonus for Bosses. This is a cash sum which is offered to the Shift Bosses and Foremen for the prevention of accidents to the men under their supervision. The form of the bonuses differs with various companies, an average being a bonus of $25.00 for each one thousand man shift worked under a single boss without a lost time accident. In general, the mines have a production bonus which is shared by both the workmen and the bosses for production above a given standard. It was realized that such a system always tends to increase the number of accidents, due to the men being willing to take unwarranted chances in their effort to earn a greater wage. The Safety Bonus was adopted in an effort to counteract this, and while not perfect, has proved to be very valuable. Only one company which has tried out the Safety Bonus, has discarded it and this one has substituted a penalty to the Bosses through depriving them of their share of the production bonus when accidents run above a prescribed maximum rate in their section of the mine.

Generally, employment departments are maintained and the men who are hired are required to submit to physical examination. Careful records are kept and the men are impressed from the start with the safety policy of the company. The new men are turned over to the safety department either before they are put to work underground or during the early part of their employment in an endeavor to teach them safe practices. The larger companies have a system of transfers; if a man does not make good or is not fitted to the work to which he is first assigned he is transferred to another department in an endeavor to place him finally in the proper position. The safety departments all maintain inspectors who make frequent inspections of all working places, report unsafe conditions, and make recommendations for their betterment. The inspectors investigate the serious accidents, keep the accident records and compile the yearly statistics.

Practically all of the mines report their yearly accident total in the Bureau of Mines Standard Form and in the form required by the respective state regulations. In addition to this they have much more detailed tabulations which vary according to the conditions in the particular mines and are designed to show as nearly as possible the principal causes of accidents. In this way, when one class of accidents shows up prominently, special effort is put forth to find a remedy for it. One company goes so far as to change its classification every year. Any classification which has shown a great number of accidents under it are classified in the minutest detail in an endeavor to .find the needed remedy. This has proved to be of very great value in their study of prevention methods.

One of the things which is common to the Western district, is the difficulty which the safety department has in getting accurate reports from the Shift Bosses on the cause of accidents to the men under them. No safety organization is able to investigate personally every minor accident, and the information from minor accidents must come from the Boss or the man injured. The Safety Inspectors are making every endeavor to get as complete information as possible for their records but often times have to be satisfied with very general reports. One company has attempted, during the last two years, to definitely place the responsibility for each accident. They have placed the responsibility under four headings: (1) Trade Risk, (2) Employees' Carelessness, (3) Fellow Workman's Fault, (4) Faulty Supervision. The last heading is intended to cover any delinquency on the part of the company or the Bosses. During the first two years the system was in effect the results of the reports turned in by the Shift Bosses, were as follows:

Responsibility for Accidents—

	Per Cent of Accidents Year 1923	Year 1924
Trade risk	97%	80%
Employees carelessness	3.3 %	17%
Fellow Workman's Fault	1.6 %	1.5 %
Fault supervision	.1 %	1.5 %

When the General Manager of the company saw the record for the first year, he called the safety division and the operating officials into conference and asked them if it was really true that only one-tenth of one per cent of the injuries could be attributed to the faulty supervision, in which case it was evident that the company was almost one hundred per cent perfect. As a result of his conference with the officials the second year's records were modified considerably. The question of placing the responsibility, is a delicate one, as the Shift Boss is generally the man who makes out an accident report and he naturally does not wish to shoulder the responsibility himself, nor yet throw it on the workman under him, if it is at all possible to shift it on the Trade Risk classification. However, the attempt to place the responsibility for the safety department's own benefit, is good, if it can be carried out at all feasibly.

The maintaining of schools of instruction for the Bosses and for the Miners themselves, has been tried out fairly thoroughly. A school for the Shift Bosses and the younger men in the organization, where all subjects relating to practical mining are given under the direction of the employment department, and where the subjects are taught by the Mine Superintendents, Engineers, and other men of the organization, who are especially fitted to instruct in their subjects, and where the safety policy of the organization and handling of men are taught, has been maintained successfully by one of the companies. The men who complete these courses satisfactorily, form a group from which promotions are made in the organization.

A training department for all men who are to be employed underground is also a feature of the organization. All of the new employees whether experienced in mining or not, are put to work in this training department where they are taught the standard practices of the company in drilling, blasting, timbering, etc., and where the safety policy of the company is thoroughly instilled into them. They are under the closest supervision of men who have been picked for their ability as instructors, as well as for knowledge of mining practices. This department forms a reservoir from which the regular producing parts of the mine are supplied with men. When a vacancy occurs the man most available for the place is sent from the instruction school, with the result that the mine is kept supplied with an adequate force of men who have been already instructed in the general working methods of the company, and so do not need so much attention from their Shift Bosses on being assigned to the work. This training school is carried on in a part of the mine which would ordinarily be turned over to "leasers" and the production from it just about offsets the cost of the school.

Other safety departments hold weekly meetings to which all newly employed are sent and where they are instilled with the companies' safety policy by the safety committee and the safety inspector. At this time they are usually advised of the First Aid instruction which is offered by the company and urged to come out to the

regular First Aid practices. Monthly inspections by safety committees and meeting of the committees with the safety inspector and the Mine Manager keep the condition of the plant or of the mine, as a whole, before the Manager and a record of these meetings is kept, including the recommendations made by the committee and their disposition. The safety inspector usually acts as secretary to the various safety committees. Some special features which they have developed in their attempt to prevent injuries may be of interest. The protection of the tops of all raises and chutes has been given a great deal of thought, and in places standard chute grizzlies for the tops of the chutes have been devised. These can be made upon the surface at less expense than building them underground and have the advantage of being transferred from one place to another until they are finally wore out. One company uses a cast iron form with railroad rail grizzly bars. At another mine where the ore is very soft the grizzlies are made of wood. It has been found that since the standard grizzly has been made up it is easier to get the men to cover all their open-chutes with these grizzlies than it was formerly, when they had to build the protection underground. The tops of manways are protected generally with railings and trapdoors where necessary.

To get away from the injuries caused by loading from chutes, loading platforms on the side of the drift opposite the chute have been built so that the loader can work from a safer and more advantageous position. One company has a loading platform the outside plank of which is hinged to the remainder of the platform and is folded back out of the way when not in use. While loading, this plank reaches over so closely to the cars that there is no possibility of a man slipping between the platform and the car. Special chute doors have been designed to meet the conditions of the ores handled. In the prevention of electrical accidents to the chute loaders, where trolley wires are used, two methods have been tried out. One mine has raised the trolley wire at the chute to about nine feet so that men may work fairly safely below it. Another scheme which has been tried out successfully is the using of a piece of small iron pipe which will just slip over the trolley wire and which forms a gate which may be slid back entirely out of the way while loading from the chute. This pipe is fastened to a section of the trough which guards the trolley wire and slides back out of the way, breaking the contact. The main current is jumped around by heavy insulated wire which runs across the cap and underneath the chute and again connects with the trolley on the opposite side. Since this device has been adopted no trouble has been found with electrical accidents to trammers.

One company has adopted the Pantograph type of trolley, for their main haulage levels which have few curves.

In a mine where numerous accidents were caused from the workmen stumbling over the switch stands, these switches were fastened to upright pieces of 4x4-inch timber painted white, with the result that the switch stands are now visible and the men avoid them

Regular air hose used in drilling has been adopted for fire hose underground with satisfactory results. One mine which maintains a special water pipe line for fire fighting has painted this line red so that it is easily distinguished by anyone underground.

In an attempt to prevent the mashing of fingers between hand trammed cars and the drift timbers, iron handles are riveted on to either end of the tram cars just below the top, in a position where it is convenient for the trammers to grasp them. It is found that the trammers will use such handles and avoid many minor accidents.

Goggles are worn by the men who sledge the rocks in the hard rock mines. The safety departments have found that it is possible to compel the majority of such men to wear their goggles while working. This has prevented a large number of eye injuries. Attempts to have the machine men use goggles while starting holes in the hard ores have not been so successful.

An interesting comparison between the results of two companies to get their men back to work after injury is given below. These companies work under very similar conditions as to type of labor, mining methods, etc., but one of the companies voluntarily pays regular compensation from the first day of disability while the second company goes according to the state law which provides that compensation shall be paid only after the disability has proceeded for fourteen days, but after fourteen days, is retroactive to the first day.

	First Company	Second Company
First seven days	49%	48%
Second week	22%	4%
Third week	13%	24%
Over three weeks	16%	24%

The above would indicate that any accident which caused disability of more than one week which occurred to men working for the second company was prolonged until after the compensation period through malignering.

The results of ten years of active safety work by the mines in the West are shown by a comparison of their records. Most of the mines which have continued intensive accident prevention, during this period, will show a decrease in their accident frequency of from forty-five to sixty-five per cent. This does not represent the district as a whole, as there are some mines whose record today is fully as had as it was ten years ago.

A comparison of the fatal accidents in the Lake Superior district with those of the State of Arizona as to cause and frequency may he interesting in light of the papers which were presented previously at this meeting. The following figures are from the 1924 report of the State Mine Inspector of Arizona. With an average of 13,276 employees for underground and open pit mines (not including reduction plants) there were forty fatalities during last year. They were classified as to cause as follows:

Cause—	Number
Fall of rock or caving ground	14
Blasting	9
Haulage	6
Shaft	4
Gas	2
Falls of person	1
Electricity	1
Machinery	1
Automobile	1
Unknown	1

This gives a percentage of 3.3 per 1,000 men employed. Of the accidents reported under “Shaft” three were cage accidents in which the cage riders left the safety gates open when moving the cage and were killed as a result. The one classified as “Unknown” referred to a man who was found dead underground presumably from natural causes.

The interest in First Aid and Mine Rescue work is practically universal. The system of training the men in First Aid differs slightly from that in use in this distrct in that the men are asked to come out for their First Aid training on their own time. The miners, as a whole, are so sold to the value of First Aid that larger percentages of men are trained through this system than the companies could afford to send out if they were paid for taking the course. It is not uncommon for the Bureau of Mines Car to train from one to three hundred men in a single mine, during a training campaign. A number of the companies carry on the First Aid work throughout the year, generally conducting one class a week for all employees who wish to take advantage of the training. A few of the companies who wish to especially encourage the men to take the work give five dollars to each employee upon the completion of the full course. Local and district First Aid contests are held to stimulate the interest in the work; one district holding a series of such contests each year, the winning team of each content being given substantial cash prizes. The number of well-trained First Aid men in the mines is large and a much greater percentage of the employees have taken the course at least once; while all of these men are not real First Aid men it is blieved that the mere taking of the First Aid course has a good influence in causing the men to be more careful of their work. The ideal of some of the Safety Departments is to have every employee on the property a trained First Aid man.

Mine Rescue training is regularly carried on and there are some excellent rescue stations throughout the district. The men are paid’ for rescue training and generally are carefully selected for the work. An interesting phase of the Mine Rescue training at several of the Arizona mines is the use of Mine Rescue Maneuvers as an advanced training course for the apparatus men. This work which has been described in different Bureau publications consists in gathering as many Mine Rescue men as possible together and working out problems in mine fire fighting and rescue of trapped men under conditions which are fairly representative of a real mine fire. The men who have been trained by these methods and who have been subsequently called upon to fight mine fire, have proven the value of this kind of training. They have worked with a minimum of supervision and confusion and have lost very little time in attacking the fire and fighting it in the most effective manner.

The above is a short description of a few of the more interesting things which the companies are doing towards safety. Taken as a rule, the managers are intensely interested in accident prevention and support the safety departments in a fine way. Every possible attempt is made to get a record of all the accidents and it is believed that the reports of these companies cover the actual underground accidents as nearly as it is possible to get them. On account of the large percentage of Mexican labor employed, the company doctors are very careful about allowing injured men to go back to work before their injuries are entirely healed. This makes the severity rate of their accidents greater than it would if a different class of miners were employed. But their work, on a whole, is showing gratifying results although none of the safety departments have approached the point where they consider that no further accidents are preventable.

BIOGRAPHICAL.

GEORGE H. ABEEL.

Born in New York City in 1863. After graduating from the Columbia School of Mines, he came to the Upper Peninsula of Michigan and was employed as mining engineer by the Iron Cliffs Company at Negaunee. From there he moved with his family to the Gogebic Range, in 1386, and for a time resided in Bessemer, Michigan.

From there he moved to the Montreal Mine, about 1889, and was placed in charge of the same, remaining as general manager of the Oglebay, Norton Company for twenty-five years. He resigned the position about 1914, but continued to reside in Ironwood.

He served as president of the Lake Superior Mining Institute during the years 1903 and 1904.

Mr. Abeel was a highly cultured gentleman and much beloved by all of his associates.

He died October 14, 1915.

JOHN F. ARMSTRONG.

Born May 1st, 1863, in Naas, Ireland. He came to Canada in 1864 and resided there until 1874, when his family moved to Marquette. In this city he attended the public schools and in 1879 entered the office of Mr. Alfred Kidder, who was for many years identified with mines in the Lake Superior district.

In 1882 Mr. Armstrong went to Champion as pit boss at the Dalliba Mine and the following year he entered the employ of the Cleveland-Cliffs Company under Mr. Doty. In 1886 the latter went to Chicago and Mr. Armstrong became the chief accountant of the company. In 1890 he went to the Fitch mine, at the old Saginaw location, when that property was being opened. At the Fitch he conducted a night school for the foreigners employed there.

In 1893 Mr. Armstrong went to the Mesaba Range, where he opened the Canton Mine for the Minnesota Iron Company, and operated this property for several years. For a short time he was the superintendent of the Mahoning Mine, at Hibbing. In 1897 he left for the West, visiting a number of the mining districts, and later carried on consulting work for iron mining companies. While making an examination of the Lake Superior Mine for the Cleveland-Cliffs Company, March 3, 1898, he fell down one of the shafts and was killed.

JOHN N. ARMSTRONG.

Born in Toronto May 23rd, 1837.

He received an excellent education in that city which was supplemented by a course in the University of Michigan. He was one of the early explorers in the iron countries of both Michigan and Minnesota.

Not much of Mr. Armstrong's activities are known, until it appears that he lived in the Marquette District in the late 60's or early 70's when he worked for Mr. Edward N. Breitung as an explorer and land looker. While in the employ of Mr. Breitung, in 1870, explorations conducted by Mr. Armstrong led to the acquiring of lands which later became the location of the Breitung Pit on the Menominee Range and subsequently led to the development of the Vulcan Mine by the Menominee Mining Company.

The explorations preliminary to the opening of the Norway Mine by the Menominee Mining Company were conducted by Mr. Armstrong. He was the original discoverer of the Mastodon Mine, in 1879, and was the first man to search for iron ore in the vicinity of Crystal Falls, in 1880, and discovered what is now known as the old Crystal Falls Mine.

This also led to the exploration and development of the Paint River Mine.

In the early 80's Mr. Breitung, hearing of the possibility of iron ore in Northern Minnesota, sent Mr. Armstrong to examine the same. At that time the trip was extremely difficult owing to the distance from Lake Superior and no rail connections. Mr. Armstrong made a favorable report to Mr. Breitung and he in turn convinced Mr. Charlemagne Tower of the great possibilities of iron mining in that vicinity.

To Mr. Armstrong, therefore, must be given quite a large amount of credit for the development of the Vermilion Range.

He died in New London, Wisconsin, in June, 1889.

JOHN L. BUELL.

Born in Lawrenceburg, Indiana, October 12, 1835.

After completing his studies at Lawrenceburg he took a scientific course in the Norwich Military School in Vermont. In 1857 he went to Kansas and spent a year in Leavenworth. In 1858 he started overland to Colorado in company with a number of other young men, and arrived at Cherry Creek, the site of the present City of Denver. In 1859 he surveyed and platted the City of Bowlder and during that winter he worked in Central City, Colo. In 1860 he engaged in mining in Leadville for six months.

In the fall of that year he went to New Mexico and in the spring of 1861 he started for the Gulf of Mexico via El Paso. As Texas had seceded at that time, by traveling at night he escaped to the Gulf of Mexico and secured passage on a vessel which landed him in New York, May 2, 1861. He served in the army until 1863 and then, after studying law, returned to Lawrenceburg and engaged in farming.

On account of ill health, he came to the Menominee Range in 1867 and put the machinery in the Jones' saw mill on the Bay Shore, operating the mill two years.

In 1871 Mr. Buell paid his first visit to the section known as the Menominee Range and upon his second visit, in 1873, commenced explorations and discovered the first merchantable ore on the range at what is known as the Quinnesec Mine. The same year he took up at homestead and in 1876 platted the Village of Quinnesec, which was the terminus of the Northwestern Railway until 1880.

From that time on he resided in Quinnesec in the home so well known by the early explorers of that region.

