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A DESCRIPTION OF THE ELECTRIC POWER SYSTEM SUPPLYING THE IRON MINES OF MINNESOTA.

BY F. S. RICE, DULUTH, MINN.*

1—History.

In Minnesota the application of electricity to iron mining was first made about 20 years ago, and use of electricity from public service companies for mining about 17 years ago. Information available indicates that the Virginia Mine on the Mesaba Range in 1913, and Armour No. 2 Mine on the Cuyuna Range in 1915, were the first mines on their respective Ranges to take electric service.

In early days of electrification, service was not entirely satisfactory. As shown on Plate I, power was furnished from small, isolated generating stations and usually over but one line. This resulted invariably in poor service with many long interruptions. With this quality of service the mining companies could hardly be blamed for lack of enthusiasm in trusting their production schedules to electric power.

However, it was not long before developments in the art of power transmission at high voltage, interconnected systems and improvements in application of electrical equipment to mining uses, were able to overcome early prejudice.

With the construction in 1915 of 33,000-volt lines on the Cuyuna Range and interconnection between the Cuyuna Range Power and the Little Falls Water Power Companies in 1916, it was possible to give a fair degree of service to several mines. On the Mesaba Range, construction of 22,000-volt lines in 1913 by the Great

Northern Power Company and Western Mesaba Electric Company provided the initial steps in the electrification of this district. Further interconnection of the Duluth and Mesaba Range properties of the Great Northern Power Company in 1918, with the construction of a 66,000-volt line from Duluth to Hibbing, provided an additional source of power to accommodate the rapidly increasing mining load. In 1923, with the construction of a 44,000-volt line from Winton to Tower, electric service on the Vermilion Range was initiated at the Soudan Mine.

During 1923, the Minnesota Power & Light Company was formed, which combined six independent operating companies. By the end of the following year all these companies were interconnected by high tension lines, resulting in a completely unified system possible of delivering power with a high degree of reliability. A comparison of Plate I, showing the original systems, with Plate II, which shows the combined system as it exists today, indicates how completely the interconnection has been accomplished.

*Electrical Engineer, Minnesota Power & Light Co.

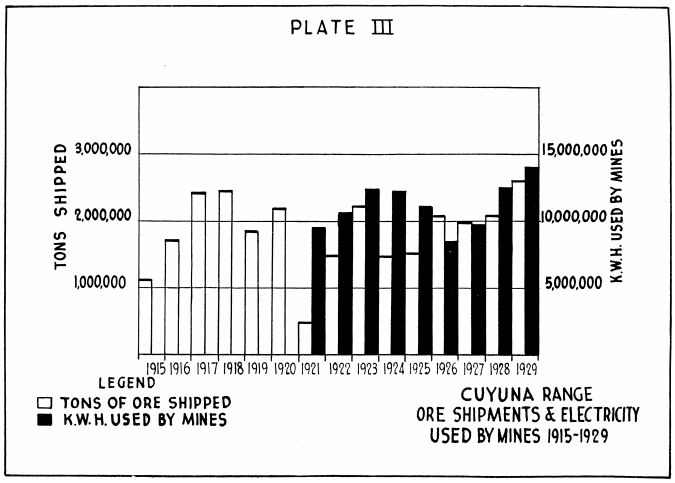
2—Description of System.

The term "Interconnection" is often loosely applied to connections ranging from the linking together of the ends of relatively small capacity lines already in service in neighboring territories, to high capacity ties built between separate high voltage systems.

The first type is of relatively little advantage, resulting only in improved service within a restricted area. To obtain the maximum benefit, however, it is necessary that the interconnecting lines be of sufficient capacity to handle an appreciable portion of the system load. With this type of interconnection, many benefits are obtained, among them being: (a) protection of consumers' service due to the possibility of obtaining power from more than one source, in case of shortage of supply or failure in any one generating plant or transmission line; (b) ability to maintain lines and stations with a minimum or entire absence of inconvenience to the customer; (c) improvement in frequency regulation, the variations caused by large fluctuating loads being' much less noticeable than on a small isolated system; (d) more uniform voltage delivered to the consumer. It is this type of interconnection which is embodied in the Minnesota Power & Light Company system.

Referring again to Plate II, it will be seen that the system, with respect to the mines, is divided into three areas containing the Cuyuna, Mesaba and Vermilion Ranges. Each of these areas is served by a system of high voltage distribution lines, the Cuyuna Range at 33,000, the Mesaba Range at 22,000 and the Vermilion Range at 44,000 volts. Connecting these areas, as shown by the heavy lines, are 110,000-volt transmission lines of large capacity. These lines also extend to the generating plants near and in Duluth. To provide for load increases, additional 110,000-volt lines are planned as shown by the heavy dotted lines.

In order to supply power to the mining areas, from the transmission system, substations are installed which transform the 110,000 volts to the particular distribution voltage used in that area. The location and size of these substations depend upon the amount of load to be served and the load centers of mining activity.



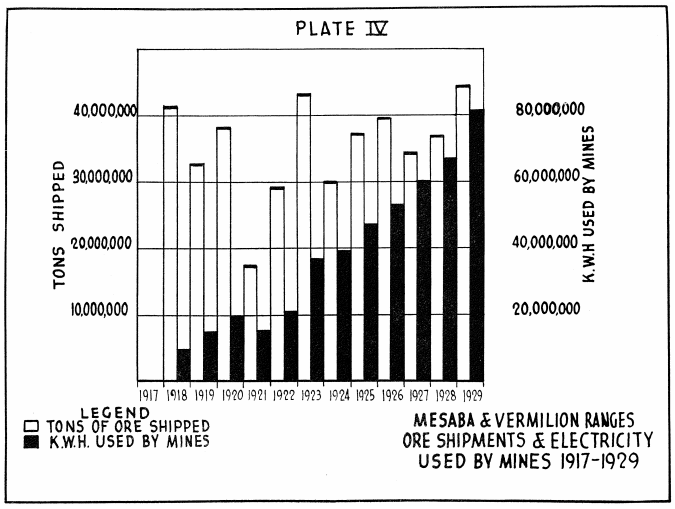
From each substation, which may have a capacity of 10,000 kilowatts or more, two to six feeders radiate to serve the mines and other load located in the vicinity. Each one of these feeders is controlled at the substation by an automatic oil circuit breaker. The operation of the breaker is guided by over-current or power directional relays which operate to trip the breaker open if trouble occurs on that particular feeder. Re-closing of the breaker, after the trouble is located and sectionalized, is done by the substation operator by means of solenoid or motor-operating mechanisms controlled from the switchboard in the substation. In order that only the line in trouble will clear itself from the remainder of the system, the setting of relays must be made quite accurately and with due reference to short circuit conditions which may exist at other points on the system. Relay settings are determined after making a short-circuit study of the system which involves eleven hydro plants, four steam plants, seven high tension substations and over one thousand miles of transmission line. This study indicates the short-circuit currents which may be expected at various points on the system and, as a result, the current and time settings which must be given to the various relays. This work is the duty of the Relay Engineer who has complete charge of setting, testing and making any changes which are necessary to improve the operation of the system protective equipment. While it has been possible to obtain system protective equipment operation efficiency of over 90 per cent perfect for all outages, increase beyond this point is difficult due to the large number of outages caused by lightning. Approximately 50 per cent of all interruptions can be traced directly to flashovers caused by lightning. In a large number of cases, no evidence remains to show where the flashover occurred and accordingly it is not known definitely that the protective equipment functioned properly. For the known cases however, an efficiency of 97 per cent was obtained in 1929 and with

improvements in relays and relaying methods it is expected that the goal of 100 per cent perfect is not far off.

At their far ends, the feeders are connected to the next adjacent substation or are tied together with switches. Along each feeder are sectionalizing switches, between tap lines which serve the mines, so that in case of a line failure, service may be restored as soon as the trouble is located and isolated by opening these switches on either side of the fault. As this method of switching permits feeding practically every mine from two directions, it results in a great improvement to service as compared to the former method of serving from one line without any possibility of service from more than one direction.

Power Supply.

The Minnesota Power & Light Company system is perhaps unique in that its hydro electric generating plants are located on three continental watersheds. From the Winton plant, the water flows north and finally into Hudson Bay; from the plants near the Cuyuna Range the flow is south to the Gulf of Mexico and from the plants near Duluth the flow is to the Gulf of St. Lawrence. This situation is also of considerable advantage since it is possible to benefit from the diversity in run-off in the different drainage areas. Repeatedly, there has been experienced high water conditions on the Mississippi simultaneously with low flow on the St. Louis River and vice versa. With the existing interconnection, the surplus power from the Mississippi may be used on the Mesaba or Vermilion Ranges.