In 1876 Mr. Buell set up the first portable saw mill and in 1877 built the pioneer school house, and donated the land for the Methodist and Catholic Churches.

During all the time he lived in Quinnesec he was greatly interested in politics and in the interests of the county and the community and for many years he was an outstanding figure in the affairs of the entire range.

He died in February, 1917.

JAMES CLANCEY.

James Clancey was born in the County of Limerick, Ireland, September 29, 1845. He came with his parents to Canada and he spent some time as a machinist apprentice. He came to the Lake Superior District late in the year 1865, locating first at Eagle Mills in Marquette County. A short time thereafter he became associated with the charcoal furnace industry.

During the winter of 1871 he was with the Bay Shore Furnace at Munising, where he had charge of the machinery and shortly thereafter he engaged in the construction of the furnace at Escanaba, which was built by Andrew Kloman, of Pittsburgh, who was one of the leading furnace men of those days and who was later connected with some of the mining ventures of the peninsula. After leaving the Escanaba Furnace, Mr. Clancey entered the employ of the Morgan Iron Company at Morgan, Marquette County, where he spent several years. He was also with the Pioneer Furnace at Negaunee. At two different occasions he was associated with the management of the Deer Lake Furnace, north of Ishpeming, once when local capital operated it and later when it was taken over by the Lake Superior Iron Company.

In 1876 he entered the mining department of the Lake Superior Iron Company at its Section 19 Mine, south of Ishpeming, which was known in those days as the New Burt. On March 1, 1879, he took charge of the mechanical department of all the company's properties in the Ishpeming District, at which work he remained until March 21, 1910, when he was retired by the Oliver Iron Mining Company.

He was identified with civic work in Ishpeming, being postmaster of the city and for 24 years was a member of the Board of Public Works. He died at Ishpeming on June 4, 1925.

Mr. Clancey was a pioneer in the mechanical service connected with the iron mining industry. He participated in solving the mechanical problems which confronted the industry in the Michigan peninsula from the days of the Cornish pump to the days of electrification. He experimented with the men

who devoted their time and genius to the development of mechanical apparatus and his counsel was sought by many of them.

During his active service he was a regular attendant of the meetings of the Institute and was a member of the Board of Managers in 1901.

PETER MITCHELL.

Born in Lancaster, Pa., September 22, 1828. Mr. Mitchell was the first person who explored for iron ore in Minnesota by showing magnetic attraction and the first one to bring results of his efforts to the attention of the public.

His father went from Lancaster to Bellvidere, Boone County, Illinois. In 1847 Peter Mitchell, hearing of the copper range in Northern Michigan, joined a party of men going to the copper region. They followed the Wisconsin River to its source at Lake Vieux Desert and thence by the old trail north to Rockland and Ontonagon, arriving in the latter place in May, 1847. He continued to reside there until after the great lire in that village in 1896.

Mr. Mitchell was an expert woodsman and had a wide acquaintance among the Indians in the vicinity of Lake Superior. When he arrived in Ontonagon he found himself in the midst of the copper excitement which commenced in 1845 and lasted for twenty years. During this time accounts were received by him from Indians and French voyageurs of great iron fields in Northern Minnesota along the Rainy Lake River. In 1869 these stories had interested a group of men who made up a pool and selected Mr. Mitchell to explore for them. The group included Mr. Mitchell, L. Willard, James Mercer, L. K. Diekins, L. J. Longpre, and L. Stannard. Later on this group was joined by Alexander Ramsey, Governor and Senator from Minnesota.

In the spring of 1870 Mr. Mitchell crossed Lake Superior to Beaver Bay and from there ascended Beaver River to the divide, and then went down the streams entering the Rainy River to a lake known as Birch Lake, from which the very high hills of the Mesaba Range were visible. He evidently went north and south from Birch Lake and took some samples from an outcropping on the Vermilion Range near the present Soudan Mine. Finally some of these samples were called to the attention of Mr. Charlemagne Tower, of Philadelphia.

Mr. Mitchell also took samples and sunk several pits on the extreme east end of the Mesaba Range near the present town of Babbitt, the site of the operations of the Mesaba Iron Company. Mr. W. G. Swart has found several of Mr. Mitchell's pits, evidently made in the summer of 1871 or 1872.

In 1872, after finding ore on the Mesaba Range, Mr. Mitchell went to Washington in an effort to have that part of the country surveyed and through the influence of Senator Ramsey, finally had such a survey completed. A ten thousand acre tract now owned by the Mesaba Iron Company was taken up, as well as other lands.

The death of Mr. Willard seemed to discourage further investigation and efforts to develop that part of the Range were discontinued.

It is noteworthy that the first exploration on the Mesaba Range and the magnetite phase of the range, were not developed into a practical operation until nearly the entire range had been well developed.

This was due to the much easier wrought hematites discovered later in the center of the range. To Mir. Mitchell, however, is due the credit for making practically the first real exploration on the Mesaba and also the Vermilion Range.

He died in Detroit, September 23, 1918.

HARRY ROBERTS.

Born in Cornwall in 1855. He came to America when a youth and engaged in gold mining in Pennsylvania, working at the mines at that time operated by Peter Kimberly.

In the early 80's he came to the Northwest and engaged in mining at Ishpeming and Negaunee for Joseph Sellwood. About 1884 he went with Mr. Sellwood to Bessemer and was employed as mining captain at the Colby Mine. He remained there until 1888, at which time he went to Ely with Mr. Sellwood and was in charge of mining operations at the Chandler Mine.

Upon the opening of the Mesaba Range, in 1893, he left Ely and worked at the McKinley Mine, in McKinley. While there he opened the Roberts Mine and operated it. A little later he went into business for himself, exploring quite a number of properties on the Mesaba Range.

About 1899 he opened up the Spruce Mine in Eveleth for Mr. P. L. Kimberly and had charge of it until 1901. In 1902 or 1903 he was interested in the exploring of the Chisholm and Clark Mines at Chisholm, which later were opened by the American Mining Company. He then went into the contracting business, mostly stripping, with the firm of Roberts-Kingston Contracting Company.

He died in October, 1914.

PERSONAL EXPERIENCES AS MINING ENGINEER IN THE MARQUETTE DISTRICT.

BY JAMES E. JOPLING, ISHPEMING, MICH.*

In response to requests for a sketch of my personal experiences as a mining engineer in the Marquette district, the following notes were compiled from dates and facts obtainable and also from my recollection:

It was in July 1881 that I landed in Marquette at 18 years of age. My education consisted of schooling until I was 16, after which there were courses in study under different tutors for a year or more. I had passed the preliminary examination for entrance to Cambridge, England, and also into the school for Woods and Forests leading to a civil service position in India and also I passed into a college of Preceptors, but not finding the money to complete my education, I wrote to my brother Alfred, who still lives in Marquette, and who had charge of the construction of a division of the D. M. & M. Railway then in the process of construction from Marquette to St. Ignace. A brief letter from him invited me to come without giving any indication of what work there was in store. My father, Charles M. Jopling, who died the year I was born, had been a civil engineer of considerable reputation and was a partner in the construction of the Italian Central Railway running through Turin to Naples. My grandfather, Joseph Jopling, was an architect in London and a mathematician of some note. Part of their records had been available so that I had a general knowledge of engineering.

The evening of my arrival I met members of the Peter White and Mather families who have always been my good friends.

The day after my arrival I was asked what I could do. I had to« own up that I had never been employed and had no profession. I was enabled to demonstrate my ability to use engineering instruments and was appointed transit man on a railway survey from Marquette to the mines at Negaunee and Ishpeming, which line was afterwards built as the Marquette & Western and is now known as the South track of the D., S. S. & A. Railway. In 1881 and 1882 while I was in their employment the railway was known as the Detroit, Mackinaw & Marquette.

The large crew of choppers needed in the forest laughed a great deal at my youthful appearance but were good hearted fellows and I soon gained their respect, even if they did have to carry my transit over the logs thrown across the streams while I climbed over on all fours.

*Chief Mining Engineer, The Cleveland-Cliffs Iron Co.

Written for the Marquette County Historical Society, Marquette, Michigan, November 14, 1924.

During my employment in and about Marquette on the railway, I came in contact with a number of men who were interested in mines and explorations .on the new Menominee and Gogebic ranges. One day A. F. Norrie came to the office and insisted that I take a long drive with him. In the course of conversation, he told me in all seriousness that he had been employed in a bank in England where he had a dream that he would come to America to discover a great mine. He was then in the office of J. M. Longyear and was about to explore on the Gogebic range. In less than two years from that time, and after considerable hardship, he discovered and sold the Norrie mine on the Gogebic range, making good the promise of the dream.

Edward A. Wetmore of Marquette had graduated as a mining engineer in Columbia University, New York. He discovered the mine now called the Imperial near Michigamme. The farmer who owned the surface of the land brought suit to gain possession of the minerals which had been reserved. This case was later decided by the Supreme Court of Michigan, which confirmed possession to the holders of reserved mineral rights.

In the fall of 1882 the engineer under whom I was employed was transferred to L'Anse in order to make a survey of the proposed extension of the M. H. & O. Railroad to Houghton. I was engaged on this work only a few weeks when the survey was temporarily stopped and I was out of a job.

After hanging around Marquette for six weeks, Peter White, the banker, who was my brother's father-in-law, sent me to Ishpeming to look for any trespass on the lands of the Teal Lake Iron Company and his own property. After waiting in vain a few days for a landlooker, I started out by myself without snow shoes, the snow being over a foot deep. My new friends at Ishpeming took me as far as the corner post from which I should start and after bidding me good bye they returned. I walked over the hill and fell into a test pit which was partly covered by the snow. It proved to be 10 feet deep but had a pole in it so that I was able to climb out. During the morning and, part of the afternoon I progressed northward, climbing the ranges of hills and reaching the top, the sun came out and the wind dropped. The view disclosed was most attractive and interesting. There were a number of French Canadian woodsmen wearing red caps and sashes and making the forest resound with their song and shouts. Some were chopping down the trees, some sawing the fallen logs into lengths and others were piling the timber or loading it upon sleighs. They were cutting the timber which I, had been sent to watch. The operations proved to be those of the Lake Superior Iron Company. Upon reporting the trespass, I was disbelieved owing to my lack of experience. Investigations found me to be correct and the matter was ended by my employment as surveyor by the Lake Superior Iron Company. This was my introduction to the mining business.

For a time I was employed in the woods running lines for timber cutting. On one of my first trips I was ambitious to see more of the timber lands and started on a long walk, expecting to encounter a snow shoe trail through the woods on which to return to a camp. As it began to get dark, I found a trail and followed it until I noticed, a tassel from my own shoe which I had evidently lost in the morning. Lighting matches I read my compass and turned about struggling through the woods in the dark. A storm came up and I had great difficulty in climbing bluffs, sliding down hill or plunging through swamps, but my sense of direction was aided by distant whistles from the mines. By nine o'clock a camp was reached and after listening to my tale, the cook gave me supper, but before I could finish, the camp caught fire. In the zero storm some one threw a bucket of water over me. After the fine was out, I was told there was no room for me but that there was an exploring camp some miles away. With the wolves howling round me, I reached that camp after midnight. The explorers were a merry lot, drinking and playing cards and next day took me out and let me shoot my first deer to provide meat for the camp.

The mines at Ishpeming and Negaunee at that time consisted mostly of open pits about 150 feet and nearly all of the product was hard ore. Several of the larger operations consisted of open stopes leading from the bottom of the pits and in a few instances incline shafts had been, sunk a few hundred feet from which sloping was in progress. The soft ores were being mined in stopes kept open by various systems of timbering. In only one soft ore mine had the caving system been introduced as an experiment. My work at first was elementary, consisting of running lines of levels for ditches, or the measurement of stopes as they progressed which were posted on an old set of maps, but some time, in 1883 I started a triangulation survey of the surface, having the unpaid advice of a United States Engineer, Frank Armstrong, of St Louis, and new lines were run through all the workings for a new sell of' maps. I had charge of diamond drill operations. My first experience as a mining engineer at the Lake Superior Iron Company was an, interesting one and I was always grateful for the help given me, especially by the mining captains, more particularly by Captain John McEncroe, who always took me with him while letting contracts to the miners, or figuring out special methods of mining. C. H. Hall was the agent and Captain W. H. Johnston was his assistant, both of whom showed great patience with my early endeavors.

During 1883 I repaired the system of electric bells which gave the signals for hoisting the skips in one of the shafts of the Lake Superior mine and while in Chicago I ordered a cable and other apparatus for another shaft from the Western Electric Company.

During the summer of 1883, a special train, consisting of the Charcoal Iron Workers Association, drew up at the mines. I was appointed as a guide to show some of the visitors the underground workings and answer questions, which I did to the best of my ability. On going to the train to say good bye, they told me I was to accompany them on their trip. I assured them that I had no money, nor permission. They said they had both. We visited mines on the Marquette and Menominee ranges and charcoal blast furnaces, the trip ending in the Lower Peninsula after a round of entertainments. The men who had

invited me were John Birkinbine of Philadelphia, and W. B. Potter of St. Louis, who were among the leading mining engineers and blast furnace experts in the United States. They continued to correspond with me for many years, and I met them later at meetings of the American Institute, particularly in Canada, in 1889, and also when that Institute came to Marquette in October 1890 together with members of the British Iron & Steel Institute and engineers from Germany. They insisted that I should write for publications and become a member of the American Institute of Mining Engineers, which happened the next year as I had to wait until I was 21 to become a member.

George P. Cummings, the veteran civil engineer of Marquette, about the same time insisted that I become a member of the Michigan Engineering Society.

A little later A. B. Miner became cashier of the new First National Bank in Ishpeming. He had lived several years in the West and his hobby was gold mining. The Ropes Gold mine was then in operation and we, spent much of our leisure in searching for other veins. Some two years later, in 1885, we paid for explorations at what was afterwards known as the Michigan Gold mine, the first blast throwing out about $500 worth of gold, causing great excitement in the country. If I had the knowledge of land titles which I later acquired, I might have retained my interest, but it passed to other hands and after $70,000 in gold had been taken out the mine was abandoned,

Among the many friends I had in Ishpeming at that time were Captain William Sedgwick, who was always ready to help and advise, A. B. Eldredge, who at that time was attorney for the C. & N. W. Railway, and Joseph Sellwood, interested in mines and banks, who later moved to Duluth.

In the fall of 1884 I left the Lake Superior Iron Company and was employed by Peter White, the banker in Marquette, who gave me a job in the First National Bank in order to learn the business, though part of my work consisted in looking after his landed property and mines in which he was interested. During this period he secured Presque Isle as a park for Marquette and employed me to lay out the roads and attend to the improvements in the winter of 1886-7. I made a triangulation survey of the Island by running base lines all round it on the ice, contoured the Island and then laid out the roads.

Keeping up with the progress in mining engineering necessitated study and I prevailed upon several men to give me instructions on different subjects in return for pay. An amusing incident happened when I asked a man to teach me enough chemistry to make analyses of iron ore, receiving the reply in the negative because I might learn enough to take his job away from him. The man never made any progress in life and the story stands out in contrast with a request of mine to learn bookkeeping. An assistant bookkeeper in the bank, Charles Joslin, kindly devoted many evenings to my education. It was only in 1923 that I learned through the newspapers of his death in Arizona, where he had become president of a large mercantile company.

In 1884 when I was working as collector in the bank, I was stopped on the street by William P. Healy, who was a prominent lawyer in Marquette and Chairman of the Republican Committee, who told me in solemn words to visit his office after banking hours, which I did. He asked me if I drank or played cards. Upon answering in the negative which might not have been absolutely truthful, he stated that he had been watching me for some months. I thought something dreadful had happened when he produced a document which proved to be an option m my name for mining leases from the Arctic Iron Company, owned by Edward Breitung and himself, on its property at Negaunee for the period of one year and told me to get busy and turn portions of the option over to explorers. I was almost overcome with surprise but was only too glad to comply with his request. The first parties to explore on what was afterwards known as the Regent Group threw up the option much to my loss and disgust because they found that unknown to me several of the test pits in soft ore formation had been “salted” with hard iron ore by some person who hoped to profit by it. These pits were immediately over the great deposits of soft ore later discovered. Then I was able to turn the option over to a mining company but after the expenditure of considerable money, they failed to find the ore and I lost my chance of making a fortune. After my option expired, local parties discovered soft ore a few feet below surface at several places in the swamps and a number of companies were formed to work the properties which were merged into the Regent Iron Company.