The following list gives the plants furnishing power to the system:

Hydro

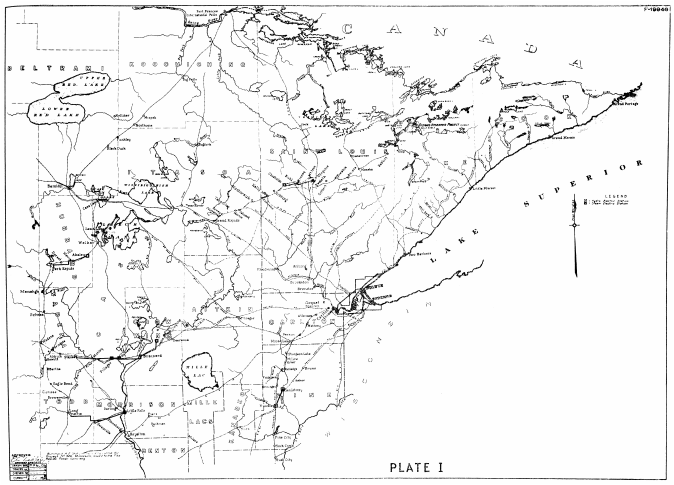
Name—	No. Units	Size Units KW	Total KW
Thomson	3	11,250	
	1	10,800	
	1	10,800	55,350
Blanchard	2	6,000	12,000
Fond du Lac	1	12,000	12,000
Winton	2	2,000	4,000
Knife Falls	3	800	2,400
Scanlon	4	400	1,600
Little Falls	2	400	
	2	800	
	1	1,120	3,520
Pillager	2	760	1,520
Sylvan	3	600	1,800
Sandstone	1	125	
	1	350	475
Park Rapids	1	96	
	1	150	246
Total hydro			94,911

Steam

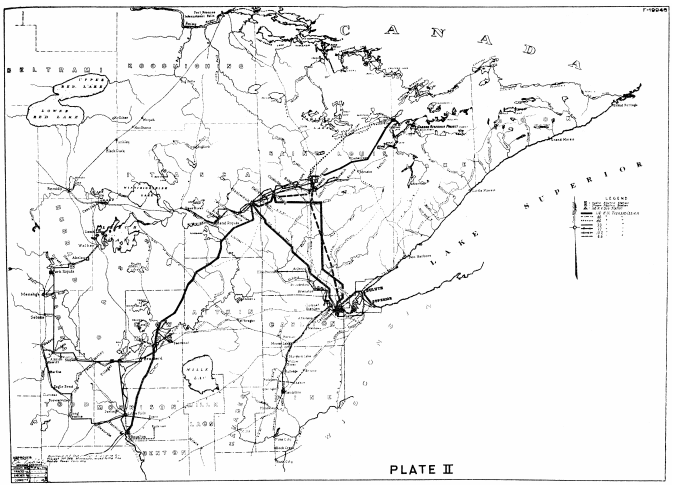
Name—	No. Units	Size Units KW	Total KW
Chisholm	1	2,500	
	1	2,000	4,500
Eveleth	1	600	
	1	450	1,050
Riverton	1	1,000	1,000
Virginia	2	2,375	4,750
Duluth	1	20,000	*20,000
Total steam			31,300
Total system			126,211

*Under construction.

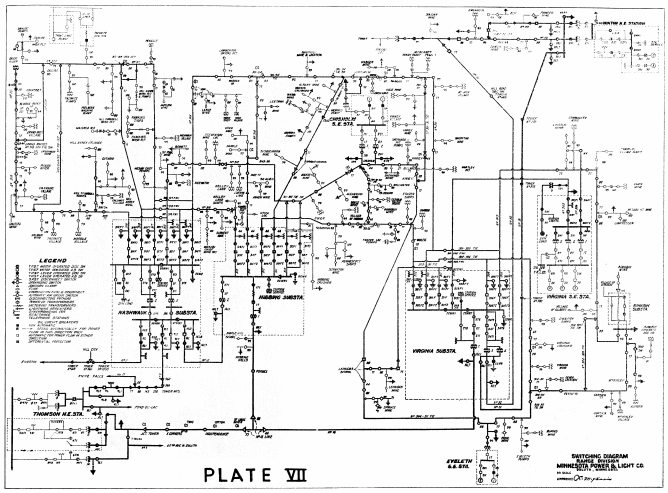
As these plants are widely distributed throughout the system and composed of a large number of relatively small units, there results a high degree of reliability of generation. With further increase in load, additional generating units will be added or new plants constructed. Such additions are planned for five years in advance as the result of studies of growth of demand and kilowatt-hour consumption.

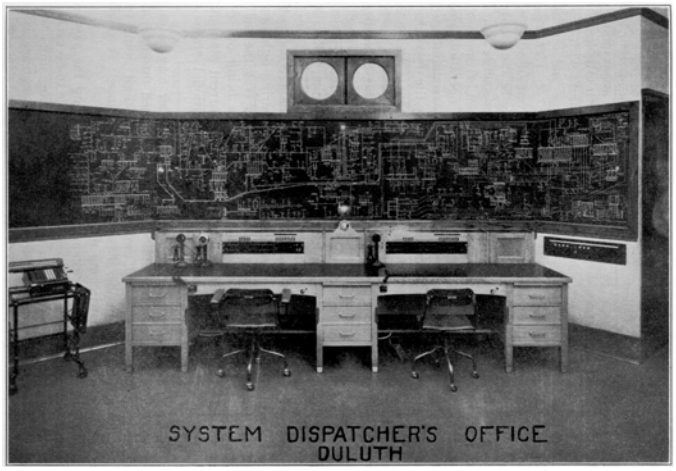


Original System of Electric Power, Furnished from Small Isolated Generating Stations, Usually Over One Line



COMBINED INTERCONNECTED SYSTEM OF ELECTRIC POWER, AS IT EXISTS TODAY



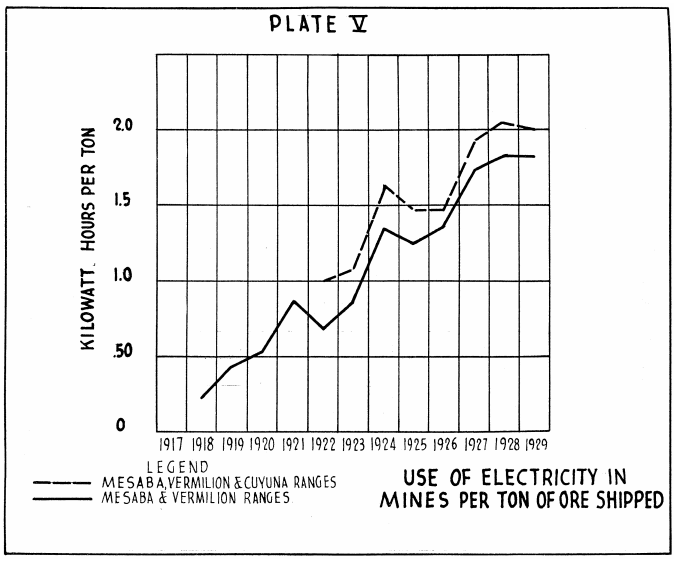


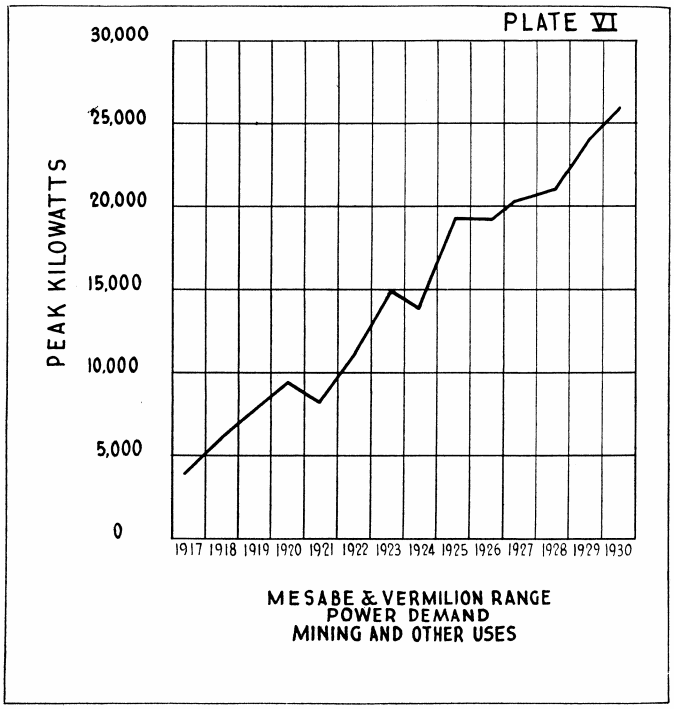
POWER CONTROL.

In order that sufficient generator capacity, transmission and distribution lines may he in service at all times to accommodate changing load conditions a dispatching system has been established. This is in charge of a Chief Dispatcher located in Duluth with sub-dispatchers located in Duluth, on the Mesaba Range and on the Cuyuna Range. Under this system all switching on transmission lines or distribution lines which form ties between substations and all changes in generator outputs or voltage may be done only by orders from the dispatcher. The Chief Dispatcher's office maintains records of demand, kilowatt-hour consumption, river flow, water stored and used, precipitation, steam plant operation and switching operations. Nearly all of these records are maintained on the various station log sheets and are combined by the dispatcher to give a picture of the operation of the entire system. As many of the stations are remotely located it is necessary to obtain hourly reports from each one by telephone in order that the dispatcher may know at all times the load and power supply conditions throughout the system.
Communication is provided by private telephone circuits strung on transmission line poles, leased circuits, toll calls and by a carrier current telephone system. The latter which uses radio telephone sets coupled to the conductors of the 110,000-volt lines has proved to be the most reliable of any. During lightning storms, there have been many instances when this was the only means of communication available, all other lines being out of commission. At present there are four carrier current stations. With extension of the 110,000-volt system, additional stations are planned.

In order that instructions given by the dispatcher may be understood clearly, a uniform numbering system is used throughout, this system being so devised that each letter and digit going to make up a complete number has a certain significance. A small section of the system switching diagram is shown.