A silver excitement came up in 1885. About twenty years before this, Silas C. (Whetstone) Smtih had found silver lead said to run $70 to the ton upon lands of the Iron Cliffs Company near the railway, about five miles west of Marquette. This company had refused to sell the land or grant a lease. Edward Breitung had backed Mr. Smith, which lead to a local fight in Negaunee politics. Peter White finally obtained a lease from the Iron Cliffs Company through his friends William T. Barnum and Samuel J. Tilden, but while on his return to Marquette, Mr. Smith died. Mr. Breitung tried to show Mr. White and me the silver find but failed. An exploring camp was established and I was put in charge. A vein 10 feet wide was discovered but only traces of silver were shown in the assays and the exploration was abandoned.

In 1887 Mr. White made me superintendent of the Phenix Iron mine at Champion but after a brief period we discovered that the ore was low in grade and small in quantity and were compelled to close down the property. Attempts to sell this ore took me to Cleveland and Youngstown and widened my acquaintance. One day taking a train east of Pittsburgh I met a man who asked many questions about the iron business and my connection with it and also discussed other topics. We talked for more than two hours and upon leaving he handed me his, card. It bore the name of William McKinley, later President of the United States. That fall I left for England and Scotland where I spent part of my time visiting mining operations, principally in the coal districts.

Returning in 1888, I was requested to open an office as mining engineer in Marquette by several of my good friends, the chief being Alfred Kidder, who was operating the Champion, Angeline and Volunteer mines, and also Walter Fitch. There was a great need in the districts of Michigan for better shafts through which hoisting might be done more rapidly than over the inclines which usually followed the footwall of the pits. During the next five years I was kept busy most of the time with this class of work, successfully holing 13 shafts raised from various levels. In most cases a vertical shaft was started from surface and in order to speed the work, raising was begun on the lower levels to meet it. This required careful surveys and much responsibility in directing the raising so as to make a perfectly straight shaft. Fortunately my shafts holed perfectly, but on one occasion I gave the course to drift underground to the shaft position from a preliminary survey which I quickly corrected by a re-survey. The captain in charge was furious because 30 feet of drifting was wasted. I offered to pay $300, which more than covered the expense. He took the money, but feeling that I needed further admonition, he knelt down in

the office and prayed the good Lord to make me a better engineer, which prayer I hope was answered.

One shaft at Champion and another at Iron Mountain were over 1,200 feet deep, the surveys for holing being complicated as they were carried through irregular and steep openings. I often wonder why careful business men ever entrusted a young man only 25 years of age with such responsible work as errors would have been extremely expensive and would have caused great delays. At that time there were but few mining engineers in the Lake Superior region and practically no trained assistants to help me with the calculations.

The work of a mining engineer meant long hours and rough conditions, both underground and also in traveling to and from the mines in all kinds of weather. Frequently, surveying had to be done out of regular hours. Saturday would be spent in preparation and the survey begun on the night shift. It was lucky if it was finished by Sunday morning and sometimes I had to work without leaving the mine until Sunday evening or even Monday morning if there was anything specially difficult. This necessitated working at times from 24 to 36 hours continuously.

During this period there were a number of men with whom I became acquainted who aided me materially by giving me advice. R. A. Parker in 1888 helped me in many ways, showing how to make a presentable map. Dr. M. E. Wadsworth stayed in Marquette for some months in 1887 before he began his work as Director of the Michigan School off Mines at Houghton. He recognized my lack of knowledge in geology and chemistry and wanted me to throw up my work and become one of his students. John F. Stevens, who has done such notable work in Panama, and on Siberian railways since the beginning of the World War, was in Marquette for a year or more. I was often in his company and he discussed at length the theory of location of railways which proved valuable to me in 1895 when I suggested the re-location of the L. S. & I. Railway line before it was constructed. He took me to Duluth in 1889 and explained the complicated location of railways and connections with the docks.

W. J. Rattle of Cleveland wanted to take me to Cuba where iron ore mines were being opened about 1890.

J. Parke Channing, now of New York, was a friend of whom I saw a great deal and to my advantage as he conveyed much valuable information received at Columbia University, together with his own style of attacking mining problems. He was in this mining region from about 1883 to 1893.

Thomas F. Cole was manager of the Queen, later Regent Group of mines at Negaunee from 1890 to 1897. He employed me first to measure his stockpiles upon which he was negotiating a loan. The result satisfied him so well that we continued our relations and later he tried to get me interested in his Arizona copper ventures.

W. F. Fitch was manager of the D., S. S. & A. Railway in 1888 and later became president. He aided me in many ways.

Charles Burt, whose grandfather invented the Solar Compass, described in 1887 the recent invention of the gas engine for which he predicted a wonderful future and wanted me to experiment with it, which I declined. Machinery was not much in my line, but I kept in touch with the manufacture of new types. William A. Parker a little later described the new invention of percussion drills and predicted their use in mining.

Geology was more in my line and I took every opportunity to learn from the many visiting geologists and mining engineers. Dr. Charles E. Wright, the State Geologist, who died at Marquette in 1888, helped me in many ways. Dr. C. R. Van Hise began his great work on the geology of the Marquette range at that time and I accompanied him on some of his trips.

My former employer, Peter White, became Master in Chancery for the Pewabic Copper mine about 1890 and employed me for a time making surveys and maps, for which purpose I had to consult the abstracts of Houghton County. This brought me in contact with a great number of men in the Copper Country and added to my experience in mining. The property was afterwards sold to the Quincy Mining Company. Don M. Dickinson, later Postmaster General under. Cleveland's second administration, was employed as a lawyer on this case and several times came to Marquette and Houghton in 1890 and 1891. Captain Samuel B. Harris was the agent of the Quincy and Captain Johnson Vivian was agent of the Franklin mine.

Mr. White had me appointed Receiver of a saw mill in 1890 and after a prosperous summer, I was in hopes of paying more than 100 cents on the dollar but unfortunately it transpired that part of the last winter's supply of timber had been taken without payment, or perhaps stolen by the former operators, who had merely negotiated for it, which necessitated a large inroad into the profits of the concern. While I continued an independent office as mining engineer in Marquette, I was employed by some 26 different mining companies, for some of which I made several reports. The pay received for ordinary work was $10.00 a day and all expenses, besides those of my assistant and draughtsman, while I got $50.00 or $100.00 for special reports. Besides conducting' explorations for others on different ranges, I was interested in several explorations, none of which turned out successfully.

During the period 1881 to 1895 most of the white pine in the district was cut, bringing many men to the county. Previously the only clearing had been around the mines and charcoal blast furnaces,—now the clearing extended over most of the county, much valuable timber being burnt during the removal of the white pine, leaving only some hardwood and smaller mixed timber.

The towns during this time increased in area considerably, although the population remained about the same. Cheap lumber meant houses for many. I was employed to lay out additions for building lots in the towns of Marquette, Negaunee, Ishpeming and elsewhere.

For amusements we had sailing on Lake Superior, fishing and hunting trips and in the winter snow shoe clubs were popular. The Marquette Club was organized in 1888. Later a charter was taken out when it was moved to its present quarters.

Sometimes the mining companies were involved in law suits. In one case of trespass, the amount of ore removed was agreed upon by two of us, but a third engineer differed by two per cent and told the Court that our method of calculation was faulty. Owing to the disagreement, a fourth engineer was called who was of the rough and ready order. He estimated the ore removed at double the amount and a sympathetic jury awarded damages on that basis.

The panic of 1893 coming on, most of the mines for which I was engineer shut down and later were absorbed by larger companies. For the next year or two it was difficult for a mining engineer to make a-living so that in 1895 when I was offered a position by the Cleveland-Cliffs Iron Company, I was only too glad to accept it and have continued as Chief Engineer of that Company.

MARQUETTE CITY WATER POWER PLANTS.

BY HARLOW A. CLARK, MARQUETTE, MICH.*

When you are at Marquette you'll want to visit the municipal hydroelectric power developments on Dead River. The City of Marquette commenced furnishing hydroelectric lighting service almost 35 years ago and as the demand for electric light and later for power has increased through the years the city has added to its power holdings and improved its original plant and built additional plants aiming always to keep ahead of the community's needs. From the time the city began to furnish the service right on down to the present time this public utility has added tremendously to the life of the community. Whether you look at the physical property, or at the property accounts, or at the earnings statements, or talk with groups of electric light and power users all will speak eloquenly of the value of this fine municipal undertaking.

The city's first step towards providing electric lighting service was taken in 1889 when 400 acres of land on Dead River was purchased for $10,000. By this purchase the city acquired 119.5 ft. of fall between elevation 31 ft. and 150.5 ft. at an average cost of $83.68 per foot of fall.

In 1901, the city bought sufficient flowage rights to allow the water to be raised 7.5 ft. from elevation 150.5 ft. to elevation 158 ft. for $266.66 per foot of fall. Ten years later the city purchased flowage rights by which it could back the head water to elevation 169.4 ft. thereby adding 11.4 ft. to the city's head, for $1,078.94 per foot-fall.

In 1920, the city bought the so-called "powder mill property" comprising 384 acres of land and timber with a fall of 20 ft. between elevation 5 ft. and 25 ft. for the sum of $25,000; and in 1922, the city also purchased 6 ft. of fall between elevation 25 ft. and elevation 31 ft. for $6,000. The original purchase of 119.5 ft. of fall has, therefore, been increased by successive purchases to 164.4 ft. of fall.

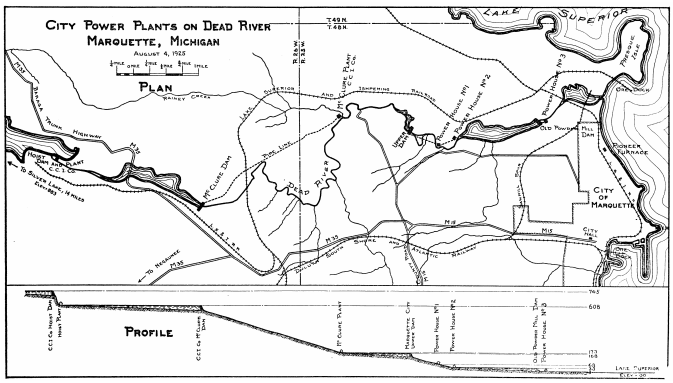
Immediately after the initial purchase of 119.5 ft. of water fall on Dead River between elevation 31 ft. and 150.5 ft. above the level of Lake Superior, Power House No. 1 was constructed at elevation 68 ft. three and one-half miles from Marquette. This original power plant was rebuilt in 1912. The original plant had a capacity of 50 continuous h.p., a momentary maximum capacity of 300 h.p. As a part of this original construction work a wooden dam was built just above the power house at elevation 92 ft. giving a head of 24 ft. This dam was rebuilt in 1907 but is no longer in use. In 1896 the city built a dam at elevation 150.5 ft. at the western limit of the city's property 50 ft. and 6 in. in height and 2,700 ft. up the river from plant No. 1. This dam which has always been known as "the upper dam" gave a head of water between elevation 68 ft. and elevation 150.5 ft. of 82.5 ft. The construction of this dam made possible an increase in continuous horsepower from 50 to 300 and raised the momentary maximum horsepower from 300 to 900. This upper dam was put into use in 1897 and was used continuously until 1911 when it was rebuilt of concrete and made higher so as to utilize additional flowage rights acquired since its original construction in 1896.

*Formerly Mayor of Marquette.

At the same time that the upper dam was constructed there was also built a 72-in. penstock from the upper dam down to power plant No. 1 to carry the water from that dam to the power house. When the upper dam was rebuilt and its height raised 17.5 ft. to elevation 168 ft., one hundred per cent was thereby added to the number of k.w.h. that could be generated annually at plant No. 1. By reason of the increased generating capacity a 1,600 h.p. generator was installed in 1912. In order to be able to operate the 1,600 h.p. and the 733 h.p. generator (which had been installed in 1904) in multiple during peak of load periods it was necessary to put in a second penstock connecting the upper dam with power house No. 1. Accordingly, a second penstock, 90 in. in diameter, was built in 1916. In 1919 the demands on the plant had increased to such an extent that the city started in to utilize additional 30 ft. of the water fall purchased in 1889 by erecting at a point on the river 1,800 ft. below plant No. 1, at elevation 38 ft., power house No. 2, with room in the new station for two generating units. The first generating unit of 2,400 h.p. was put into commission at the end of 1920, and early in 1923 an additional generating unit of 2,400 h.p. was installed. The 90-in. penstock was extended from plant No. 1 down the river 1,800 ft. to power station No. 2. At the same time a surge tank was constructed on the hill back of power station No. 2, and two penstocks 600 ft. long and 78 in. in diameter were built to connect the surge tank with the power house. Plant No. 2 including the cost of the power station, 1,800 ft. of 90-in. penstock, 1,200 ft. of 78 in. penstock, the surge tank, and machinery, cost $396,327.87, and added 55 per cent to the city's generating capacity.

After the erection of power station No. 2 at elevation 38, there was still available 33 ft. of fall between elevation 5 ft. and elevation 38 ft. The city owned 7 ft. of this as a part of its original purchase in 1889 and acquired the additional 26 ft. of fall in 1920 and in 1922, thereby making possible the construction of a third power plant and a concrete and earth filled storage dam at elevation 5 ft. There was an old dam on the powder mill property when it was purchased which raised the water to elevation 25 ft. The level of the spillway at the new Powder Mill dam is 38 ft., so that the level of the water has been raised from 25 ft. to 38 ft. by the new construction work. This last dam has flooded 88 acres of land. Power plant No. 3 has a generating capacity of 1,000 h.p., and its cost including land, dam, machinery and concrete highway bridge below the station was $192,000.

Power house No. 1 is not operated now but is kept in readiness for use in the event of any unforseen emergency. At station No. 2 with a capacity of 4,800 h.p., at least one of the two 2,400 h.p. units is operated continuously. The continuity of the daily operation of station No. 3 is dependent upon the amount of water available for use. Plant No. 3 is connected with the dam by 135 ft. of 96-in. penstock.



The construction of the Powder Mill dam and power station No. 3 has actually increased the city's generating capacity 33 per cent.

Up to this point no mention has been made of the storage dam located at Silver Lake at the head water of Dead River, 30 miles from Marquette. In 1911 the natural elevation of the

water in Silver Lake was 863 ft. above Lake Superior. It was determined that if a dam was constructed at this lake to bring the water to elevation 883 ft. at high water period, the storage of water gained thereby would make a vast increase in the amount of continuous h.p. that the city could generate. Such a dam was constructed (after flowage rights were purchased and a 20-year lease obtained) and the continuous h.p. thereby increased from 365 to 890 ft. and the momentary maximum from 1,100 to 1,930 h.p. This storage dam has served a valuable purpose for many years. The extensive storage dam constructed by the Cleveland-Cliffs Iron company, in 1924, above the plants owned by the City of Marquette, is going to prove of immense benefit to the city's power operations.

The natural flow of Dead River is 70 second-ft. The construction of the storage dam at Silver Lake increased the flow to 133 second-ft. and the Cleveland-Cliffs Iron Company Hoist Dam has raised the river flow to 216 second-ft. The great value to the city's power plants of conservation of water during high water periods for use in low water periods at a point up the river from the city's installations is apparent.

The operating results and plant value are exceedingly interesting as will appear from the following summary going back to the year 1905:

Year.	K.W.H. Earnings.	Gross Earnings.	Net Earnings.	Book Value.
1905	1,666,200	$ 39,386.22	$16,355.53	$ 170,213.71
1910	2,476,400	61,594.34	40,375.90	250,121.65
1915	5,109,800	75,815.95	28,370.28	449,571.76
1920	5,768,800	104,023.45	22,396.63	769,269.30
1924	8,529,300	151,105.13	95,147.63	1,079,176.18

It will be noted that there has been a large growth in power generated, in gross earnings, in net earnings and in book value. While the plant has a book value of $1,079,176.18, the only indebtedness is $25,000 in bonds which, it is understood, are to be retired this year. Gross earnings have increased in four years about 50 per cent and net earnings have increased over 400 per cent, while in the same period the increase in book value has been in the neighborhood of 25 per cent. The outlay of the last two years has resulted in harnessing all of the city's available water power. The program of hydro-electric construction has been completed and the entire plant stands as a model of municipal efficiency. The rates have been low and now stand at a maximum for lighting purposes of 5 cents per k.w.h. and scale down to a minimum of 2 cents per k.w.h. The power rates have a maximum of 3 cents per kw.h. and scale down as low as 1 cent per k.w.h. for electric stoves. Only six-tenth of a cent per k.w.h. is charged the department of water for furnishing power for the pumping station, and the streets are lighted at a charge around $6,000 per year. Furthermore, the Department of Light & Power pays into the general fund for general city purposes an annual sum amounting to one and one-half per cent of two-thirds of the book value of the plant, aggregating at present over $9,000 per year, as equivalent of what it would probably be called upon to pay into the city treasury if it was a privately owned instead of a municipally owned public utility.