The dispatcher is also responsible for maintaining the system frequency, which is held at all times as close as possible to 60 cycles. While ordinarily governors on the various generating units will hold this frequency, during periods of rapid load increase it is necessary to add generators in order that those already in service will not be loaded beyond their limits and so let the frequency drop. To assist in maintaining 60 cycles, indicating and graphic frequency meters are used. In addition a motor driven clock in the dispatcher's office is compared at frequent intervals with a clock regulated by Western Union. In the photograph of the system dispatcher's office, these two clocks are shown side by side above the switching diagram. Maintenance of constant frequency has been quite successful, the average frequency seldom departing from 60 cycles by more than 15 seconds in any 24 hour period. In fact, there are a number of electrically driven clocks around the system giving satisfactory service as time keepers. While the company does not maintain constant frequency for this purpose, but for the benefit of customers operating motor driven equipment, apparently the slight variation in frequency is not objectionable to those wishing to use electric clocks.





Load Growth.

The use of electricity in the iron mines of Minnesota has experienced a remarkably rapid growth as shown on the accompanying charts. Plate III shows the growth in kilowatt-hours used by mines on the Cuyuna Range, ore shipments being shown for comparison. Plate IV is similar, but for the Mesaba and Vermilion Ranges combined. An interesting point brought out by a study of these charts is the increased use of electricity per ton of ore shipped. This is shown in curve form on Plate V and represents the average use for all the mines served. Another curve of interest which indicates increased mining use of electricity is on Plate VI showing the increase in peak kilowatt demand of the combined Mesaba and Vermilion Range loads.

REPAIR SHOP PRACTICE AROUND MINNESOTA IRON MINES.

BY ANTON TANCIG, CHISHOLM, MINN.*

In dealing with the subject of mine repair shops and the general practice pertaining thereto, we are concerned mainly with the district or headquarters shop in which are made the major repairs, the important overhauling and in which manufacturing is carried on to a limited extent. It is only in such a plant that it is possible to concentrate on skilled labor, improved tools and methods, from which we can expect good reliable work. Most of us know that shop practice today is a very different matter compared to what it was twenty years ago when the mining equipment was designed for simplicity and ruggedness and a good handy man could look after the maintenance and make the necessary repairs. Today our conditions and requirements are becoming more complex, because, with the gradual introduction of the latest improved and very efficient mining equipment, the quality of the repair shop work had to be improved to the point where today our men can turn out work that is second to none.

*Mechanical Superintendent, Snyder Mining Co.

Materials, Workmanship and New Developments

Along with the better class of skilled men now employed in our shops, we have likewise had to advance in every phase and condition bearing any relationship to modern repair shop practice. One of the most striking improvements in this connection is in the type and class of materials used. Where formerly the principal shop specifications for materials called for mild or hard steel, red or yellow brass, and cast iron, we seldom, if ever, hear such elementary specifications used today. The present practice is to specify material most suitable for a certain known requirement. For instance, rods and bolts subject to shock and severe tension give the best results when made from a chrome-vanadium alloy steel. Again, we have definite uses for steel containing various percentages of carbon, nickel, nickel-chromium, chromium, tungsten, silico-manganese, etc. The use of these alloy steels is due to our continually striving for better results. Where we used to use a mild steel with a 55,000-lb. tensile strength and resulting in frequent failures, today we make such parts out of steel having a tensile strength of 90,000 lb., reducing the failures to practically nothing.

The same is true with our grey iron, cast steel and non-ferrous metal castings. The metallurgists have shown that these metals can he made to fit almost every particular duty if the percentage of the different basic ingredients is properly varied. At one time we used to make piston rings, flanges, cylinders and car wheels out of the same stock poured out of the same ladle. To do so today would be an evidence of the rankest kind of ignorance or because it was necessary to tide over a breakdown until the proper material was available.

Regarding the use of brass, here again the custom has changed. Certain jobs require a hard or tough bronze, depending on the service, and only the most unimportant pieces are made of plain soft brass. The bearings that formerly were babbitted are now fitted with machined liners of specification bronze and usually pressure lubricated or ring oiled. Where we have very high speeds to contend with or where the duty is continuous, the bronze is giving way to ball and roller bearings. These changes are of course all made to reduce repairs and to reduce bearing friction. The old faithful babbitt pot is now used but seldom, because babbitt bearings are gradually passing out and those that are still used are made of a high grade frictionless metal and usually provided with some one of the well known self-oiling devices.

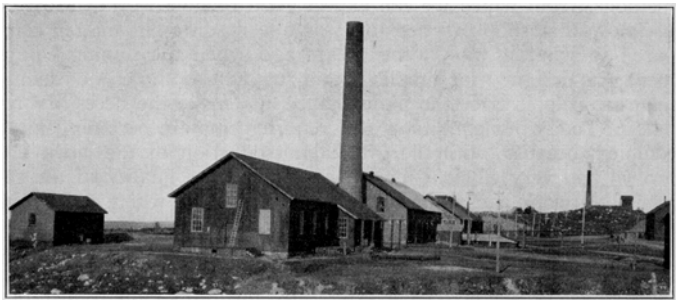


FIG. 1—THE FIRST DISTRICT REPAIR SHOPS FOR IRON MINING EQUIPMENT. THE SOUDAN SHOPS BUILT BY THE MINNESOTA IRON COMPANY IN 1890, DESTROYED BY FIRE ABOUT 1918

In addition to using improved materials and methods we have developed a class of workmanship in keeping with our advance in other directions. Making a press fit by using a certain amount of caliper drag for the required tons pressure has been superceded by making the bore diameter minus or the shaft plus a definite number of thousandths of an inch. The result is a very superior job with no delays due to loose wheels, cranks or other parts that must be tight. Machinists today work to closer tolerances—up to 1/10,000 of an inch—than any other industrial workman, possibly excepting a few specialists whose work is of small volume compared to what is turned out by the machinist.

Within the past decade, we have seen the commercial development of one of the most important phases of shop work and that is autogenous and electric welding. This development has already saved countless hours of time and expense because of, the ease with which metals are cut, welded or worn parts built up. Broken, or badly worn parts are today built up with some ferrous or non-ferrous metal, then machined or finished off and put back into service as good as new. Not only have we been able to save a tremendous amount of money in reclaiming worn or broken parts by this new method, but in many cases serious delays were averted because it was possible to weld a crack just opened and before complete failure could occur.

Mining shops have been very successful in adopting this new tool and a few of the characteristic jobs we handle are as follows: building up locomotive tire flanges, locomotive frame jaws, welding cracked cylinders with bronze, welding fire box cracks, building up worn pump rods with bronze and refinishing, building up worn locomotive pistons with bronze and refinishing for new rings to fit the rebored cylinders, replacing broken gear teeth with steel or bronze, facing slusher scraper cutting edges with extra hard steel, welding special hard steel cutting edges to machine tools in the shop as well as welding steam, water and air pipe lines. Pages could be filled telling of the many successful jobs we do with our welding apparatus which has been one of the big factors in the line of labor-saving devices employed in the mining industry.

Increasing the quantity and improving the quality of the work done in our shops was not accomplished without the addition of modern machine tools. While we still use the regular standard tools like the lathes, drill presses, planers, bolt and pipe cutters, we have added wheel turning lathes, milling machines, shaft and guide grinders, and other machines similar to those used in modern railroad shops, principally because our problems are fundamentally the same as theirs. The biggest single improvement has been in the line of hand held tools such as air or electric driven drills, grinders, chippers, riveters and buffers.

With the ever increasing use of welding around a mine shop, it would be almost impossible to properly dress off the job in the old way with a large bastard file. We do the job in a fraction of the old time and do a much better job of it with a hand held portable grinder. Because of the many grades and shapes of grinding wheels that are available, it is possible to apply portable grinding to almost every job that was formerly hand filed.

While the foregoing applies most generally to the machine shop, it is nevertheless an indicator of similar improvements in every department of our modern mine shop. The blacksmith, carpenter and electric shops have all kept pace with the times. The old hand methods have been and are being supplanted with modern tools and ideas, because production and efficiency in the mining industry make imperative the use of the best tools and methods available.

The modern mine repair shop has to face problems that are unlike those of any other shop. It has to handle work that is a combination of the railroad shop, electric, woodworking, forging and paint shops, quite a little jobbing work, and, in many cases, during quiet periods in the shop we manufacture a considerable quantity of the simpler and less intricate parts. The manufacturing is not done with any idea of competing with the factory as to prices, but because the shop has rush periods when it takes all of the men available to handle the repairs, followed almost immediately by periods of comparative quiet which are made use of as manufacturing periods. Repeating what is probably well known to mining men, a mine mechanic is one of the most versatile of skilled workmen—he can make simple common parts or repair a locomotive; the electrician can do plain wiring, vulcanize power cables, rewind motors or test the

apparatus in use; the blacksmith does light or heavy forging, difficult tempering and heat-treating.

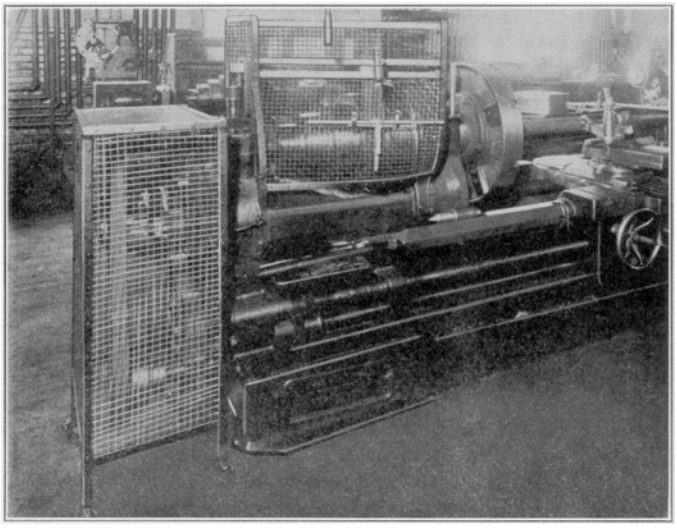


FIG. 2—HOW MACHINE TOOLS ARE GUARDED FOR SAFETY

All of this is not due to any higher order of intelligence on the part of the shop workmen, but because the equipment we now use in our mines demands ability of the highest order for its repair and maintenance and this is only accomplished through continual training. In speaking of training the workmen in the shops, of course much could be written on the subject, but what the writer had; in mind particularly, was that periodically, the department heads or foremen or the one man in general charge of the plant, should make a trip of inspection through some important railroad or jobbing shop, visiting a different shop each year. It is surprising the amount of information that is collected in this way and which finds its way into the shop in the line of new and modern methods. This idea of visiting shops is most important because the mine shops are rather isolated anyway, a condition conducive to getting into a rut.

GENERAL PLAN.

It was suggested that a plan drawing be made a part of this paper, showing how one of these up-to-date mine shops are laid out, the general arrangement of departments, location of machine tools, or in other words a general plan for an entire new plant. This is not so easy to do because conditions, requirements and locations vary so much that what would be suitable for one plant would be impractical for another plant. Another reason for not submitting a plan is that when designing a new plant, the person to have charge of its operation should be allowed considerable latitude in the matter of design and location of machinery. A general description or word picture, if you will, may perhaps be made sufficiently clear to enable one to grasp the writer's ideas on this subject. Views of several representative shops are shown to give a general idea of building types and arrangements.

To begin the design of such a headquarters shop, it is first necessary to make a survey of the present and future requirements, the type of equipment to be repaired, bearing in mind the continual trend toward larger and better made improved mining machinery. The spacing between machine tools should be liberal as the diversified class of work handled sometimes calls for all the available space, and a few extra square feet of floor space often more than pays for itself.

The building should be located near the point of greatest use over the longest term of years, and the main storeroom must be close by to save time in obtaining supplies. Fire proof construction should be adhered to, ample provision being made for the maximum amount of natural light, ventilation, heat and sanitation. The artificial light supply must be ample, 8-16 foot candle illumination, with individual lamps at each machine to overcome shadows and for ease in reading measurements. Lockers, wash and toilet rooms and ample supplies of good drinking water are all most essential to a well designed and properly run shop.

The departments that go to make up such a headquarters .shop are a machine, blacksmith, carpenter, welding, and electric shop. At one time we used a small foundry as well, but since the advent of gas and electric welding, together with the uneven foundry job factor, it was found that the foundry could well be dispensed with.

The machine shop must naturally be the largest, because the locomotives, shovels and other large pieces of equipment are set in there for overhauling. This shop must be equipped with suitable overhead traveling cranes, drop pits, floor cranes, smoke jacks and conveniently spaced wall and floor outlets for compressed air, steam, water and electricity. The best floors are of wooden blocks on a concrete base. All piping and conduits within the building should be painted in individual colors for steam, air, etc., to facilitate connections and as an added precaution for safety.

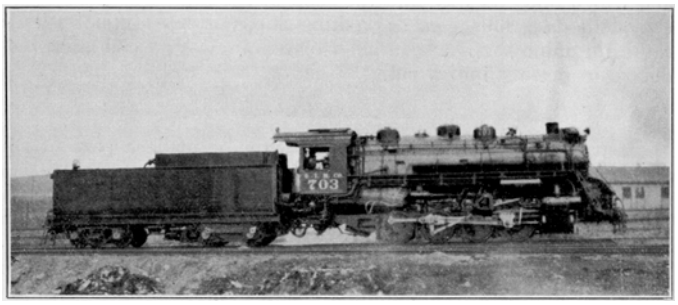


FIG. 3—TYPE OF LARGE EQUIPMENT KEPT IN REPAIR BY THE MINE SHOPS

In order that there be no misunderstanding regarding the use of the word shops, it is not intended that separate building's are to be used, but only separate rooms in one large building. Aside from the wood working or carpenter shop, it isn't even necessary to have solid partitions or partitions extending clear to the roof between the different departments.

When planning the construction of a repair shop to serve a district using modern steam and electric equipment in

the open pits and underground mines, the following list of tools will serve as a basis for shop equipment. A slight change may be advisable with variable conditions, but on the whole, the list as given below will answer for all purposes in the majority of installations:

Electric Shop Equipment

1-Hand operated, 2-ton capacity traveling crane,
1-Floor crane for carrying heavy parts into machine shop,
1-Power cable vulcanizer with molds,
1-Electrically heated drying and baking oven,
1-Grinding and buffing wheel set,
1-Combination vacuum and blowing apparatus, hand held,
One or more adjustable metal made armature winding stands,
Several work benches with vises and tool drawers,
Several armature and commutator pullers,
Different sizes of gear and pinion pullers,
Racks for storing repaired armatures,
Complete outfit of testing instruments,
Cupboards for storing supplies and wire used in making repairs,
Complete line of small tools.

Blacksmith Shop

1-Steam hammer, approximately 1100 to 1500 lb.,
1-Light air operated forging hammer,
1-Rock drill steel sharpener,
1-Motor operated blast hole bit sharpener,
Several oil burning steel heating furnaces,
Several coke burning forges with individual blowers,
1-Combination motor driven punch and shear,
Overhead, hand operated cranes, serving forges and forging hammers,
Racks for forging dies and dollies,
Racks for all hand tools and tongs,
Several portable forges for outside work,
Work benches with vises and tool drawers,
Quenching tanks for water and oil,
Bulldozing dies and formers, made as needed,
Removable water cooled forging oven,
Extra heavy flatter plates, 3 to 4 feet square,
Necessary riveting hammers and chipping hammers,
Anvils and forming blocks,
Complete line of standard small tools.

Carpenter Shop

1-Rip saw,
1-Band saw,
1-Joiner,
1-Planer,
1-Boring machine,
1-Grind stone,
1-Wood turning lathe,
1-Electric saw brazer,
1-Saw filing and setting machine,
1-Electrically heated glue pot,
Work benches with usual working vises, drawers, etc.,
Lockers for paint and painting apparatus,
1-Spray gun painting apparatus,
1-Wedge cutting attachment for band saw,
Complete outfit of clamps and small tools.

Welding Shop

The equipment in this shop will depend on the amount of work-to be done and will include gas and electric welders of the portable type, welding benches, pre-heating burners, racks for welding-rods and supplies.

It is imperative that good ventilation be provided to carry off injurious gases when working non-ferrous metals:

1-Truck for handling oxygen and acetylene tanks,
1-Air operated portable grinder,
1-Air operated portable chipping hammer.

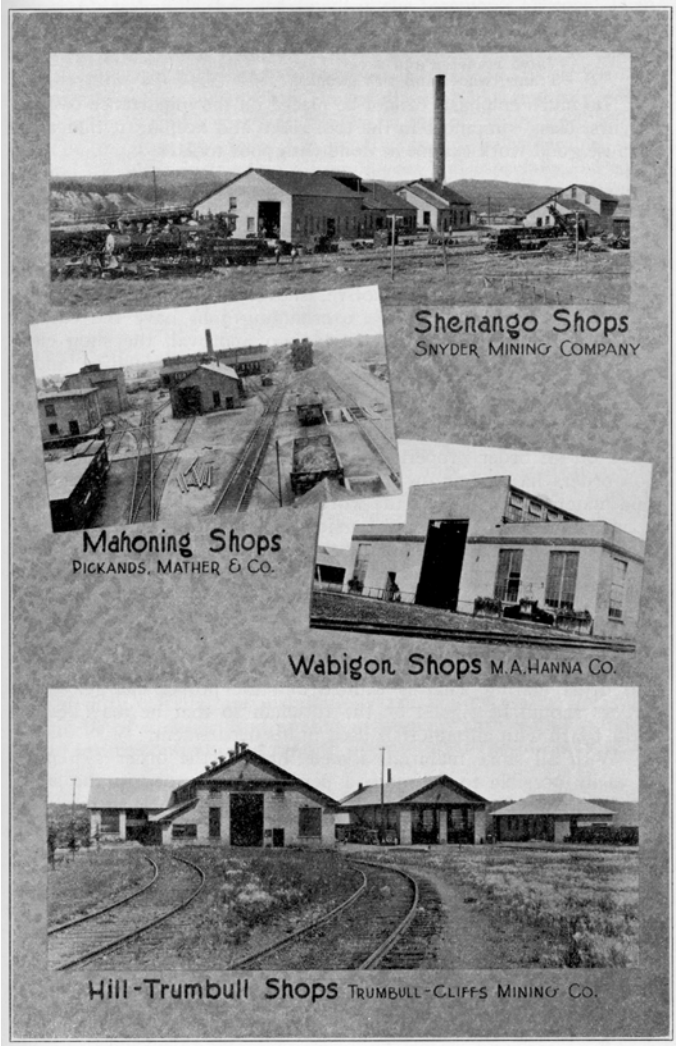
Machine Shop

3 or more motor-driven engine lathes with swings from 14 to 36 inches, having beds 10 feet to 22 feet long with a complete line of attachments. These must be high quality machines for accurate work that will range from the smallest to the heaviest the machines will take.
1-Locomotive tire turning lathe,
1-Car wheel boring machine,
1-5½-foot radial drill press,
1-Upright drill press,
1-Shaper,
1-Milling machine,
1-Planer,
1-Pipe threading machine with 3-inch to 10-inch capacity,
1-Bolt and small pipe cutter and threader,
1-Hydraulic wheel press to take up to 84 inches and made for pressures up to 300 tons,
1-Automatic metal saw, 8 by 8-inch capacity,
1-Portable cylinder boring bar outfit,
1-Twist drill grinder,
1-Emery wheel stand for rough grinding,
1-Emery wheel stand for tool work,
1-Buffing wheel stand,
1-Grinding machine for round rods,
1-Grinding machine for flat work, such as locomotive guides, links, etc.,
Several hand held air or electric operated grinders and drills,
Several chipping and riveting hammers,
Traveling cranes to serve locomotive and shovel tracks and the heavy machine tools,
Floor cranes to serve the smaller machine tools,
Work benches with vises and tool drawers,
Tool benches to serve machine tools,
Outlets of ample capacity for compressed air, water, steam and electricity,
1-Portable heater for setting locomotive tires.