It should be added that every cent of the cost of the plant has been paid out of earnings from the plant. In 1889 when the original purchase of 119.5 ft. of fall was made at a cost of $10,000, the general city fund was drawn on to make the payment. At a subsequent date $12,500 was likewise advanced for improvements and the credit of the city has been pledged at different times in the issuance of bonds for light and power improvements. However, all of this money has been paid back to the general fund and all hydro-electric bonds, with the exception of the block of $25,000 to be retired this year, have been paid off out of earnings of the plant, but at all times the rates have been exceedingly low.

Do you wonder that the people of Marquette are proud of their municipal light and power plant and the service it has rendered and that it is destined to render in this day when people are becoming more and; more dependent upon electricity in their daily living?

Great credit is due to the men who were instrumental in launching this splendid enterprise thirty-five years ago. They rendered a service of lasting benefit to the community. In the upbuilding of the utility through the years no one public official has been closer identified with its progress than James E. Sherman, who first became connected with its management as a public official in June 1898 and continued with it up to January, 1923, a period of nearly twenty-five years, when he was succeeded by Edward J. Hudson, the present commissioner of the department of light and power. It should be a crowning satisfaction to Mr. Sherman that this valuable public utility to which he gave so generously of his time, energy and ability, is widely recognized as an outstandng example of a highly successful municipally operated hydroelectric plant.

MOVEMENT OF LAKE SUPERIOR IRON ORE BY LAKE, DURING SEASON TO NOVEMBER 30TH, 1925, AND COMPARISON WITH 1924.

Shipments—Upper Lake Ports (Railroad Weights)

Port—	To Dec. 1st, 1925.	To Dec. 1st, 1924.
Escanaba	5,644,276	4,244,669
Marquette	3,480,751	2,516,548
Ashland	6,664,501	4,807,565
Superior	14,560,477	13,355,214
Duluth	17,707,978	12,882,082
Two Harbors	6,016,096	4,817,494
Total	54,074,079	42,623,572

Receipts, Shipments and Balance on Dock—Lake Erie Ports (B/L Weights)

Port—	Dock Bal. Apr. 1, '25.	Receipts*	Shipments.	Dock Bal. Dec. 1, '25.
Buffalo, No. Tonawanda, Port Colborne	92,908	4,111,463	501,081	68,226
Erie	189,393	647,414	734,825	107,856
Conneaut	1,011,164	8,635,835	7,592,842	2,101,486
Ashtabula	1,341,928	7,781,964	6,656,423	2,504,098
Fairport	290,141	2,116,442	1,934,096	485,648
Cleveland	1,196,497	8,754,884	5,884,910	1,251,411
Lorain	296,267	4,116,192	2,115,739	703,331
Huron	476,389	1,001,317	932,139	548,095
Toledo	201,517	1,431,312	744,718	86,003
Total	5,096,204	38,596,823	27,096,773	7,856,154
Comparative total 1 year previous	6,062,589	31,534,493	22,108,509	8,049,276

Receipts at Other Than Lake Erie Ports (B/L Weights)

Port—	Season '25.	Season '24.
Detroit	937,900	826,369
Indiana Harbor	1,891,232	1,553,600
Gary	4,889,039	3,093,427
South Chicago	6,442,034	4,533,707
Milwaukee	67,166	
East Jordan	9,217	32,166
Sault Ste. Marie, Ontario	227,532	360,215
Point Edward, Ontario	375,411	231,308
Total	14,839,531	10,630,792
Comparative total 1 year previous	10,630,792	14,656,472
Total receipts, lower lake ports	53,436,354	42,165,285

Receipts at Lake Front Furnaces—Lake Erie Ports

	November.	To Dec. 1st.
1925	880,583	8,893,375
1924	736,114	7,610,627

*Receipts at Lake Front Furnaces shown only as receipts.

The Lake Superior Iron Ore Association—December 7th, 1925.

TOTAL PRODUCTION MICHIGAN COPPER MINES TO JANUARY 1, 1925 (in pounds).

Previous to	1855	13,419,227	1890	100,695,359
	1855	5,820,170	1891	114,408,626
	1856	7,752,268	1892	107,540,354
	1857	9,708,135	1893	113,511,805
	1858	9,023,163	1894	114,474,074
	1859	8,999,595	1895	129,676,402
	1860	11,791,518	1896	145,744,726
	1861	14,842,474	1897	142,702,586
	1862	13,647,785	1898	147,965,738
	1863	12,812,183	1899	148,444,489
	1864	12,402,577	1900	142,078,171
	1865	14,046,582	1901	155,616,848
	1866	13,240,405	1902	170,175,598
	1867	16,750,070	1903	192,249,201
	1868	19,795,068	1904	208,279,248
	1869	26,583,959	1905	229,119,645
	1870	24,286,661	1906	230,524,600
	1871	25,707,021	1907	216,006,747
	1872	24,821,140	1908	223,539,515
	1873	29,876,478	1909	233,515,522
	1874	34,266,771	1910	221,163,271
	1875	36,070,099	1911	219,771,477
	1876	38,143,001	1912	216,792,974
	1877	38,880,351	1913	139,656,075
	1878	41,486,252	1914	166,184,386
	1879	42,838,468	1915	258,103,217
	1880	49,601,399	1916	266,839,475
	1881	53,871,959	1917	256,037,005
	1882	56,582,734	1918	228,137,863
	1883	59,256,786	1919	178,365,567
	1884	69,327,796	1920	161,343,880
	1885	72,759,082	1921	92,262,083
	1886	80,259,832	1922	121,386,726
	1887	75,793,363	1923	137,952,586
	1888	86,502,886	1924	138,159,553
	1889	87,413,996		

Grand total of Michigan (pounds) 7,306,800,646

U. S. production from 1845 to January 1, 1924 (pounds)....32,498,219,363

Per cent production Michigan copper mines, to total U. S. production..22.5

By courtesy of L. P. Barrett, Appraiser of Mines, Lansing, Mich.

GENERAL INDEX.

VOLUMES I to XXIII (1893-1923.)

(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.)

ABBOTT, C. E.: *Iron Ore Deposits of the Ely Trough, Vermilion Range, Minnesota,* XII 116, 1906.
ABEEL, GEORGE H.: *Iron and Steel Consumption,* X 27, 1904.
Acetylene As An Underground Light (SLAUGHTER), XIII 205, 1908.
Accidents in the Transportation, Storage and Use of Explosives (HURTER), XVI 177, 1911.
Active Mining Companies in Lake Superior Copper District, XVII 48, 1912.
Additional Pumping Data (MILLS), III 63, 1895.
Address of Retiring President (CHANNING), III 34, 1895.
Address of Retiring President (HULST), II 11, 1894.
ADGATE, FREDERICK W.: *Sinking Reinforced Concrete Shafts Through Quicksand,* XIV 55, 1909.
ALLEN, R. C.: *Michigan Iron Ore Reserves; Methods of Appraisal for Taxation,* XIX 229, 1914.
Application of Mining Machines to Underground Mining on the Mesabi Range (MARTIN-KAISER), XVIII 187, 1913.
ARMSTRONG, FRANK H.: *Notes on Some of the Recent Changes in the Equipment of the Republic Mine, Republic, Michigan, Marquette Range,* XI 181, 1906.
ARMSTRONG, FRANK H.: *Electrical Operation of the Plants of the Penn Iron Mining Company, Menominee Range,* XVI 244, 1911.
ARMSTRONG, F. H. and KELLY, WILLIAM: *Use of Electricity at the Penn and Republic Iron Mines, Michigan, Menominee and Marquette Ranges,* XIX 35, 1914.
ARMSTRONG, F. H. and ORBISON, T. W.: *Hydro-Electric Plant of Penn Iron Mining Co., at Vulcan, Mich., Menominee Range,* XIII 153, 1908.
ARMSTRONG, RAY W.: *Compound Steam Hoist Installation of the Quincy Mining Company,* XXII 39, 1922.
AUSTIN, L. S.: *Sampling of Iron Ores,* XIII 225, 1908.
Athens System of Mining (ELLIOTT), XXII 135, 1922.
Automatic Throttle Closing Device for Hoisting Machinery (RUMSEY), XIII 183, 1908.
Balancing Bailers (KELLY), VI 54, 1900.
Balancing Rock Crushers (HOOD), XVII 162, 1912.
BARBER, G. S.: *New Stockpile Trestle, Colby Iron Mining Company, Bessemer, Michigan, Gogebic Range,* XX 65, 1915.
BATTU, L.: *Utilization of Exhaust Steam from Rolling Mill Engines, Hoisting Engines, Steam Hammers, Etc., By Means of Steam Regenerators and Low-Pressure Turbines on the Rateau System,* XI 50, 1906.
BAXTER, CHARLES H.: *Diversion of the Sturgeon River at the Loretto Mine, Menominee Range,* XVI 168, 1911.
BAXTER, C. H.: *Method of Mining at the Loretto Mine, Menominee Range,* XXI 29, 1917.
BAXTER, C. H., ERICSON, RUDOLPH and RICHARDS, M. E.: *Mining Methods on the Menominee Iron Range,* XXI 8, 1917.
BAYLISS, WILLARD, MCNEIL, E. D. and LUTES, J. S.: *Mining Methods on the Missabe Iron Range,* XVIII 133, 1913.
Biography—Index will be found in each Volume.
Birmingham District—Institute Trip, March, 1917 (HISTORICAL), XXI 280, 1917.
Bisbee, Arizona, Copper Camp (NEWETT), X 127, 1904.
BJORK, ARVID: *Mining Methods Used at the Bristol Mine, Crystal Falls, Mich., Menominee Range,* XXI 258, 1917.
BLACKWELL, FRANK: *Sinking of a Vertical Shaft at the Palms Mine of the Newport Mining Company, at Bessemer, Michign, Gogebic Range,* XIX 116, 1914.
BLACKWELL, FRANK, OLSEN, O. E. and SCHAUS, O. M.: *Mining Methods on the Gogebic Range,* XX 54, 1915.
Blasting Explosives and Their Accessories (HURTER), XXI 141, 1917.
Block-Caving System Used at the Pewabic Mine, Menominee Range (MYERS), XXI 25, 1917.
Block Caving and Sub-Stope System at the Tobin Mine, Menominee Range (ROBERTS), XVI 218, 1911.
BOND, WILLIAM: *Sinking "C" Shaft at the West Vulcan Mine, Michigan, Menominee Range,* II 105, 1894.
BONNELL, E. S.: *Surface Equipment for Iron Mines,* XXIII 56, 1923.
BOYD, F. E.: *Slushing Practice in the Mines of the Oliver Iron Mining Company, Duluth,* XXIII 68, 1923.
BRADT, E. F.: *Electric Mine Haulage Plant, Pittsburgh and Lake Angeline Iron Co.,* IV 9, 1896.
BRADY, HOWARD S.: *Tapping the Water in the Old Minnesota Mine, Copper District,* VII 119, 1901.
BREWER, CARL C.: *List of Iron Mining Properties of Michigan and Wisconsin,* XIX 252, 1914.
Brief Description of Steel Lining for Shafts, Gogebic Range (THOMPSON), X 163, 1904.
Brier Hill Concrete-Lined Shaft, Menominee Range (KELLY), XIV 140, 1909.
Brief Description of the Distillation of Hardwood As Practiced by the Cleveland-Cliffs Iron Company, Marquette, Michigan (HUDSON), XXII 168, 1922.
Brief History of the Cuyuna Range (VAN EVERA), XXIII 85, 1923.
BROWN, E. F.: *Distribution of Phosphorus and System of Sampling at the Pewabic Mine, Michigan, Menominee Range,* III 49, 1895.
BROWN, E. F.: *System of Mining Ore Bodies of Uniform Grade,* V 40, 1898.
BROAN, J. M.: *Sinking of the Woodbury Shaft at the Newport Mine, Ironwood, Michigan, Gogebic Range,* XX 37, 1915.
BUELL, JOHN L.: *Menominee Range,* XI 38, 1906.
Building Reinforced Concrete Shaft Houses (HAYDEN and EATON), XXII 124, 1922.
BURR, FLOYD L.: *Method of Survey for Secondary Mine Openings,* XI 164, 1906.
BURR, FLOYD L.: *Square Set Mining at the Vulcan Mines, Menominee Range,* XVI 144, 1911.
BURR, FLOYD L.: *New Change House at Vulcan Mine, Menominee Range,* XVIII 211, 1913.
BURR, FLOYD L.: *Crushing Plant at Brier Hill Shaft, Menominee Range,* XXI 125, 1917.
Capillary Attraction in Diamond Drill Test Tubes (JOPLING), XIV 131, 1909.
Card System for Mine Supply Accounts (DENTON), IX 114, 1903.
Card System of Accounting for Mining Supplies (JEFFERY), XI 152, 1906.
Cargo Sampling of Iron Ores Received at Lower Lake Ports—Including the Methods Used in the Analysis of the Same (RATTLE & SON), XI 173, 1905.
CARNAHAN, A. L.: *Geological Notes of the Lake Superior Copper Formation, Copper District,* XVII 9, 1912.
Cause for Inaccuracy in Colorimetric Copper Determinations (KOENIG), VII 65, 1901.
Caving System of Mining in Lake Superior Iron Mines (CHANNING), XIX 245, 1914.
Champion Mill Intake Tunnel, Copper District (O'NEIL), IX 127, 1903.
CHANNING, J. PARKE: *Curvature of Diamond Drill Holes,* II 23, 1894.
CHANNING, J. PARKE: *Address of Retiring President,* III 34, 1895.

CHANNING, J. PARKE: *New Pumping Plant of the Stirling Iron and Zinc Co., New Jersey,* III 64, 1895.
CHANNING, J. PARKE: *Efficiency Test of a Nordberg Air Compressor at the Burra Burra Mine of the Tennessee Copper Company,* VIII 82, 1902.
CHANNING, J. PARKE: *Caving System of Mining in Lake Superior Iron Mines,* XIX 245, 1914.
Charcoal Iron Industry of the Upper Peninsula of Michigan (MATHER), IX 63, 1903.
Chart Showing Shipments of Lake Superior Iron Ore from 1887 *to* 1922 *Inclusive,* XXII 203.
Code of Mine Signals—The Cleveland-Cliffs Iron Company, Marquette Ranges (MCCLURE), XIV 147, 1909.
COLE, THOMAS F.: *Single Hoisting Plant,* IV 81, 1896.
College View of Mining Graduate (MCNAIR), VII 101, 1901.
Company Surgeon (LIBBY), XV 195, 1910.
Comparative Tests of Bracing for Wooden Bents (KIDWELL), IV 34, 1896.
Comparison of the Origin and Development of the Iron Ores of the Mesabi and Gogebic Ranges (LEITH), VIII 75, 1902.
Compensation to Workmen in Case of Injuries (DUNCAN), XIV 47, 1909.
Compound Steam Hoist Installation of the Quincy Mining Company (ARMSTRONG), XXII 39, 1922.
Concentrating at the Madrid Mine, Mesabi Range (CROWELL), XVIII 129, 1913.
Concentration of Cuyuna Ores, Cuyuna Range (NEWTON), XX 200, 1915.
CONIBEAR, WILLIAM: *System of Safety Inspection of The Cleveland-Cliffs Iron Company, Marquette Range,* XVII 94, 1912.
CONLIN, THOMAS and O'BRIEN, P.: *Historical Sketch of Menominee Range,* XVI 7, 1911.
CONSTABLE, WILLIAM: *The Wear and Care of Wire Rope,* XXIII 78, 1923.
Construction of Intakes at the Mills of the Trimountain and Champion Mining Companies, Copper District (KOEPEL), XVII 186, 1912.
COOPER, JAMES B.: *Historical Sketch of Smelting and Refining Lake Copper,* VII 44, 1901.
Co-Operative Effort in the Study of Mining Methods (JACKSON), XXII 24, 1922.
CORBETT, R. H.: *Description of an Air Balanced Hoisting Engine, Franklin Mining Company, Copper District,* XVII 211, 1912.
Corliss Cross-Compound Pumping Engine in Penobscot Mine, Mesabi Range (REDFERN), VII 83, 1901.
Cornwall, Pa., Magnetite Deposits, Pennsylvania District (WILSON), XVI 227, 1911.