Tool Room

Complete line of master gauges, reamers of the solid, shell and expanding types, twist, drills, taps, dies and other small tools of this nature,
Large and small surface plates, complete inside and outside large size micrometers,
Storage space for jigs, templates, mandrils,
Metal files for working drawings and sketches,
If tools are dressed and repaired in the tool room, then the necessary equipment for doing such work should be added,
Complete supply of cutting tools and parts for lathes, planers and milling; machines,
Steam gauge testing equipment,
Valve reseater and facer,
Trams, wheel and tire gauges.

Too much emphasis cannot he placed on the importance of having first class equipment in the tool room and keeping it that way, because good work cannot be done with poor tools.



How Work is Handled

The procedure usually followed in taking care of the various jobs is such that the workmen know what each job is charged to, and this is handled as follows: ordinary breakdown repairs are charged direct to the locomotive, shovel or whatever particular unit needs the work. Large overhauling jobs have the cost of repairs estimated in advance and upon approval, the shop clerk fills out a work requisition bearing complete information and a key number. Each foreman is furnished with the necessary information and all charges are made against the key number.

Jobs of manufacturing, such as making warehouse stock, are done on an order properly made out by the storekeeper. These job orders have their own set of key numbers to facilitate labor and material charging by the workmen.

Certain shops handle all outside or job work in the nature of a warehouse sale which is handled by the shops through an order from the storekeeper. This is by far the best procedure, as it centers the sales and collection of accounts in the storeroom where it properly belongs.

When any workman requires new materials of any sort, it is obtained from the storeroom upon presentation of a properly made out order stating what is wanted and the proper charge. Such orders should be signed by the foreman so that he may keep in close touch with all materials used in his department.

With all store materials issued through the order system, it is easily possible to maintain a perpetual inventory in the storeroom so the general office will know at all times what investment is carried on stores as a whole as well as on specific items.

Personnel

The headquarters shops are usually under the general supervision of the district master mechanic or mechanical superintendent, and, if the size of the plant warrants doing so, a general foreman has direct charge of all departments with a foreman for each department.

Each foreman has one or more key men that are capable enough to send out on any breakdown or repair job as well as being able to handle the department in the foreman's absence. Then comes the necessary number of skilled workmen, one or two apprentices and several helpers. The cleaning and janitor service is usually attended to by one or more of the helpers. This item of janitor service is not the least important work around any plant, as cleanliness and order are necessary for efficiency and safety. The mine safety inspector usually spends considerable time around the plant instructing all employees and especially the foremen, on the proper guarding of all machines, the use of goggles and various other safety measures. Tools that become defective and consequently dangerous, should be made right or discarded and the foremen can be of assistance to the inspector by attending to this matter personally.

Conclusion

While the repair shop is an absolute necessity around iron mines, in order that the mining equipment may be kept in good working-order at all times, the amount of repair work can sometimes be considerably lessened if the equipment is carefully watched and given complete periodic inspections, a practice that in many instances will prevent costly delays through anticipating breakdowns. These careful inspections wall also disclose any improper lubrication, wasteful practices, excessive wear or any of the innumerable defects that in time may cause delays or shutdowns.

Many items of interest to men having to do with repair shops have necessarily been omitted because of the lack of time and space, the outstanding features only having been mentioned. The idea carried in mind by the author, and which he has attempted to convey, is that

everything connected with a mine shop should be of the latest design and of the best quality in keeping with the required duty. Elaborate installations are not necessary, but they should be of a design and quality in keeping with a major industry to insure continuity of mining operations at the lowest possible cost.

[Lake Superior Mining Section, National Safety Council]

ACCIDENT PREVENTION THROUGH STANDARDIZATION OF MINING OPERATIONS.

BY WM. R. MEYERS, ISHPEMING, MICH.*

We find from time to time that accident prevention work reaches a condition where a new approach is necessary to attain further improvement. Several years ago, we awakened to the fact that the success of any safety movement was dependent on the interest of the executive. Safety in industry is now acknowledged an executive matter, due to the overwhelming evidence that a safe mine or plant is an efficient one and conversely an efficient mine or plant is a safe one. Through an executive's knowledge of the processes of the industry, his sympathy and understanding of the problems which confront his employees, a spirit of enthusiastic cooperation and loyalty is created in those associated with him.

Industry today recognizes the interdependence of employer and employee. It realizes that the employer prospers in direct ratio to the prosperity of his employees; that maximum productivity cannot be attained until accidents are reduced to a minimum. As a means to this end of increased efficiency and a new approach to further improvement in accident prevention, I will endeavor to show the reason for Standardization of Operating Methods, the success of which is dependent on supervision and discipline.

It has been truly said that, "Present day advanced safety practice in industry places the responsibility for accidents and their prevention directly upon the employer. Self protection on his part forces him to resort to intensive supervision and discipline, which, in order to make these even reasonably effective, must be supplemented by educational activities of various kinds. Of prime importance is the education of the supervisory officials, since they very obviously cannot tell their employees what to do or not to do unless they themselves know what is safe against what is unsafe in mining, including methods, practices, equipment, installation, etc."

*Superintendent Holmes and Tilden Mines, Cleveland-Cliffs Iron Co., Ishpeming.

(Paper presented at the annual meeting of the Lake Superior Section of the National Safety Council, June 1930. Published by permission.)

In reducing the number of preventable accidents as in any other human activity, orderly planned, intelligent effort results in greater accomplishment than loose, slipshod, hit or miss methods.

If an accident occurs, does it not mean that we have done the work in an improper way? Standardization of operating methods is therefore an answer to this question. Almost immediately objection against standardization arises on the ground that it will retard progress or throttle the possibility of change, but when it is carried out on a practical and sound basis the contrary is true. The idea of perfection is not involved in standardization. Standard methods of operations should be simply the best methods that can be devised at the time they are adopted. The work in itself is a powerful incentive to accumulate the correct data upon which uniform requirements can best be decided. Improvements should always be wanted and adopted, whenever and wherever they are found.

Standardization with respect to equipment, installations and other essential elements covering interchangeability between its mines has been practiced for many years by The Cleveland-Cliffs Iron Company, in the belief that it increases efficiency and produces larger economies. In recent years we have found the need for codes of safety standards to control those operations which experience has proven to be prolific sources of accidents. Unsafe methods of doing work, negligence, and indifference should be no more inherent or prevalent to the mining industry than they are in other industries, but the number of accidents that are traceable to those causes is convincing proof that ways and means should be designated to stop or to eliminate them, as much as it is possible within human skill and power. The fact that carelessness may be an underlying cause for many accidents does not lessen their social or economic loss, nor lighten the burden of responsibility of those who are most concerned in the work of accident prevention. The significance of the safety movement will not be understood or appreciated where doubts exist or opinions differ as to what really constitutes safe practices. Fairness, in dealing with men, demands that supervision and discipline should be directed by carefully thought-out standards of operation that will prevent the things responsible for accidents.

The whole purpose of analyzing and classifying accidents by causes should point to the next logical and tangible preventives. We know that many are the outcome of a long train of events, but if only complete information were available, it would be possible to trace any accident to its initiating cause—to some failure of insight or foresight on the part of some human agent, or, in many cases ultimately, to a failure on the part of the management, due to unsafe mining methods, defective equipment, faulty installation, or inadequate supervision or instruction. In prevention work, it is needful to know how and why accidents occur, and while causes are almost as varied as the circumstances which give rise to them, yet the large majority may be charged to

conditions or circumstances that can be prevented. Although the field is broad and includes the experience of years, the success and permanency of the movement requires that the multiplicity of operations involved in mining shall be closely associated with safety and directed under capable supervision. It is not expected that our industry will ever be entirely free from accidents, but occupational hazards can be reduced and men must be led to give their hearty cooperation to a work that so vitally concerns them.

In attempting to arrive at standards for operating methods, it is very important that all men who hold supervisory positions shall have an opportunity to participate in their formulation. Conferences of these men, as a sponsor body for recommending standards, help to eliminate practices and customs that impede progress and lead to the getting of those facts which will inevitably increase safety and efficiency. By pooling the experience and skill of such a group of men, management shows that its policy is conducive to cordial cooperative work and assures itself of the best methods of performing its various operations. The possibilities of bettering conditions are great enough to warrant the participation of the men who know their jobs and its needs better than any others and whose services have only to be commanded. By keeping their interest and enthusiasm directed towards this work, there is developed a spirit of mutual helpfulness and coordination of effort that will produce results as fast as the need for progress in standardization demands. By basing standards upon the collective opinion of foremen, they are placed in the position of being asked to put into effect their own ideas rather than the ideas given them by others.

There are many operations in mining to which standardization can be applied, such as mining methods, transportation, explosives, mechanization, etc. In many phases of these operations, past practices covered the desired field and it is only necessary to use the combined judgment of the foremen to pick out and recommend the best. In other cases, the essential details may have to be worked out with extreme care in order to insure the greatest accuracy in operative work, combined with maximum safety. By bringing out and sorting the accumulated experience of a representative group of men, whose membership includes those who are familiar with the equipment and activities of a mine, a workable basis is laid upon which standardization can be built without interfering with production and at the same time inestimable results toward safety will accrue.

The top slicing or the caving method of mining, which is used very extensively on the Marquette Range, has accounted for one-third of the fatal accidents over an extended period of time. It is true that natural circumstances vary from mine to mine, even within a limited area, but they should not be interpreted as meaning that well-defined safety standards cannot be made to play an important role in reducing the hazards that cause these accidents. Time and thought should be devoted in an intensive study in building up and maintaining a strong protective mat or gob, in every mine where this method is used. Physical inequalities in ore bodies and associated rocks, large dikes or horses of rock within an ore deposit, the presence of water, etc., are obstacles in the way of safe mining and only by agreeing upon the best and safest methods of procedure and following those methods very rigidly is there promise or likelihood of success in our efforts to master the occupational hazards of this work. Attention should also be given to the unusual and little-known factors, for they may furnish information that will prove invaluable in the development of better practices.

It is not too much to say that standardization offers a major opportunity towards the integration of the various operations involved in underground transportation so that the system may be made to function efficiently and safely. It has been said that 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.” On the other hand, it is not only very essential, but possible, to make standards sufficiently complete so that all operations in connection with this work can be comparatively safe to perform. It is work that gives primary occupations for younger men, which is but another reason why the standards should be specific in their requirements and regarded as mandatory in enforcement.

The reliability, efficiency and stability of explosives, whereby they have become comparatively safe to handle and use, hear testimony to the great progress that has been made by the manufacturers in cooperating to reduce the danger and disadvantages of mining. The millions of pounds of dynamite used annually without accident testify to the constant effort being exerted to increase safety in their usage. But while it is true that if miners will remember the nature of explosives and are careful in handling them, there will be little danger of accidents, the fact must not be forgotten that many accidents by explosives are of a fatal or serious nature and that the records of such events contain the names of experienced men. The information for the setting of standards by which men can do this work exceptionally well is not lacking and management must use that information and force men to observe safe practices in exact keeping with an occupation that has such possibilities for death and injury as exists in the careless use of explosives.

Because mechanization is rapidly increasing at our mines, does not signify that it is a factor that decreases, or increases the safety of mining. It has eliminated many old hazards under hand loading but it has also brought out new hazards. It will make mining more safe only if proper precaution is used and intelligence applied in its application. As one authority states, “It is true that mechanization requires greater caution, greater skill and a higher degree of intelligence from the worker. It requires training; the creation of the new term

'mechanical-mindedness,' and an adherence to standards and safety-codes."

In the standardization work of The Cleveland-Cliffs Iron Company, we have been studying the following specific projects:

1. Providing and maintaining ample equipment.
2. Proper installation of equipment.
3. Safe mining methods.
4. Safety codes for hazardous occupations.
5. Uniformity in the requirements demanded of employees.
6. Improved discipline.

Formulating or prescribing a code of safety standards for the various operations incidental to hazardous occupations will not of itself stop accidents. It is hardly necessary for me to say in the presence of this body of men, that how to reach and influence effectively the personal equation is a most important factor. In securing the highest standards of safety in operation, the cooperation of employees is absolutely essential and there must be painstaking-effort to destroy as far as possible the interrelationship, between safety and universal human shortcomings. Employees must not be permitted to lag behind in this movement and the responsibility for administering standards must rest with the management.

In the development of newer and possibly more progressive conditions and methods under which we operate our mines, modification and sympathetic consideration are being evinced by employers toward employees. Education and persuasion have brought better general results than prevailed many years ago and there has been a decided tendency towards better discipline. Infraction of rules or regulations may be excused or condoned where human effort is ignorant or misdirected, but if accidents are ever to be reduced to a minimum, men must be awakened to the realization of the fact that management's only alternative is an arbitrary action in dealing with offenders. Disciplinary leniency will not direct the serious attention of men to the object and purpose to be derived from the observance of standards. Indifference or carelessness will be a less cause of accident only when the enforcement of standards is made mandatory and accompanied with severe penalties. Our company has put the responsibility directly upon the foremen and for this added responsibility are paying them a safety bonus. Each shift boss, surface foreman, chief electrician and mechanic, who has men working under him, in addition to his regular daily wage or salary, receives a safety bonus of thirty-five cents per day for each two-week period in which no lost time accident occurs to any of the men under his supervision.

In order for standardization to be effective, it must be backed up by supervision and discipline, two of the most important factors in accident prevention work. Men must first be instructed in the safe and efficient way of doing their work and then be compelled to work in that way. We must make the conduct of carelessness and indifference so discouraging and futile that there will be an abandonment of all habits and customs that endanger life. If men are unwilling to observe safe practices, we can at least deprive them of the privileges of such action by separating them from their jobs. If we do not assume this prerogative, the prop and mainstay is knocked out from under effective accident prevention work.

SAFETY PRACTICES IN DRIFTING, RAISING AND SINKING.

BY RAY C. MAHON, IRON RIVER, MICH.*

The safety suggestions contained in this paper were made by various employees of the M. A. Hanna Company at safety meetings held under the direction of the safety organization.**

This safety organization is made up and functions as follows: A safety engineer has charge, under supervision of the management, of all safety work. He visits each mine periodically to inspect and recommend improvements promoting safety. He has charge of the safety crews at the different mines and instructs them in their duties. He arranges for the conducting of monthly safety meetings at the mines and, when possible, gives safety talks at these meetings. He assists by providing material for discussion at monthly safety meetings of the district safety organization. He also compiles data on accidents; makes comparative reports on the safety records of the various mines and furnishes material to be used on the mine bulletin boards to instill safety.

The mine safety organization is made up of a first-aid crew who are instructed in the use of various mine rescue apparatus and first-aid work. In addition to this crew, two or three men are selected by the underground employees, for a period of one month, to make an inspection of the mine and report at the monthly safety meeting. These men are kept on for only one month at a time in order to give every man an opportunity to visit the entire mine. These inspections also serve to make the men doing this work, think more of safety and to become more instilled with the safety spirit. Monthly meetings are held at each mine, at which the above referred to men report on their inspection and make recommendations.

*Superintendent Homer Mine, M. A. Hanna Co.

**Paper prepared for June meeting of the Lake Superior Section of the National Safety Council at Duluth, Minn.

A general discussion is held and the men are asked to make suggestions. These meetings are very valuable if conducted properly, for they serve to keep all of the men interested in safety and as at least eighty per cent of accident prevention is up to the man himself, too much stress cannot be laid upon anything that will accomplish this result. To have these meetings successful, they

must be short, kept interesting with plenty of discussion, must not drag, and the management must give full co-operation by carrying out any reasonable suggestions made. The minutes of these meetings are taken and copies sent to the management and safety engineer. At some of the mines, in addition to this organization, a safety inspector is appointed who makes a daily inspection of the mine and who receives safety recommendations from the men during the month. In small mines, this man can have other duties such as piping or timbering. A man in this position can be very valuable, as dangerous conditions are corrected more promptly and as the man is available to receive suggestions from the crew immediately.

The district safety organization takes in all of the officials and bosses of each district. This organization holds monthly meetings at which general safety conditions are discussed. The safety suggestions made at the various meetings, as well as those offered by the men present are discussed. Copies of these suggestions accepted are sent to the different mines, posted on the bulletin boards and discussed at the next monthly mine meeting.

Supplementary to this paper, we are listing safety suggestions and practices in drifting, raising and sinking, which were developed as outlined above. We realize that many of these suggestions are peculiar to our mines and that many points peculiar to other mines are not covered. Also, that by combining- the experience of all the operators in the Lake Superior District, this list will be greatly improved. To that end, we believe it would be very advisable to have a committee formed to handle such an interchange of ideas.

Suggestions for Drifting Safely.