CORY, EDWIN N.: *Raising Shaft at Rolling Mill Mine, Negaunee, Michigan, Marquette Range,* XVII 112, 1912.
Cost of Crushing Hard Hematite (DENTON), III 93, 1895.
COX, WILLIAM F.: *Reforestation and Fire Protection,* XXIII 163, 1923.
CROWELL, BENEDICT: *Methods of Sampling at Lake Superior Iron Mines,* XVII 76, 1912.
CROWELL, BENEDICT: *Concentrating at the Madrid Mine, Mesabi Range,* XVIII 129, 1913.
CROZE, W. W. J.: *Duluth and the Minnesota Iron Ranges,* XVIII Appendix 1, 1913.
Crushing Plant at Brier Hill Shaft, Menominee Range (BURR), XXI 125, 1917.
Crystallization of Mohawkite, Domeykite and Other Similar Arsenides (KOENIG), VII 62, 1901.
Curvature of Diamond Drill Holes (CHANNING), II 23, 1894.
Data Relating to Railroads, Docks and Shipments from Minnesota Ranges, XIII 20, 1908.
Dates of Opening Navigation (HISTORICAL), IX 145, 1903.
DAVIS, W. M.: *Economical Lubrication,* XVII 247, 1912.
DAVIDSON, O. C.: *Method of Mining at the Badger Mine, Menominee Range,* VI 52, 1900.
DENTON, F. W.: *Open-Pit Mining, With Special Reference to the Mesabi Range,* III 84, 1895.
DENTON, F. W.: *Cost of Crushing Hard Hematite,* III 93, 1895.
DENTON, F. W.: *Card System for Mine Supply Accounts,* IX 114, 1903.
DENTON, F. W.: *Development and Extraction Methods for Lake Superior Copper Deposits,* XXII 46, 1922.
DESOLLAR, T. C.: *Rockhouse Practice of the Quincy Mining Co., Copper District,* XVII 217, 1912.
DESOLLAR, T. C.: *Handling Underground Waste Rock Through Underground Skip Dump, Quincy Mining Company,* XXII 42, 1922.
Description of an Air Balanced Hoisting Engine, Franklin Mining Company, Copper District (CORBETT), XVII 211, 1912.
Description of Indiana Steel Co., Gary Indiana, XV 201, 1910.
Description of Mechanical Underground Shovel (LAKE SHORE ENGINE WORKS), XIX 30, 1914.
Determination of Angles of Diamond Drill Holes (JANSON), XI 148, 1906.
Development and Extraction Methods for Lake Superior Copper Deposits (DENTON), XXII 46, 1922.
Developments of the Use of Cuyuna Range Manganiferous Iron Ores (IVES), XXIII 91, 1923.
Diamond Drill Core Section of the Mesabi Rocks (WINCHELL), XIV 156, 1909.
Diamond Drill Core Section of the Mesabi Rocks—II and III, Mesabi Range (WINCHELL), XV 100, 1910.
Diamond Drill Core Section of the Mesabi Rocks—IV, Mesabi Range (WINCHELL), XVI 61, 1911.
Distribution of Phosphorus and System of Sampling at the Pewabic Mine, Michigan, Menominee Range (BROWN), III 49, 1895.
Discussion—Of Mr. Jackson's Paper on Co-Operative Effort in the Study of Mining Methods (JACKSON), XXII 191, 1922.
Diversion of the Sturgeon River at the Loretto Mine, Menominee Range (BAXTER), XVI 168, 1911.
DOBBS, GERALD C.: *Ore Mining Method Used at the Raimund Division, Birmingham District, Alabama,* XXI 212, 1917.
DONOVAN, P. W.: *Some Aspects of Exploration and Drilling on the Cuyuna Range,* XX 136, 1915.
Drag-Line Stripping and Mining, Balkan Mine, Alpha, Michigan, Menominee Range (LAWRENCE), XX 174, 1915.
DRAKE, FRANK: *Use of Steel in Lining Mine Shafts,* VIII 34, 1902.
Duluth and the Minnesota Iron Ranges (CROZE), XVIII Appendix 1, 1913.
DUNCAN, MURRAY M.: *Compensation to Workmen in Case of Injuries,* XIV 47, 1909.
Early Reminiscences of the Mining and Furnace Industry on the Marquette Range (HISTORICAL), X 165, 1904.
Early History of the Marquette Iron Ore Ranges (NEWETT), XIX 297, 1914.
EATON, LUCIEN and CONIBEAR, WILLIAM: *Fire Prevention and Fire Fighting in Metal Mines,* XXIII 34, 1923.
EATON, LUCIEN: *Methods of Stocking Ore on the Marquette Range,* XIX 72, 1914.
EATON, LUCIEN: *Equipping and Sinking the No. 1 Shaft at the Holmes Mine, Marquette Range,* XXI 106, 1917.
EATON, LUCIEN: *Mechanical Ventilation at Lake Mine,* XXII 106, 1922.
EATON, LUCIEN: *Recent Practice in the Use of Scrapers on Sub-Levels,* XXII 63, 1922.
EBY, J. H.: *Occurrence of Copper Minerals in Hematite Ore,* IV 69, 1896.
Economy in the Manufacture of Mining Machinery (FITCH), VI 44, 1900.
Economical Lubrication (DAVIS), XVII 247, 1912.
Efficiencies of Some Pumping Plants on the Menominee Range, Michigan (LARSSON), III 56, 1895.
Efficiency Test of a Nordberg Air Compressor at the Burra Burra Mine of the Tennessee Copper Company (CHANNING), VIII 82, 1902.

Electric Mine Haulage Plant, Pittsburgh and Lake Angeline Iron Co. (BRADT), IV 9, 1896.
Electric Haulage Plant, Underground, Cleveland Lake Mine (JOPLING), IV 17, 1896.
Electric Signals at the West Vulcan Mine, Menominee Range (THOMPSON), VI 27, 1900.
Electrical Operation of the Plants of the Penn Iron Mining Company, Menominee Range (ARMSTRONG), XVI 244, 1911.
Electrification of the Mines of The Cleveland-Cliffs Iron Company, Marquette Range (STANFORD), XIX 189, 1914.
Electrical Power in Mining on the Menominee Range (HARGAR), XXI 79, 1917.
ELLARD, H. F.: *Sinking and Equipping No. 9 Shaft, Ashland Mine, Gogebic Range,* IX 24, 1903.
ELLIOTT, S. R.: *Athens System of Mining,* XXII 135, 1922.
ELLIOTT, S. R.: *Raising, Sinking and Concreting No. 3 Shaft, Negaunee Mine, Marquette Range,* XVII 260, 1912.
ELLIOTT, STUART R.: *Steel Stocking Trestle at No. 3 Shaft, Negaunee Mine, Marquette Range,* XIX 142, 1914.
ELLIOTT, S. R.: *Spies Open-Stope System of Mining,* XXII 113, 1922.
Equipment at Various Copper Mines, XVII 18, 1912.
Equipping and Sinking the No. 1 Shaft at the Holmes Mine, Marquette Range (EATON), XXI 106, 1917.
ERICSON, RUDOLPH: *Method of Opening and Mining the Davidson No. 2 Mine, Menominee Range,* XXI 40, 1917.
ERICSON, RUDOLPH: *Mining Methods in the Iron River District of Michigan, Menominee Range,* XXI 33, 1917.
ERICSON, RUDOLPH, BAXTER, C. H. and RICHARDS, M. E.: *Mining Methods on the Menominee Iron Range,* XXI 8, 1917.
Failure of the Rule of Following the Hanging, in the Development of Lake Superior Copper Mines, Copper District (SPERR), XVII 238, 1912.
FARRELL, AUSTIN: *Pioneer Furnace No. 2, Description, Marquette Range,* IX 89, 1903.
FAY, ALBERT H.: *Mine Accidents Classified by Mining Methods for the Lake Superior District,* 1915, XXI 65, 1917.
Fire Prevention and Fire Fighting in Metal Mines (EATON-CONIBEAR), XXIII 34, 1923.
FISHER, HERBERT J.: *Follow-Up System and Method of Recording Injuries in Compliance With the Workmen's Compensation Law,* XIX 177, 1914.
FITCH, CHARLES H.: *Economy in the Manufacture of Mining Machinery,* VI 44, 1900.
FITCH, WALTER: *New Form of Mine Drill Bit,* VII 94, 1901.

FITCH, WALTER, JR.: *Record Sinking at the Homansville Shaft of the Chief Consolidated Mining Company, Tintic District, Utah,* XXI 192, 1917.
Five Years of Progress in the Lake Superior Copper Country (JACKSON), XII 143, 1907.
Follow-Up System and Method of Recording Injuries in Compliance With the Workmen's Compensation Law (FISHER), XIX 177, 1914.
Footwall Shafts in Lake Superior Copper Mines, Copper District (HUBBARD), XVII 144, 1912.
Founding of the Calumet & Hecla Mine, 1866-1916, *Copper Range* (HISTORICAL), XXI 71, 1917.
Fragmentary History of Powerhouses of Cleveland Iron Mining Company (NELSON), XXII 153, 1922.
General Description of the Gogebic Range (ROYCE), XX 22, 1915.
General Outline of Mining Methods Used in the Copper Queen Mine, Bisbee, Arizona (HODGSON), XIX 100, 1914.
Geological Notes of the Lake Superior Copper Formation, Copper District (CARNAHAN), XVII 9, 1912.
Geological Work on the Lake Superior Region (VAN HISE), VIII 62, 1902.
Geology of Keweenaw Point—A Brief Description, Copper District (LANE), XII 81, 1907.
Geology of Some of the Lands in the Upper Peninsula (ROSE), X 88, 1904.
Geology of That Portion of the Menominee Range, East of the Menominee River (HULST), I 19, 1893.
Gogebic Range (HISTORICAL), X 158, 1904.
GOODMAN, FRANK B.: *Steel Head Frame, No. 4 Shaft, Montreal Mine, Gogebic Range,* XV 209, 1910.
GOODNEY, S. J.: *Raising Shaft on Timber in Hard Rock at the Armenia Mine, Menominee Range,* XVI 171, 1911.
GORDON, W. C.: *Methods of Mining at Chapin Mine, Menominee Range,* XXI 9, 1917.
GOW, A. M.: *Standard Boiler House of The Oliver Iron Mining Co. (With Drawings),* XIII 209, 1908.
GOW, ALEXANDER M.: *Some Safety Devices of the Oliver Iron Mining Company,* XVI 156, 1911.
Greenway Ore Unloader, Description (NEWETT), IX 119, 1903.
Grouting at the Francis Mine Shaft of The Cleveland-Cliffs Iron Company, Marquette Range (REIGART), XX 72, 1915.
Guniting in the Athens Shaft, Marquette Range (NICOLSON), XXIII 103, 1923.
HALL, C. W.: *History of Exploration for Gold in the Central States,* V 49, 1898.
HARDENBURGH, L. M.: *Pewabic Concentrating Works, Menominee Range,* VI 23, 1900.

HARGAR, CHARLES: *Electrical Power in Mining on the Menominee Range,* XXI 79, 1917.
HART, W. C.: *Opening of the Wakefield Mine, Gogebic Range,* XX 103, 1915.
HAYDEN, J. E.: *Rock Drifting in the Morris-Lloyd Mine, The Cleveland-Cliffs Iron Company, Marquette Range,* XX 142, 1915.
HAYDEN J. ELLZEY and EATON, LUCIEN: *Building Reinforced Concrete Shaft Houses,* XXII 124, 1922.
HEARDING, J. H.: *Reminiscences of the Gogebic Range, Ironwood in* 1887, XVI 251, 1911.
HEATH, GEORGE L.: *Testing and Control of the Product in a Modern Copper Refinery,* VII 68, 1901.
Handling Underground Waste Rock Through Underground Skip Dump, Quincy Mining Company (DESOLLAR), XXII 42, 1922.
HENRY, EARL C.: *Mining Methods in the Mineville (N. Y.) District,* XXII 195, 1922.
Herringbone Gears Used on Pumps (PRESCOTT), XXI 61, 1917.
HIGGINS, EDWIN: *Safety in the Mines of the Lake Superior Iron Ranges,* XVIII 63, 1913.
HIGGINS, EDWIN: *Ventilation in the Iron Mines of the Lake Superior District,* XIX 154, 1914.
HIGGINS, EDWIN: *Sheet Ground Mining in the Joplin District, Missouri,* XX 88, 1915.
HIGGINS, EDWIN: *Second Annual First-Aid Contest, Gogebic Range,* XX 181, 1915.
High Duty Air Compressor at the Champion Mine (Copper) (HOOD), XII 164, 1907.
High Explosives, Their Safe and Economical Methods of Handling (KARKEET), IX 39, 1903.
HILLYER, V. S.: *Practical Use of Magnetic Attractions,* X 48, 1904.
HISTORICAL: *Birmingham District—Institute Trip March,* 1917, XXI 280, 1917.
HISTORICAL: *Dates of Opening of Navigation,* IX 145, 1903.
HISTORICAL: *Early Reminiscences of the Mining and Furnace Industry on the Marquette Range,* X 165, 1904.
HISTORICAL: *Founding of the Calumet & Hecla Mine* 1866-1916, *Copper Range,* XXI 71, 1917.
HISTORICAL: *Gogebic Range,* X 158, 1904.
Historical Sketch of the Discovery of Mineral Deposits in the Lake Superior Region (WINCHELL), II 33, 1894.
Historical Sketch of Menominee Range (CONLIN-O'BRIEN), XVI 7, 1911.
Historical Sketch of Smelting and Refining Lake Copper (COOPER), VII 44, 1901.

HISTORICAL: *Visit to the Mines in* 1856, *Marquette Range,* IX 147, 1903.
History of Exploration for Gold in the Central States (HALL), V 49, 1898.
History of Marquette Ore Docks, Marquette Range (MERRITT), XIX 305, 1914.
HODGSON, J. P.: *General Outline of Mining Methods Used in the Copper Queen Mine, Bisbee, Arizona,* XIX 100, 1914.
Hoisting Plant of the Lake Mine, Cleveland Iron Mining Company, Marquette Range (VICKERS), III 69, 1895.
Hoisting Problem (THOMPSON), X 72, 1904.
HOOD, O. P.: *Invasion of the Water Tube Boiler Into the Copper Country,* VII 88, 1901.
HOOD, O. P.: *High Duty Air Compressor at the Champion Mine (Copper),* XII 164, 1907.
HOOD, O. P.: *Balancing Rock Crushers,* XVII 162, 1912.
How Reforestation May Be Applied to the Mine Timber Industry (WYMAN), XIV 116, 1909.
HOTCHKISS, W. O.: *Recent Developments in the Geology of the Gogebic Range,* XXIII 47, 1923.
HUBBARD, L. L.: *Two New Geological Cross-Sections of Keweenaw Point, With a Brief Description of the Main Geological Features of the Copper Range,* II 79, 1894.
HUBBARD, L. L.: *Relation of the Vein at the Central Mine, Keweenaw Point, to the Kearsarge Conglomerate,* III 74, 1895.
HUBBARD, L. L.: *Plea for Accurate Maps,* VII 105, 1901.
HUBBARD, L. L.: *Footwall Shafts in Lake Superior Copper Mines, Copper District,* XVII 144, 1912.
HUBBARD, L. L.: *In the Lake Superior Area What Influence If Any, Did the Thickness and Contour of Foot-Wall Beds Have Upon the Subsequent Deposition and Distribution of Copper in Over-Lying Beds, Copper District,* XVII 227, 1912.
HUDSON, E. J.: *Brief Description of the Distillation of Hardwood as Practiced by the Cleveland-Cliffs Iron Company, Marquette, Michigan,* XXII 168, 1922.
HUEY, RAY S.: *The Cement Industry in Duluth,* XXIII 97, 1923.
HULST, NELSON P.: *Geology of That Portion of the Menominee Range, East of the Menominee River,* I 19, 1893.
HULST, NELSON P.: *Address of the Retiring President,* II 11, 1894.
HULST, DR. N. P.: *Moisture in Lake Superior Iron Ores,* VIII 21, 1902.
HULST, DR. NELSON P.: *Titanium and Titaniferous Iron Ores,* X 31, 1904.
HULST, H. T., JACKSON, G. R. and SIEBENTHAL, W. A.: *Mining Methods on the Marquette Range,* XIX 131, 1914.

HUNT, GEORGE M.: *Study Your Mine Timber Problem,* XXII 119, 1922.
HUNT, GEORGE M.: *Views of Mine Timbers in Reference to Mr. Hunt's Paper* (page 119) following page 194, XXII, 1922.
HURTER, CHARLES S.: *Proper Detonation of High Explosives,* XV 142, 1910.
HURTER, CHARLES S.: *Accidents in the Transportation, Storage and Use of Explosives,* XVI 177, 1911.
HURTER, CHARLES S.: *Blasting Explosives and Their Accessories,* XXI 141, 1917.
HYDE, F. W.: *Reminiscences of the Upper Peninsula of Michigan, Menominee Range,* XXI 300, 1917.
Hydraulic Stripping at Rowe and Hillcrest Mines on the Cuyuna Range, Minnesota (MCCARTY), XX 162, 1915.
Hydro-Electric Plant of Penn Iron Mining Co., at Vulcan, Mich., Menominee Range (ORBISON-ARMSTRONG), XIII 153, 1908.
Importance of the Ordinary Sanitary Precautions in the Prevention of Water Borne Disease in Mines (JONES, M. D.), XII 105, 1907.
Index to Papers in Each Volume, XXII 19, 1922.
In the Lake Superior Area What Influence If Any, Did the Thickness and Contour of Foot-Wall Beds Have Upon the Subsequent Deposition and Distribution of Copper in Over-Lying Beds, Copper District (HUBBARD), XVII 227, 1912.
Invasion of the Water Tube Boiler Into the Copper Country (HOOD), VII 88, 1901.
Iron Ores of Arctic Lapland, Sweden (OSBORN), IX 94, 1903.
Iron Ore Deposits of the Ely Trough, Vermilion Range, Minnesota (ABBOTT), XII 116, 1906.
Iron Ranges of Minnesota (WINCHELL), III 11, 1895.
Iron and Steel Consumption (ABEEL), X 27, 1904.
IVES, L. E.: *Developments of the Use of Cuyuna Range Manganiferous Iron Ores,* XXIII 91, 1923.
JACKA, J. S.: *Standard Boiler House and Coal Handling System of the Crystal Falls Iron Mining Co., Menominee Range,* XVI 82, 1911.
JACKSON, C. F.: *Co-Operative Effort in the Study of Mining Methods,* XXII 24, 1922.
JACKSON, C. F.: *Discussion—Of Mr. Jackson's Paper on Co-Operative Effort in the Study of Mining Methods,* XXII 191, 1922.
JACKSON, J. F.: *Steel Construction for Mines,* VII 32, 1901.
JACKSON, J. F.: *Mine Machine Shop,* VIII 89, 1902.
JACKSON, J. F.: *Five Years of Progress in the Lake Superior Copper Country,* XII 143, 1907.
JACKSON, G. R., SIEBENTHAL, W. A. and HULST, H. T.: *Mining Methods on the Marquette Range,* XIX 131, 1914.

JACKSON, GEORGE R.: *Mayne Loader,* XXII 143, 1922.
JANSON, F. A.: *Determination of Angles of Diamond Drill Holes,* XI 148, 1906.
JEFFERY, W. M.: *Mine Accounting,* IX 48, 1903.
JEFFERY, W. M.: *Card System of Accounting for Mining Supplies,* XI 152, 1906.
JOHNSON, JOHN M.: *Recording and Signalling Device for Mines,* XVI 88, 1911.
JONES, JOHN T.: *Unwatering of the Hamilton and Ludington Mines, Menominee Range,* XI 139, 1906.
JONES, B. W., M. D.: *Importance of the Ordinary Sanitary Precautions in the Prevention of Water Borne Disease in Mines,* XII 105, 1907.
JOPLING, JAMES E.: *Electric Haulage Plant, Underground, Cleveland Lake Mine,* IV 17, 1896.
JOPLING, J. E.: *Capillary Attraction in Diamond Drill Test Tubes,* XIV 131, 1909.
KAISER, W. J. and MARTIN, H. E.: *Application of Mining Machines to Underground Mining on the Mesabi Range,* XVIII 187, 1913.
KARKEET, J. H.: *High Explosives, Their Safe and Economical Methods of Handling,* IX 39, 1903.
KELLY WILLIAM: *Pocket Stop,* II 111, 1894.
KELLY, WILLIAM: *New Changing-House at the West Vulcan Mine, Menominee Range,* VIII 70, 1902.
KELLY, WILLIAM: *Balancing Bailers,* VI 54, 1900.
KELLY, WILLIAM: *Presidential Address,* VI 13, 1900.
KELLY, WILLIAM: *Underground Magazine and Electric Powder Thawer,* X 66, 1904.
KELLY, WILLIAM: *Brier Hill Concrete-Lined Shaft, Menominee Range,* XIV 140, 1909.
KELLY, WILLIAM and ARMSTRONG, F. H.: *Use of Electricity at the Penn and Republic Iron Mines, Michigan, Menominee and Marquette Ranges,* XIX 35, 1914.
KELLY, ROBERT: *Trip to Lake Superior in* 1853, XIX 309, 1914.
KIDWELL, EDGAR: *Comparative Tests of Bracing for Wooden Bents,* IV 34, 1896.
KNOX, JOHN, JR.: *Notes on the Calumet & Hecla Mine Fire, Copper Range,* XXI 135, 1917.
KOENIG, DR. GEORGE A.: *Crystallization of Mohawkite, Domeykite and Other Similar Arsenides,* VII 62, 1901.
KOENIG, DR. GEORGE A.: *Cause for Inaccuracy in Colorimetric Copper Determinations,* VII 65, 1901.
KOEPEL, EDWARD: *Construction of Intakes at the Mills of the Trimountain and Champion Mining Companies, Copper District,* XVII 186, 1912.

Lake Superior Meeting (SECTION NATIONAL SAFETY COUNCIL), XXIII 117, 1923.
LANE, ALFRED C.: *Salt Water in the Lake Mines,* XII 154, 1907.
LANE, ALFRED C.: *Geology of Keweenaw Point—A Brief Description, Copper District,* XII 81, 1907.
LANE, ALFRED C.: *Mine Waters,* XIII 63, 1908.
LANE, ALFRED C.: *Unexplored Parts of the Copper Range of Keweenaw Point,* XVII 127, 1912.
LARSSON, PER: *Soft Ore Mining on Lake Superior, Menominee Range,* I 13, 1893.
LARSSON, PER: *Efficiencies of Some Pumping Plants on the Menominee Range, Michigan,* III 56, 1895.
LAWRENCE, CHARLES E.: *Social Surroundings of the Mine Employe,* XVI 121, 1911.
LAWRENCE, C. E.: *Report of Committee on the Practice for the Prevention of Accidents,* XVIII 31, 1913.
LAKE SHORE ENGINE WORKS: *Description of Mechanical Underground Shovel,* XIX 30, 1914.
LAWRENCE, CHARLES E.: *Drag-Line Stripping and Mining, Balkan Mine, Alpha, Michigan, Menominee Range,* XX 174, 1915.
LAWRENCE, CHARLES E.: *Progress of Mining in Lake Superior District,* 1894 *to* 1917—*Address of President,* XXI 276, 1917.
LEITH, KENNETH: *Comparison of the Origin and Development of the Iron Ores of the Mesabi and Gogebic Ranges,* VIII 75, 1902.
LEONARD, C. M.: *Suggestions on the Application of Efficiency Methods to Mining,* XVIII 103, 1913.
LIBBY, E. M.: *Company Surgeon,* XV 195, 1910.
List of Iron Mining Properties of Michigan and Wisconsin (BREWER), XIX 252, 1914.
LONGYEAR, J. M.: *Reminiscences of the Development of the Lake Superior Iron Districts,* XXI 92, 1917.
LOYE, H. E.: *Opening the Leonidas Mine at Eveleth, Minnesota, Mesabi Range,* XVIII 192, 1913.
LUTES, J. S., MCNEILL, E. D. and BAYLISS, WILLARD: *Mining Methods on the Missabe Iron Range,* XVIII 133, 1913.
MACNAUGHTON, JAMES: *Mine Dams,* VI 37, 1900.
MACGREGOR, A. H.: *Signalling System at Bengal Mine, Palatka, Michigan, Menominee Range,* XXI 195, 1917.
MCCARTY, EDWARD P.: *Hydraulic Stripping at Rowe and Hillcrest Mines on the Cuyuna Range, Minnesota,* XX 162, 1915.
MCCLURE, O. D.: *Code of Mine Signals—The Cleveland-Cliffs Iron Company, Marquette Range,* XIV 147, 1909.
MCCORMACK, C. P. and WALSH, C. C.: *Unloading and Sampling Ore at Lower Lake Ports,* XXIII 147, 1923.
Map of Ranges—See Index by Volumes.
Mayne Loader (JACKSON), XXII 143, 1922.
MCEACHERN, WILLAM A.: *Top Slicing at the Caspian Mine, Menominee Range,* XVI 239, 1911.
MCNAIR, F. W.: *College View of Mining Graduate,* VII 101, 1901.
MCNEIL, E. D., LUTES, J. S. and BAYLISS, WILLARD: *Mining Methods on the Missabe Iron Range,* XVIII 133, 1913.
Marquette Iron Range of Michigan (NEWETT), IV 87, 1896.
Marquette Iron Range (NEWETT), XIV 19, 1909.
MARTIN, H. E. and KAISER, W. J.: *Application of Mining Machines to Underground Mining on the Mesabi Range,* XVIII 187, 1913.
MARTINSON, GEORGE: *Report on the 1922 Lake Superior Mine Safety Conference,* XXIII, 63, 1923.
MATHER, WILLIAM G.: *Some Observations on the Principle of Benefit Funds and Their Place in the Lake Superior Iron Mining Industry,* V 10, 1898.
MATHER, WILLIAM G.: *Charcoal Iron Industry of the Upper Peninsula of Michigan,* IX 63, 1903.
Matters of Interest to Operators Regarding the Cuyuna District (ZAPFFE), XX 191, 1915.
Mechanical Ventilation at Lake Mine (EATON), XXII 106, 1922.
Mechanically Operated Door to Control Air Currents on Main Haulage Levels (MILLER), XXII 140, 1922.
MENNIE, J. S.: *New Changing House at the Cliffs Shaft Mine, Marquette Range,* IX 121, 1903.
Menominee Range (BUELL), XI 38, 1906.
MERCER, H. T.: *Some Applications of Concrete Underground, Copper District,* XVII 167, 1912.
MERCER, H. T.: *Rockhouse Practice of the Copper Range Consolidated Company, Copper District,* XVII 283, 1912.
MERRITT, D. H.: *History of Marquette Ore Docks, Marquette Range,* XIX 305, 1914.
Mesabi Iron Company's Reduction Plant, Mesaba Range (SWART), XXIII 111, 1923.
Methods of Iron Ore Analysis Used in the Laboratories of the Iron Mining Companies of the Lake Superior Mining Region (SIEBENTHAL), XI 71, 1906.
Method of Mining at the Badger Mine, Menominee Range (DAVIDSON), VI 52, 1900.
Method of Mining at the Loretto Mine, Menominee Range (BAXTER), XXI 29, 1917.
Methods of Mining at Chapin Mine, Menominee Range (GORDON), XXI 9, 1917.
Method of Opening and Mining the Davidson No. 2 Mine, Menominee Range (ERICSON), XXI 40, 1917.
Methods of Sampling Iron Ore (MIXER), IV 27, 1896.

Methods of Sampling at Lake Superior Iron Mines (CROWELL), XVII 76, 1912.
Method of Survey for Secondary Mine Openings (BURR), XI 164, 1906.
Methods of Stocking Ore on the Marquette Range (EATON), XIX 72, 1914.
MEUCHE, A. H.: *Some Practical Suggestions for Diamond Drill Explorations,* XVI 77, 1911.
Michigan Iron Ore Reserves; Methods of Appraisal for Taxation (ALLEN), XIX 229, 1914.
MILLER TOM A.: *Mechanically Operated Door to Control Air Currents on Main Haulage Levels,* XXII 140, 1922.
MILLS, F. P.: *Additional Pumping Data,* III 63, 1895.
Mine Accidents Classified By Mining Methods for the Lake Superior District, 1915 (FAY), XXI 65, 1917.
Mine Accidents (QUINE), XIV 71, 1909.
Mine Accounts (YUNGBLUTH), V 21, 1898.
Mine Accounting (JEFFERY), IX 48, 1903.
Mine Dams (MACNAUGHTON), VI 37, 1900.
Mine Laws, Special Rules and the Prevention of Accidents (WILSON), XVIII 108, 1913.
Mine Sanitation (WILSON), XVII 117, 1912.
Mine Timber Used Underground, Questionnaire (UNITED STATES BUREAU OF CENSUS), XXIII 155, 1923.
Mine Waters (LANE), *State Geologist, Michigan,* XIII 63, 1908.
Mines of the Lake Superior Copper District (STEVENS), XII 8, 1907.
Mine Machine Shop (JACKSON), VIII 89, 1902.
MINNESOTA RANGES: *Data Relating to Railroads, Docks, and Shipments from Minnesota Ranges,* XIII 20, 1908.
Mining Methods Used at the Bristol Mine, Crystal Falls, Mich., Menominee Range (BJORK), XXI 258, 1917.
Mining Methods in the Crystal Falls, Amasa and Florence Districts, Menominee Range (RICHARDS), XXI 50, 1917.
Mining Methods of the Copper Range Company, Houghton County, Mich. (SCHACHT), XXII 76, 1922.
Mining Methods in the Florence District, Menominee Range (RIDDELL), XXI 56, 1917.
Mining Methods on the Gogebic Range (OLSEN-SCHAUS-BLACKWELL), XX 54, 1915.
Mining Methods in the Iron River District of Michigan, Menominee Range (ERICSON), XXI 33, 1917.
Mining Methods in the Mineville (N. Y.) District (HENRY), XXII 195, 1922.
Mining Methods on the Marquette Range (HULST-JACKSON-SIEBENTHAL), XIX 131, 1914.

Mining Methods on the Missabe Iron Range (Bayliss-McNeil-Lutes), XVIII 133, 1913.
Mining Methods on the Menominee Iron Range (Baxter-Ericson-Richards), XXI 8, 1917.
Mining Methods in the Vermilion and Mesabi Districts (Thomas), X 144, 1904.
Mining School of The Cleveland-Cliffs Iron Company, Marquette Range (Stevenson), XX 148, 1915.
Mitchell, J. A.: *The Lake States Forest Experiment Station and the Mining Industry,* XXIII 160, 1923.
Mixer, C. T.: *Methods of Sampling Iron Ore,* IV 27, 1896.
Moisture in Lake Superior Iron Ores (Hulst), VIII 21, 1902.
Moulton, W. H.: *Sanitation for Mine Locations,* XVIII 38, 1913.
Moulton, W. H.: *Sociological Side of the Mining Industry,* XIV 82, 1909.
Myers, A. J.: *Block-Caving System Used at the Pewabic Mine, Menominee Range,* XXI 25, 1917.
Nelson, John M. Jr.: *Wood Preservation With Especial Reference to Mine Timbers,* XIV 99, 1909.
Nelson, S. T.: *Fragmentary History of Powerhouses of Cleveland Iron Mining Company,* XXII 153, 1922.
New Changing House at the Cliffs Shaft Mine, Marquette Range (Mennie), IX 121, 1903.
New Change House at Vulcan Mine, Menominee Range (Burr), XVIII 211, 1913.
New Changing-House at the West Vulcan Mine, Menominee Range (Kelly), VIII 70, 1902.
New Form of Mine Drill Bits (Fitch), VII 94, 1901.
New Iron-Bearing Horizon in the Kewatin in Minnesota (Winchell), V 46, 1898.
New Pumping Plant of the Stirling Iron and Zinc Co., New Jersey (Channing), III 64, 1895.
New Stockpile Trestle, Colby Iron Mining Company, Bessemer, Michigan, Gogebic Range (Barber), XX 65, 1915.
Newett, George A.: *Marquette Iron Range of Michigan,* IV 87, 1896.
Newett, George A.: *Greenway Ore Unloader, Description,* IX 119, 1903.
Newett, George A.: *Bisbee, Arizona, Copper Camp,* X 127, 1904.
Newett, George A.: *Marquette Iron Range,* XIV 19, 1909.
Newett, George A.: *Early History of the Marquette Iron Range,* XIX 297, 1914.
Newton, Edmund: *Concentration of Cuyuna Ores, Cuyuna Range,* XX 200, 1915.
Nicolson, C. W.: *Guniting in the Athens Shaft, Marquette Range,* XXIII 103, 1923.