1. The miners shall wear goggles while drilling.
2. When drill machines are mounted on a bar, the footings shall be made solid and soft wood plank used for wedges.
3. If a scraper slide is used, the tugger shall be guarded and the men shall stand in the clear of the ropes and blocks, and wear gloves.
4. To erect timber, safety chain hooks shall be used and the staging shall not be less than two inches in thickness.
5. The back and sides of all timbered drifts shall be thoroughly lagged.
6. Drifts in soft material shall not be advanced more than six feet beyond the last set of timber. In very soft ground poles shall be placed in the back of the drift from the last set to the face and thoroughly blocked. Where hitches cannot be cut in the breast for these poles, props and head boards shall be used.
7. The back and sides of the drift at the breast shall be thoroughly trimmed after every blast.
8. All drifts shall be inspected frequently for loose ground, crushing timber and other dangerous conditions. Any needed repairs shall be made at once.
9. Special rules for drift blasting: 1—Two men shall be required to light the fuses. 2—The entrance to the drift shall be guarded while charges are exploding. 3—The miners shall count the charges as they explode and report the number of missed holes to the shift boss.
10. The miners shall be instructed to be always on the alert for missed holes. All missed holes shall be reported to the shift boss and not touched without instructions from him. No miner shall be allowed to enter a face in which there is a missed hole, within thirty minutes of the blast.
11. When a drift is within thirty feet of holing through to another drift or opening, the miners on both sides shall be required to keep each other informed as to the exact time of firing.

Suggestions for Raising Safely.

1. Wear goggles when drilling or trimming.
2. The cut should not be drilled deeper than can be broken cleanly, to avoid having loose material in the face after the blast.
3. Stage poles should be not less than four inches in diameter and not more than four feet apart in height. Hitches for stage poles should be cut from the top down and deep enough so that the poles cannot possibly come out. Staging plank-should reach from wall to wall, should be sound and not less than two inches thick.
4. A chain safety grizzly should be used in all raises and should be kept not less than ten feet from the face . After a sub-level has been holed, the raise shall be covered with a grizzly, level with the floor of the sublevel.
5. When holing through to any opening, the nearby miners shall be warned and guards placed to keep anyone from walking into the opening.
6. Two men shall be required to blast a cut in a raise and the man not lighting the fuse shall be instructed to always have his light in readiness should the other man's light go out.
7. After blasting, air should be blown into the raise to clear it of gas and the men shall be instructed to be on the alert for gas when climbing the raise after a blast.
8. After blasting, the back and sides of the raise shall be trimmed, and broken stage poles replaced before work at the face is started.

9. Raises over fifty feet high should have two compartments or an auxiliary raise should be driven near it and connected to it at intervals of not over twenty-five feet. These high raises should be blasted electrically, using a good grade of blasting cable, with a safety switch at a safe distance from the bottom of the raise

10. The foot of the raise machine shall be kept sharp so as not to slip off of the staging plank.

11. Ladders shall be kept as near the face as possible.

12. All tools shall be placed in a safe position so as not to be jarred down while men are working in the raise.

13. All tools, staging, etc., shall be hoisted with a rope, which shall be kept in good condition.

Suggestions for Sinking Safely.

1. Experienced shaft miners should be employed if possible, also a capable hoist man and bucket lander.

2. The miners should provide themselves with hard-boiled hats, hard-toe boots, wire mesh goggles, and gloves.

3. Good tools are essential to safe shaft sinking.

4. The landing station and engine room should be well lighted.

5. A non-spinning hoist rope should be used.

6. Clevises or safety hooks must be used on all buckets.

7. A cross-head should be provided with a suitable safety device which will effectually prevent the bucket from lowering in case the cross-head should stick in the runners.

8. No one should ride the skip or bucket unless same is equipped with safety catches and protecting roof

9. When sinking, bucket must be stopped in the clear at the bottom and rung down when needed by the miners.

10. Everyone must stand in the clear at the bottom when the bucket or other material is being hoisted or lowered.

11. When tools, timber or other material are to be lowered or hoisted in the bucket, they shall be securely fastened to the hoisting rope or bail of bucket.

12. During sinking, suitable equipment must be provided so that signals can be given from the bottom of the shaft.

13. Standard hoist signals should be used, however small the job, and all men involved should be acquainted with them.

14. A toe-board should be used around the collar of the shaft to prevent chunks and other material from being kicked down upon the workmen.

15. The workmen should be protected with suitable doors, and these doors must be kept closed when bucket is being dumped.

16. While sinking, the collar of the shaft or winze should be guarded with substantial railings not less than forty inches high, spaced far enough from opening to prevent any person from walking into shaft or being hit by falling chunks.

17. Excavated material should be dumped where it is impossible for it to slide back into the shaft.

18. All blasting in shafts must be done by firing electrically, after a depth of five feet has been reached.

19. The ropes, head sheaves and puffer shall be inspected at least every two weeks and all bearings oiled or greased daily.

20. The following safety devices and safety methods should be used to fire electrically safely:

    A. Holes must be connected up in parallel when power is obtained from the trolley circuit, and in series when connected to firing machine.

    B. Prevent high resistance in circuit by scraping wire ends clean and making all joints tight.

    C. Do not untwist the wires of the shorted electric blasting cap until ready to connect them to the shot firing cable.

    D. Test all multiple shot circuits with a galvanometer to insure against failures from high resistance or broken wires.

    E. Use only well insulated firing cable and keep it dry.

    F. Suspend the firing cable over a dry board in center of shaft, keeping it from coming in contact with timber, pipe lines, etc.

    G. Firing cable should be shorted on end where the short portable cable is inserted in the circuit.

    H. Use a short cable with proper electrical connections to insert in firing cable to complete the circuit. This cable is in possession of man doing* the firing only.

    I. Use a spring knife switch which keeps the circuit open except when pressure is applied when firing.

    J. Switch should be enclosed and padlocked and key in possession of man doing the firing only.

    K. A switch should be placed in the trolley line so that the power can be cut off from the shaft vicinity when ready to charge the holes. This switch should be provided with a strap and padlock; the key in the hands of the man doing the blasting.

L. In retreating from charged holes, always be certain that each section of the firing cable which you are about to connect to, is shorted before making the connection, and then open the circuit nearer the charged holes.

M. At all times before connecting lead to exploder wires, a delay igniter should be connected to lead wire to determine the presence of a stray current. It is evident that should this igniter give off a harmless flash, there is a dangerous leak in the line, an ample warning that the charge must not be connected.

21. The portion of the shaft that is not timbered should be well trimmed.

22. When cleaning up a cut after blasting, special care should be taken to see that there are no missed holes.

23. The bucket should not be so full that there is any possibility of chunks rolling off while it is being hoisted.

24. All timber longer than six feet must be lowered with a devise.

25. Timber sets should be carried as close to the bottom of the shaft as found practicable.

26. Great care should be used in blocking shaft sets; a jar might loosen a poorly blocked set and the blocking spill down upon the workmen.

27. All boards, planks, loose rock and other material must be removed from each set as completed.

28. The timber should also be cleaned and inspected after each blast.

PROTECTIVE WEARING APPAREL AND EQUIPMENT.

BY G. H. LOHNEIS, DULUTH, MINN.*

It is with pleasure that we make this effort to respond to the wishes of the "Practice For The Prevention of Accidents" committee of the Lake Superior Mining Institute in preparing a paper for this meeting.

By way of an introduction then to the subject at hand, we wish briefly and somewhat chronologically to review the efforts of the Institute along safety lines leading up to this phase of accident prevention work,—Protective Wearing Apparel and Equipment. Such a review must incorporate the thoughts and work of the operators in the Lake Superior District, who for the most part comprise the Lake Superior Mining Institute. To quote from the first Section of the rules of the Institute, we find:

> "The objects of the Lake Superior Mining Institute are to promote the arts and sciences connected with the economical production of the useful minerals and metals in the Lake Superior region and the welfare of those employed in these industries by means of social intercourse by excursions, and by the reading and discussion of practical and professional papers and to circulate, by means of publications among its members, the information thus obtained."

Thus we see that like the inspired founders of the constitution of this glorious country, the founders of the Lake Superior Mining Institute included all, and did not lose sight of that vast majority in the industry, when they incorporated into the objects of that Institute, that phrase, "the welfare of those employed in the industries." That phrase implies certain obligations to those employed in the mining industries of this district, which the operators have accepted and which generally have been and are now being more intensively fulfilled with reference to accident prevention.

*Safety Supervisor, Northern Ore Mines, Republic Steel Corporation.

We recall Mr. J. H. Hearding's opening address to the Lake Superior Section of the National Safety Council at Duluth, Minnesota, in 1923. Mr. Hearding stated that that body of men were carrying on the work started by Mr. J. Parke Channing, the second president of the Institute and he quoted from Mr. Channing's address to the Institute at Virginia in 1895. To show that Mr. Channing saw the obligations referred to above as early as 1895, we again quote in part from his address:

> "Have we in the rush and push of the last fifty years' struggle for material prosperity, devoted a proper amount of attention to the life and health and comfort of the miner? A large proportion of humanity will not take care of itself, will not follow the common laws of health or nature. I regret to say we must use force to compel them. While the natural carelessness of mankind is difficult to overcome, it does not excuse us who know better from continually exerting our influence for right."

Thus, from its first inception, over thirty-five years ago, the Institute was interested in the problems of safety in the mines. In the succeeding years as the mines developed from the primitive mining methods of old to those of the modern mechanized methods of today, we find the Institute further interested in the ever changing problems of accident prevention.

From 1895 to 1922 we find in the Institute proceedings papers covering welfare, safety and accident prevention work on such subjects as: Bracing in Stockpile Bents, Benefit Funds, Social Surroundings of the Mine Employee, Compensation, Electric Signals, Signal Codes, Water Problems, Fire Fighting and Prevention, Ventilation, Sanitation, Change Houses, Man Hoists, Safety Devices, Safe Mining Methods, Safety Systems, Handling and Storage of Explosives, etc. By 1911 enough thought had been given to the subject of safety to warrant the creation of Safety Departments by the larger Iron Operators of the Lake Superior District. Accordingly these departments were formed and though the beginnings were rather crude, as in most pioneering adventures, the thought and effort developed through

these original safety departments have placed this district in a position of national prominence in accident prevention work.