No. 5 Shaft at the Tamarack Mine, Copper District (Parnall), VII 50, 1901.
Nordberg Compound Steam Hoisting Engine, Quincy Mining Company, No. 2 Shaft, Hancock, Mich., XXII 192, 1922.
Notes on the Calumet & Hecla Mine Fire, Copper Range (Knox, Jr.), XXI 135, 1917.
Notes on Some of the Recent Changes in the Equipment of the Republic Mine, Republic, Michigan, Marquette Range (Armstrong), XI 181, 1906.
O'Brien, P. and Conlin, Thomas: *Historical Sketch of Menominee Range,* XVI 7, 1911.
Occurrence of Copper Minerals in Hematite Ore (Eby), IV 69, 1896.
Olsen, O. E., Schaus, O. M. and Blackwell, Frank: *Mining Methods on the Gogebic Range,* XX 54, 1915.
Olson, G. L.: *Time Keeping System and Labor Distribution at the Newport Mine, Gogebic Range,* XVI 127, 1911.
O'Neil, F. W.: *Champion Mill Intake Tunnel, Copper District,* IX 127, 1903.
Opening the Leonidas Mine at Eveleth, Minnesota, Mesabi Range (Loye), XVIII 192, 1913.
Open-Pit Mining, With Special Reference to the Mesabi Range (Denton), III 84, 1895.
Opening of the Wakefield Mine, Gogebic Range (Hart), XX 103, 1915.
Organization, Re-Organization, and Consolidation of the Arcadian Mine (Shields), XXII 100, 1922.
Orbison, T. W. and Armstrong, F. H.: *Hydro-Electric Plant of Penn Iron Mining Co., at Vulcan, Mich., Menominee Range,* XIII 153, 1908.
Ore Dressing on Lake Superior (Sharpless), II 97, 1894.
Ore Mining Method Used at the Raimund Division, Birmingham District, Alabama (Dobbs), XXI 212, 1917.
Osborn, Chase S.: *Iron Ores of Arctic Lapland, Sweden,* IX 94, 1903.
Parnall, W. E. Jr.: *No. 5 Shaft at the Tamarack Mine, Copper District,* VII 50, 1901.
Partial Bibliography of the History of Mining on Lake Superior (Winchell), II 71, 1894.
Pewabic Concentrating Works, Menominee Range (Hardenburgh), VI 23, 1900.
Pioneer Furnace, No. 2, Description, Marquette Range (Farrell) IX 89, 1903.
Pioneer Mine Pumping Engines, Vermilion Range (Sturtevant), IV 84, 1896.
Plea for Accurate Maps (Hubbard), VII 105, 1901.
Pocket Stop (Kelly), II 111, 1894.
Practical Use of Magnetic Attractions (Hillyer), X 48, 1904.
Prescott, Fred M.: *Herringbone Gears Used on Pumps,* XXI 61, 1917.
Presidential Address (Kelly), VI 13, 1900.
Progress of Mining in Lake Superior District, 1894 to 1917—Address of President (Lawrence), XXI 276, 1917.
Progress in Underground Ore Loading (Richards), XX 213, 1915.
Proper Detonation of High Explosives (Hurter), XV 142, 1910.
Pope, Graham: *Some Early Mining Days at Portage Lake, Copper District,* VII 17, 1901.
Quine, John T.: *Mine Accidents,* XIV 71, 1909.
Raising Shaft on Timber in Hard Rock at the Armenia Mine, Menominee Range (Goodney), XVI 171, 1911.
Raising Shaft at Rolling Mill Mine, Negaunee, Michigan, Marquette Range (Cory), XVII 112, 1912.
Raising, Sinking and Concreting No. 3 Shaft, Negaunee Mine, Marquette Range (Elliott), XVII 260, 1912.
Rattle, W. J. and Son: *Cargo Sampling of Iron Ores Received at Lower Lake Ports—Including the Methods Used in the Analysis of the Same,* XI 173, 1905.
Recent Developments in the Geology of the Gogebic Range (Hotchkiss), XXIII 47, 1923.
Recent Geologic Development on the Mesabi Iron Range, Minnesota (Wolff), XXI 229, 1917.
Recent Practice in the Use of Scrapers on Sub-Levels (Eaton), XXII 63, 1922.
Record Sinking at the Homansville Shaft of the Chief Consolidated Mining Company, Tintic District, Utah (Fitch, Jr.), XXI 192, 1917.
Recording and Signalling Device for Mines (Johnson), XVI 88, 1911.
Redfern, John A.: *Corliss Cross-Compound Pumping Engine in Penobscot Mine, Mesabi Range,* VII 83, 1901.
Reforestation and Fire Protection (Cox), XXIII 163, 1923.
Reigart, J. R.: *Grouting at the Francis Mine Shaft of The Cleveland-Cliffs Iron Company, Marquette Range,* XX 72, 1915.
Relation of the Vein at the Central Mine, Keweenaw Point, to the Kearsarge Conglomerate (Hubbard), III 74, 1895.
Relations of the Mining Industry to the Prevention of Forest Fires (Wyman), XVI 211, 1911.
Relining No. 2 Hamilton Shaft With Reinforced Dividers, End Plates and Poured Concrete Walls, Menominee Range (Tarr), XVIII 90, 1913.
Reminiscences of the Gogebic Range, Ironwood in 1887 (Hearding), XVI 251, 1911.

Reminiscences of the Upper Peninsula of Michigan, Menominee Range (Hyde), XXI 300, 1917.
Reminiscences of the Development of the Lake Superior Iron Districts (Longyear), XXI 92, 1917.
Report of Committee on the Practice for the Prevention of Accidents (Lawrence), XVIII 31, 1913.
Report of the First Annual First-Aid Contest, Marquette Range (Stevenson), XIX 269, 1914.
Report on the 1922 Lake Superior Mine Safety Conference (Martinson), XXIII 63, 1923.
Richards, M. E.: *Progress in Underground Ore Loading,* XX 213, 1915.
Riddell, J. M.: *Mining Methods in the Florence District, Menominee Range,* XXI 56, 1917.
Richards, M. E.: *Sub-Stoping at the Amasa-Porter Mine, Menominee Range,* XXI 52, 1917.
Richards, M. E.: *Mining Methods in the Crystal Falls, Amasa and Florence Districts, Menominee Range,* XXI 50, 1917.
Richards, M. E., Ericson, Rudolph and Baxter, C. H.: *Mining Methods on the Menominee Iron Range,* XXI 8, 1917.
Roberts, Fred C.: *Block Caving and Sub-Stope System at the Tobin Mine, Menominee Range,* XVI 218, 1911.
Robinson, A. W.: *Steam Shovel in Mining,* IV 59, 1896.
Rock Drifting in the Morris-Lloyd Mine, The Cleveland-Cliffs Iron Company, Marquette Range (Hayden), XX 142, 1915.
Rockhouse Practice of the Quincy Mining Co., Copper District (DeSollar), XVII 217, 1912.
Rockhouse Practice of the Copper Range Consolidated Company, Copper District (Mercer), XVII 283, 1912.
Rose, Robert Seldon: *Geology of Some of the Lands in the Upper Peninsula,* X 88, 1904.
Royce, Stephen: *General Description of the Gogebic Range,* XX 22, 1915.
Royce, Stephen: *Use of Gunite in a Steel Shaft and in an Underground Pump-House on the Gogebic Range,* XX 114, 1915.
Rumsey, Spencer S.: *Automatic Throttle Closing Device for Hoisting Machinery,* XIII 183, 1908.
Safety in Electrical Installations in Mines (Stanford), XXIII 130, 1923.
Safety in the Mines of the Lake Superior Iron Ranges (Higgins), XVIII 63, 1913.
Salt Water in the Lake Mines (Lane), *State Geologist,* XII 154, 1907.
Sampling of Iron Ores (Austin), XIII 225, 1908.
Sanitation for Mine Locations (Moulton), XVIII 38, 1913.

SCHACHT, W. H.: *Mining Methods of the Copper Range Company, Houghton County, Mich.*, XXII 76 1922.
SCHAUS, O. M., OLSEN, O. E. and BLACKWELL, FRANK: *Mining Methods on the Gogebic Range*, XX 54, 1915.
SEBENIUS, JOHN UNO: *Wash Ores of Western Missabe Range and the Coleraine Concentrating Plant*, XVIII 155, 1913.
Second Annual First-Aid Contest, Gogebic Range (HIGGINS), XX 181, 1915.
SECTION NATIONAL SAFETY COUNCIL: *Lake Superior Meeting*, XXIII 117, 1923.
SEEBER, R. R.: *Winona Stamp-Mill, Copper Range*, XVIII 43, 1913.
SEPARK, EDWARD A.: *Some Aspects of the Analyzing and Grading of Iron Ores of the Gogebic Range*, X 103, 1904.
Shaft Sinking Through Quicksand at Susquehanna Mine, Mesabi Range (STURTEVANT), X 60, 1904.
SHARPLESS, F. F.: *Ore Dressing on Lake Superior*, II 97, 1894.
Sheet Ground Mining in the Joplin District, Missouri (HIGGINS), XX 88, 1915.
SHIELDS, ROBERT H.: *Organization, Re-Organization, and Consolidation of the Arcadian Mine*, XXII 100, 1922.
SIEBENTHAL, W. A.: *Methods of Iron Ore Analysis Used in the Laboratories of the Iron Mining Companies of the Lake Superior Mining Region*, XI 71, 1906.
SIEBENTHAL, W. A., JACKSON, G. R. and HULST, H. T.: *Mining Methods on the Marquette Range*, XIX 131, 1914.
Signalling System at Bengal Mine, Palatka, Michigan, Menominee Range (MACGREGOR), XXI 195, 1917.
Single Engine Hoisting Plant (COLE), IV 81, 1896.
Sinking and Equipping No. 9 Shaft, Ashland Mine, Gogebic Range (ELLARD), IX 24, 1903.
Sinking "C" Shaft at the West Vulcan Mine, Michigan, Menominee Range (BOND), II 105, 1894.
Sinking Reinforced Concrete Shafts Through Quicksand (ADGATE), XIV 55, 1909.
Sinking of a Vertical Shaft at the Palms Mine of the Newport Mining Company, at Bessemer, Michigan, Gogebic Range (BLACKWELL), XIX 116, 1914.
Sinking of the Woodbury Shaft at the Newport Mine, Ironwood, Michigan, Gogebic Range (BROAN), XX 37, 1915.
SLAUGHTER, WILLIAM F.: *Acetylene as an Underground Light*, XIII 205, 1908.
Slushing Practice in the Mines of the Oliver Iron Mining Company, Duluth (BOYD), XXIII 68, 1923.
SMITH, F. J.: *Sub-Stoping Method of Mining As Used at the Chatham Mine, Menominee Range*, XXI 46, 1917.

Sociological Side of the Mining Industry (MOULTON), XIV 82, 1909.
Soft Ore Mining on Lake Superior, Menominee Range (LARSSON), I 13, 1893.
Some Applications of Concrete Underground, Copper District (MERCER), XVII 167, 1912.
Some Aspects of the Analyzing and Grading of Iron Ores of the Gogebic Range (SEPARK), X 103, 1904.
Some Aspects of Exploration and Drilling on the Cuyuna Range (DONOVAN), XX 136, 1915.
Some Early Mining Days at Portage Lake, Copper District (POPE), VII 17, 1901.
Some Observations on the Principle of Benefit Funds and Their Place in the Lake Superior Iron Mining Industry (MATHER), V 10, 1898.
Some Practical Suggestions for Diamond Drill Explorations (MEUCHE), XVI 77, 1911.
Some Safety Devices of the Oliver Iron Mining Company (GOW), XVI 156, 1911.
Social Surroundings of the Mine Employe (LAWRENCE), XVI 121, 1911.
SPERR, F. W.: *Failure of the Rule of Following the Hanging, in the Development of Lake Superior Copper Mines, Copper District*, XVII 238, 1912.
SPERR, F. W.: *Stoping to Branched Raises*, XXI 205, 1917.
SPERR, F. W.: *Why Do We Need a Classification of Mining Methods?* XXII 177, 1922.
Spies Open-Stope System of Mining (ELLIOTT), XXII 113, 1922.
Square Set Mining at the Vulcan Mines, Menominee Range (BURR), XVI 144, 1911.
Standard Boiler House and Coal Handling System of the Crystal Falls Iron Mining Co., Menominee Range (JACKA), XVI 82, 1911.
Standard Boiler House of The Oliver Iron Mining Co. (With Drawings) (GOW), XIII 209, 1908.
Standard Method for Sampling Cargoes of Iron Ore at Lower Lake Ports—1907 (TEXTOR), XIII 231, 1908.
STANFORD, F. C.: *Electrification of the Mines of The Cleveland-Cliffs Iron Company, Marquette Range*, XIX 189, 1914.
STANFORD, F. C.: *Safety in Electrical Installations in Mines*, XXIII 130, 1923.
Steam Shovel in Mining (ROBINSON), IV 59, 1896.
Steel Construction for Mines (JACKSON), VII 32, 1901.
Steel Headframe, No. 4 Shaft, Montreal Mine, Gogebic Range (GOODMAN), XV 209, 1910.
Steel Stocking Trestle at No. 3 Shaft, Negaunee Mine, Marquette Range (ELLIOTT), XIX 142, 1914.

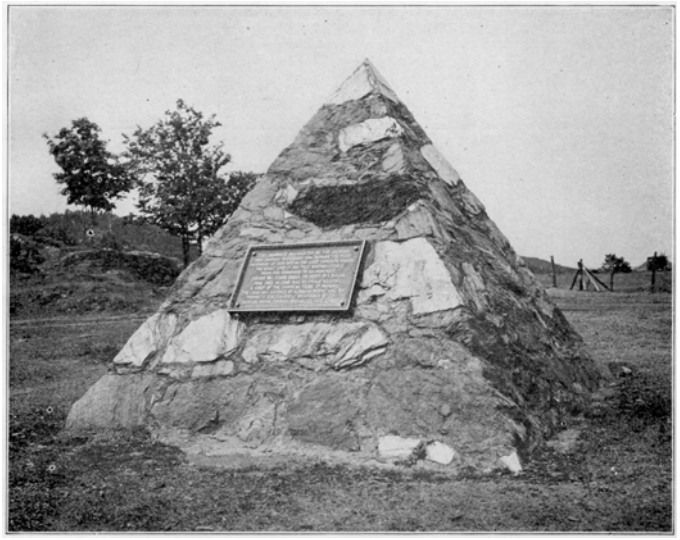
STEVENS, HORACE J.: *Mines of the Lake Superior Copper District*, XII 8, 1907.
STEVENSON, C. S.: *Report of the First Annual First-Aid Contest, Marquette Range*, XIX 269, 1914.
STEVENSON, C. S.: *Mining School of The Cleveland-Cliffs Iron Company, Marquette Range*, XX 148, 1915.
Stoping to Branched Raises (SPERR), XXI 205, 1917.
Structures of Mesabi Iron Ore, Mesabi Range (WINCHELL), XIII 189, 1908.
Study Your Mine Timber Problem (HUNT), XXII 119, 1922.
STURTEVANT, H. B.: *Pioneer Mine Pumping Engines, Vermilion Range*, IV 84, 1896.
STURTEVANT, H. B.: *Shaft Sinking Through Quicksand at Susquehanna Mine, Mesabi Range*, X 60, 1904.
Sub-Stoping at the Amasa-Porter Mine, Menominee Range (RICHARDS), XXI 52, 1917.
Sub-Stoping Method of Mining As Used at the Chatham Mine, Menominee Range (SMITH), XXI 46, 1917.
Suggestions on the Application of Efficiency Methods to Mining (LEONARD), XVIII 103, 1913.
Surface Equipment for Iron Mines (BONNELL), XXIII 56, 1923.
Survey of the Developments and Operation in the Cuyuna Ore District of Minnesota (ZAPFFE), XX 125, 1915.
Surveying and Sampling Diamond Drill Holes (WHITE), XVI 100, 1911.
SWART, W. G.: *Mesabi Iron Company's Reduction Plant, Mesaba Range*, XXIII 111, 1923.
System of Mining Ore Bodies of Uniform Grade (BROWN), V 40, 1898.
System of Safety Inspection of The Cleveland-Cliffs Iron Company, Marquette Range (CONIBEAR), XVII 94, 1912.
Tapping the Water in the Old Minnesota Mine, Copper District (BRADY), VII 119, 1901.
TARR, S. W.: *Relining No. 2 Hamilton Shaft With Reinforced Dividers, End Plates and Poured Concrete Walls, Menominee Range*, XVIII 90, 1913.
Tariff on Iron Ore (YOUNG), XIV 179, 1909.
Testing and Control of the Product in a Modern Copper Refinery (HEATH), VII 68, 1901.
TEXTOR, OSCAR: *Standard Method for Sampling Cargoes of Iron Ore at Lower Lake Ports*—1907, XIII 231, 1908.
The Cement Industry in Duluth (HUEY), XXIII 97, 1923.
The Lake States Forest Experiment Station and the Mining Industry (MITCHELL), XXIII 160, 1923.
The Wear and Care of Wire Rope (CONSTABLE), XXIII 78, 1923.
THOMAS, KIRBY: *Mining Methods in the Vermilion and Mesabi Districts*, X 144, 1904.

THOMPSON, A. W.: *Electric Signals at the West Vulcan Mine, Menominee Range*, VI 27, 1900.
THOMPSON, J. R.: *Hoisting Problem*, X 72, 1904.
THOMPSON, J. R.: *Brief Description of Steel Lining for Shafts, Gogebic Range*, X 163, 1904.
Time Keeping System of the Crystal Falls Iron Mining Co., Menominee Range (VIVIAN), XVI 70, 1911.
Time Keeping System and Labor Distribution at the Newport Mine, Gogebic Range (OLSON), XVI 127, 1911.
Titanium and Titaniferous Iron Ores (DR. HULST), X 31, 1904.
Titaniferous Ores in the Blast Furnace—A Recent Experiment, New York State (WOODBRIDGE), XIX 223, 1914.
Top Slicing at the Caspian Mine, Menominee Range (MCEACHERN), XVI 239, 1911.
Trip to Lake Superior in 1853 (KELLY), XIX 309, 1914.
Two New Geological Cross-Sections of Keweenaw Point, With a Brief Description of the Main Geological Features of the Copper Range (HUBBARD), II 79, 1894.
Unexplored Parts of the Copper Range of Keweenaw Point (LANE), XVII 127, 1912.
Underground Magazine and Electric Powder Thawer (KELLY), X 66, 1904.
Underground Methods of Mining Used on the Gogebic Range (WILLIAMS), XV 179, 1910.
Underground Steel Construction (WOODWORTH), XV 45, 1910.
UNITED STATES BUREAU OF CENSUS: *Mine Timber Used Underground, Questionnaire*, XXIII 155, 1923.
Unloading and Sampling Ore at Lower Lake Ports (MCCORMACK-WALSH), XXIII 147, 1923.
Unwatering of the Hamilton and Ludington Mines, Menominee Range (JONES), XI 139, 1906.
Use of Electricity at the Penn and Republic Iron Mines, Michigan, Menominee and Marquette Ranges (KELLY-ARMSTRONG), XIX 35, 1914.
Use of Gunite in a Steel Shaft and in an Underground Pump-House on the Gogebic Range (ROYCE), XX 114, 1915.
Use of Steel in Lining Mine Shafts (DRAKE), VIII 34, 1902.
Utilization of Exhaust Steam from Rolling Mill Engines, Hoisting Engines, Steam Hammers, Etc., By Means of Steam Regenerators and Low-Pressure Turbines on the Rateau System (BATTU), XI 50, 1906.
VAN EVERA, J. W.: *Brief History of the Cuyuna Range* XXIII 85, 1923.
VAN HISE, C. R.: *Geological Work on the Lake Superior Region*, VIII 62, 1902.
Ventilation in the Iron Mines of the Lake Superior District (HIGGINS), XIX 154, 1914.

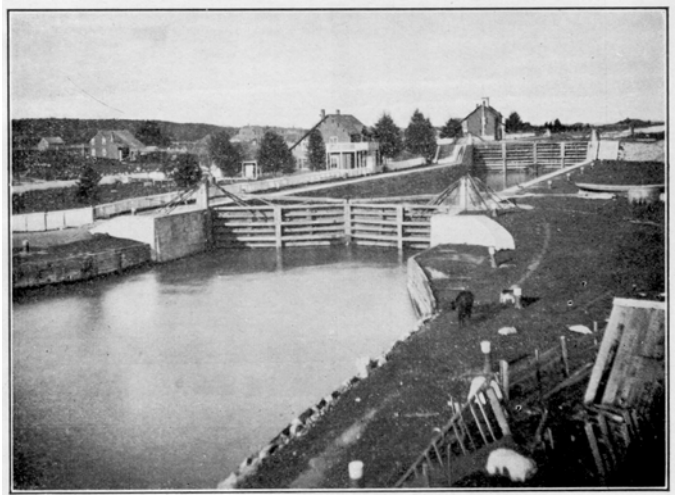
VICKERS, J. M.: *Hoisting Plant of the Lake Mine, Cleveland Iron Mining Company, Marquette Range,* III 69, 1895.
Visit to the Mines in 1856, Marquette Range (HISTORICAL), IX 147, 1903.
Views of Mine Timbers in Reference to Mr. Hunt's Paper (page 119 following page 194, XXII, 1922.
VIVIAN, JAMES D.: *Time Keeping System of the Crystal Falls Iron Mining Co., Menominee Range,* XVI 70, 1911.
Wash Ores of Western Missabe Range and the Coleraine Concentrating Plant (SEBENIUS), XVIII 155, 1913.
What Our Neighbors Can Do in Mining Iron Ore (WOODBRIDGE), XVIII 85, 1913.
WHITE, E. E.: *Surveying and Sampling Diamond Drill Holes,* XVI 100, 1911.
Why Do We Need a Classification of Mining Methods? (SPERR), XXII 177, 1922.
WILLIAMS, PERCIVAL S.: *Underground Methods of Mining Used on the Gogebic Range,* XV 179, 1910.
WILSON, E. B.: *Cornwall, Pa., Magnetite Deposits, Pennsylvania District,* XVI 227, 1911.
WILSON, E. B.: *Mine Sanitation,* XVII 117, 1912.
WILSON, E. B.: *Mine Laws, Special Rules and the Prevention of Accidents,* XVIII 108, 1913.
WINCHELL, H. V.: *Historical Sketch of the Discovery of Mineral Deposits in the Lake Superior Region,* II 33, 1894.
WINCHELL, H. V.: *Partial Bibliography of the History of Mining on Lake Superior,* II 71, 1894.
WINCHELL, H. V.: *Iron Ranges of Minnesota,* III 11, 1895.
WINCHELL, N. H.: *New Iron-Bearing Horizon in the Kewatin in Minnesota,* V 46, 1898.
WINCHELL, N. H.: *Structures of Mesabi Iron Ore, Mesabi Range,* XIII 189, 1908.
WINCHELL, N. H.: *Diamond Drill Core Section of the Mesabi Rocks,* XIV 156, 1909.
WINCHELL, N. H.: *Diamond Drill Core Section of the Mesabi Rocks—II and III, Mesabi Range,* XV 100, 1910.
WINCHELL, N. H.: *Diamond Drill Core Section of the Mesabi Rocks—IV, Mesabi Range,* XVI 61, 1911.
Winona Stamp-Mill, Copper Range (SEEBER), XVIII 43, 1913.
Wood Preservation With Especial Reference to Mine Timbers (NELSON), XIV 99, 1909.
WOODWORTH, R. B.: *Underground Steel Construction,* XV 45, 1910.
WOODBRIDGE, DWIGHT E.: *What Our Neighbors Can Do in Mining Iron Ore,* XVIII 85, 1913.
WOODBRIDGE, DWIGHT E.: *Titaniferous Ores in the Blast Furnace —A Recent Experiment, New York State,* XIX 223, 1914.

WOLFF, J. F.: *Recent Geologic Development on the Mesabi Iron Range, Minnesota,* XXI 229, 1917.
WYMAN, THOMAS B.: *How Reforestation May Be Applied to the Mine Timber Industry,* XIV 116, 1909.
WYMAN, THOMAS B.: *Relations of the Mining Industry to the Prevention of Forest Fires,* XVI 211, 1911.
YOUNG, H. OLIN: *Tariff on Iron Ore,* XIV 179, 1909.
YUNGBLUTH, A. J.: *Mine Accounts,* V 21, 1898.
ZAPFFE, CARL: *Matters of Interest to Operators Regarding the Cuyuna District,* XX 191, 1915.
ZAPFFE, CARL: *Survey of the Developments and Operations in the Cuyuna Ore District of Minnesota,* XX 125, 1915.

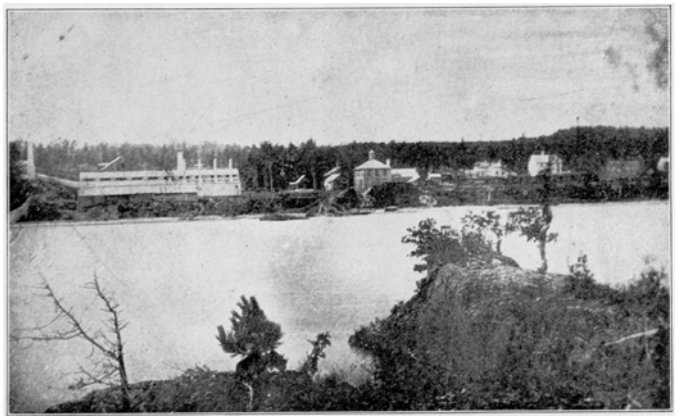
[Scenes on the Marquette Range and Sault Ste. Marie, following page]



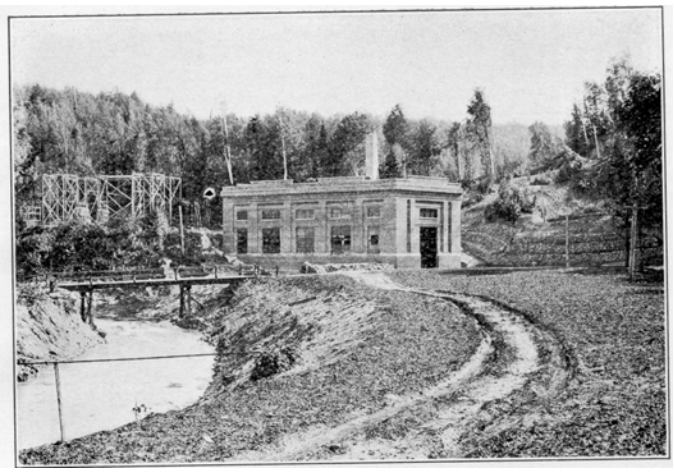
JACKSON MONUMENT, AT NEGAUNEE, MARKING DISCOVERY OF IRON ORE THERE IN 1845.



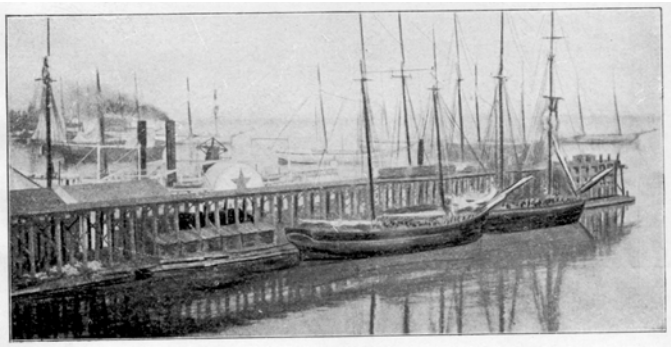
LOCKS AT SAULT STE, MARIE—1870.



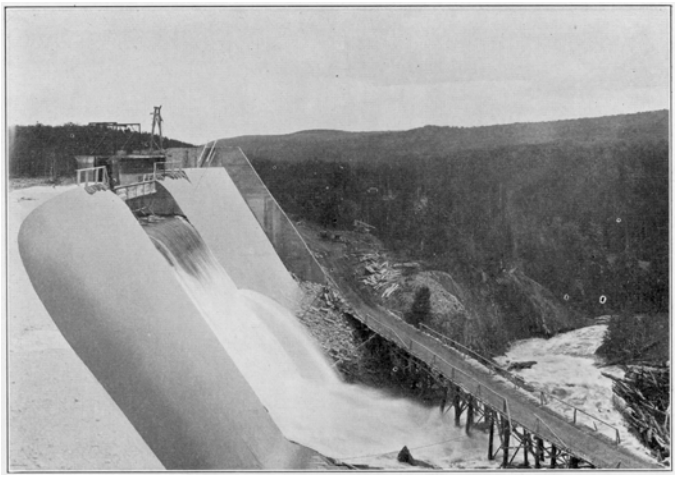
MARQUETTE, MICH., IN 1852 SHOWING FORGE BUILT BY MARQUETTE IRON CO., 1849. PUT IN OPERATION DURING 1850.



CLEVELAND-CLIFFS IRON COMPANY MCCLURE PLANT ON DEAD RIVER.



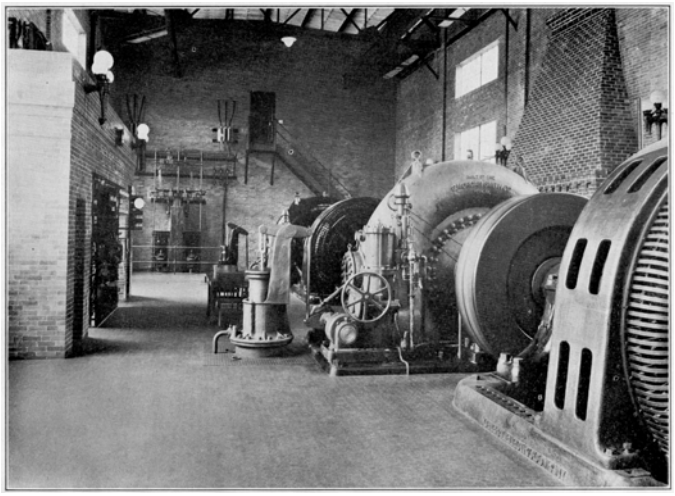
MARQUETTE DOCKS AND SHIPPING, ABOUT 1861.



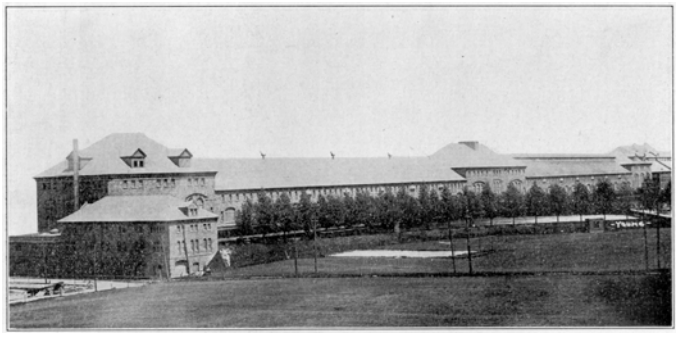
CLEVELAND-CLIFFS IRON COMPANY—STORAGE DAM ON DEAD RIVER.

Below this dam are the following power plants: Cleveland-Cliffs Iron Co. Hoist Plant, 140-ft. head; McClure Plant, 420-ft. head and two plants owned by the City of Marquette, one with 134-ft. head and one with a 34-ft. haul.

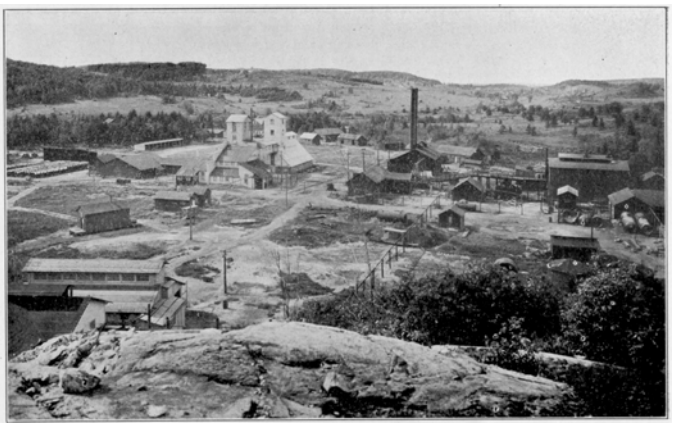
ST. MARY'S FALLS SHIP CANAL—THE FAMOUS SAULT STE. MARIE LOCKS



INTERIOR MCCLURE PLANT, CLEVELAND-CLIFFS IRON COMPANY—TWO 5,000 K. W. UNITS.



POWER HOUSE OF THE MICHIGAN NORTHERN POWER CO., SAULT STE. MARIE, MICH.
Capacity, 45,000 Horsepower; Length of Building, 1,340 Feet.



ACID AREA OF HERCULES POWDER COMPANY'S HIGH EXPLOSIVES PLANT AT ISHPEMING MICHIGAN

Building at the right is the Nitric Acid Plant, with five tanks in the foreground. To the right center is the Boiler House, with Machine Shop in the foreground. The buildings with the two towers are the Soda Storage and Soda Dry Houses with the Dope Mixing House in the front. The buildings to the left are the warehouses, with Glycerine Drums on skids on the extreme left. The building in the immediate foreground is the Ammonium Nitrate Plant. The buildings seen in the far distance are on the location of the Winthrop Mine.

The powder line proper is over the hill in back of the bluff on which the photographer stood to take this picture. The nearest explosives manufacturing buildings are the Nitroglycerine Storehouse and the Dynamite Mixing House, which are approximately 1,400 and 1,600 feet, respectively, by air line south of the Power House. Next in order come the Machine Packing Houses, Box Packing House, Box Storage Warehouse, and finished powder Magazines. The latter are located on broad gauge tracks about one mile from the Acid Area.