In April of 1919 at the invitation of Mr. B. O. Pickard, then District Mining Engineer of the United States Bureau of Mines at Duluth, the safety engineers of four iron operators, two representatives of the claim department of copper operators, met with ten County Mine Inspectors, a professor of the Michigan College of Mining and Technology and the Bureau of Mines staff at Houghton, Michigan. After two days round table discussion on safety and accident prevention work, the meeting was adjourned to the first Annual Safety Conference of the Lake Superior Section of the National Safety Council. It has been our privilege to attend all of these conferences and it is with great pleasure that "we rake the ashes of memory" when we recall that the attendance (in the ten years of this organization) has grown from 28 with six operators and one general superintendent present to over 30 operators and 70 general managers and superintendents from over 100 mines. The Lake Superior Section of the .National Safety Council, without any regular membership, has been made possible by the operators in this district by the same men who comprise the Lake Superior Mining Institute.

Volumes have been written covering every phase of accident prevention work by the various men interested in the Lake Superior Section of the National Safety Council and in 1923 the Institute first commenced publishing the proceedings of the aforementioned organization. As these proceedings grew from year to year and realizing that to secure a wider distribution of them directly to the bosses and foremen in the mines, the operators by subscription made possible publishing them separately from the Institute proceedings, so that now they are available to practically every one who is connected with the supervision of the employees in the Lake Superior mines. That the efforts of the operators in the Lake Superior mines on accident prevention work has been recognized nationally may be seen from the following complimentary quotation by Mr. J. T. Ryan, Mine Safety Appliance Company, Pittsburgh, in speaking of the 1927 meeting of the Lake Superior Section of the National Safety Council at Duluth to the Mining Section of the National Safety Council at Chicago in 1927, Mr. Ryan says:

> "I attended this conference and it was my first offense. I had been invited in previous years, but I had never gotten to it. I will say it was one of the most interesting and inspiring mine safety meetings that I ever attended. The particular feature of the program that appealed to me was a managers' section. It was a splendid idea and the execution was good because the chairman had not only the managers, but in some cases the presidents of some of the companies.
>
> The best feature of that, I think, was the fact that those men came there, the higher operating officials, and they went publicly on record before approximately 350 men, many of them their own employees, as to their attitude on safety and pledged themselves to support the safety movement.
>
> Those conferences are a splendid thing. We have been conducting one in Pittsburgh under the auspices of the Western Pennsylvania Division of the National Safety Council for several years. I will admit that we have not put the pep into it that you have up in the Lake Superior District, but we get a lot of good out of it in Western Pennsylvania.
>
> We take a particular interest in that conference up in Duluth judging from my observation of the one I attended.
>
> There are many sections of the country where this regional conference could be held to great advantage and the men get a lot of good out of it and I believe that it will stimulate the work of this section, because we have an unusually large attendance from the Lake Superior District and I believe part of that is due to the interest that has been stimulated in their section."

In concluding this brief review of the active interest of the operators of the Lake Superior District from 1895 down to the present time, we wish to thank those operators for being so patient with those whose direct work it is to meet the everchanging conditions of accident prevention work. With their continued assistance and with the persistent efforts of the safety men we will find that each year advances the work of accident prevention a little closer to the goal, that ideal situation, elimination of accidents in the Lake Superior mines.

While the goal like the rainbow's end may never be reached and we cannot now or ever produce a set of safety rules or devise a safety organization that can always function as a 100 per cent eliminator, the problem remains one that most nearly approaches that goal from two standpoints, the humanitarian and the economic. As Mr. Channing pointed out, accident prevention becomes a moral duty, so that the humanitarian side of this problem automatically precludes any argument against it and no one can refute the fact that accident prevention and elimination makes for efficiency, which, of course, means more economic mining.

We have spoken of mechanization in modern mining methods and if we take that mechanization underground as we have in this district, we encounter additional dangers not found on surface, such as provisions for lighting, falls of rock, ore, etc., gas from fires, dangers from flooding, together with the inherent introduced dangers from electrical hazards, the motive power of most of that mechanization. It is probably right to say that these additional elements of danger today present greater hazards to the miner than formerly by reason of greater exposure and by just that degree does this call for additional precaution to safeguard against accidents.

The favorable decreasing accident frequency and severity rates in this district point out that this added precaution has been applied through the clear thinking, research interchange of ideas, and experimental work with new safety devices and equipment by the safety men in enabling the operator to meet and anticipate the accident prevention problems in this district. Among the newer ideas in accident prevention work, we find many articles of protective wearing apparel and equipment. In combat man has always sought to protect himself, as we know from the recounts of the oldest recorded battles down to the present modern protective equipment used by the players in various athletic games, yet in hazardous peaceful pursuit that protective equipment is often sorely lacking. Protective apparel and equipment do not in themselves prevent accidents, but they do prevent and lessen disability due to accidents and hence form an important phase of any safety program.

In speaking of protective clothing and apparel we wish to distinguish it from safe clothing by one illustration. A shop machinist may be said to be equipped with safe and protective clothing were he supplied with a snug fitting coverall with no loose end dangling, a pair of goggles for certain classes of work, and hard-toed shoes, but that clothing would not be protective were he impressed into service pouring babbit unless supplied with a mask, proper leggings and possibly an apron depending upon the particular hazards involved.

Several essentials must be considered in selecting protective apparel and equipment if we are to expect the men to wear them, such as price, durability and comfort, which will not unduly interfere with the efficiency of the wearer and adequate protection for the particular hazard involved.

With the introduction of power slushers into the mines many finger and hand injuries involving infections occurred as a result of punctures received in handling the steel pull cables after they had become somewhat worn and frayed. (One manufacturer of first-aid supplies learned from a study of 74,000 injuries, that of 34,000 finger and hand injuries, 27.7 per cent became infected.) The introduction of leather gloves and mitts soon eliminated most of the finger and hand injuries in the mines. Besides miners, chutemen, pocketmen, scraper operators and other mine laborers who handle rough objects should be required to wear leather gloves or mitts to eliminate small lacerations, punctures, etc., which very often develop infections.

The type of glove or mitt is not so important except that no metal should be used in gloves used around electrical apparatus and in the case of cutters, welders and babbitt men, the gloves should be long enough to allow the sleeve or coat or jumper to fall over the glove to keep hot metal from running down inside the glove to the hand. In no case should any gloves be worn around machinery where there is a possibility of them being caught in the moving parts of that machinery. Certain kinds of electrical work demand a rubber glove specially constructed, which is usually worn with an over-glove of leather. Pads or hand protectors should also be used where excessive abrasion of hands and fingers might occur in handling stone, brick or other very rough articles.

In the past many eyes have been lost in the mining industry because of the failure to provide or the failure to wear protective eye equipment. Around the mine where there is the slightest possibility that an eye accident might occur goggles, shields or masks should be worn to afford complete eye protection. The attempt to compile statistics covering the number of eyes saved or probably saved due to the use of goggles in the Lake Superior District would entail considerable time and would comprise a lengthy paper on that subject alone. It is to be hoped that the results of the various operators may at some future time be incorporated into such a paper to be presented to the Institute. Our experience shows seven cases where super-armorplate lens goggles have been shattered by rock particles in sledging either manually or by power and that the goggles worn in these cases have unquestionably saved an eye. Numerous other instances of wire cloth goggles being crushed back toward the eye also indicate that eyes have been saved from total or partial loss of vision due to the use of protective eye equipment.

It is not always easy to determine just when goggles should be worn and we recall one instance in which an eye injury occurred in a peculiar way when to all purposes it was not necessary that goggles be worn. A miner was walking along a well covered (timbered) drift, when he stubbed his toe against a sliver of lagging which was completely covered with a thin layer of ore in such a manner as to cause the chip to flip dirt in his eye, with a resulting 28 days disability. In this case there was no evidence of bad housekeeping, as there was not a chip or sliver of timber visible on the floor and as there was no extreme circulation of air in this area, it was not deemed necessary to wear goggles while traveling in this particular area although goggles would have saved the disability. However, the line is quite clearly defined in most instances when and for what occasions it is necessary to wear goggles. In all cases a thorough study of the eye hazards for any particular task should be made and the policy to wear or not to wear should be determined from that study.

Breaking chunks either manually or by machines, starting holes in drilling operations, chipping, calking and some riveting demand a heavy framed goggle with an extra strong lens as the hazards encountered here are from the comparatively large and heavy particles which might fly to the eye. In some instances, such as when cutting rivets, it may be that in addition to the goggles a helmet of strong heavy wire with small mesh, somewhat on the order of a catcher's mask, might be necessary to keep the flying rivets away from the face.

There are other tasks in and around our mines where the hazard is from smaller particles down to dust, examples of which are scaling, grinding, certain wood working operations, locomotive driving, blacksmithing,

drill-sharpening, picking and at times working with an axe. In these instances goggles of a lighter type may be used.

Processes where protection from splashing metal are required are babbitting, pouring lead joints in cast iron pipe, casting of metal and dipping in metal. If when handling molten metal it comes into contact with moisture, a splash results which endangers not only the eyes, but the whole body, so that for the above mentioned processes a suitable face mask and other equipment is necessary. The mask should be lined with asbestos and the glass shield is preferable to the ware one for eye covering.

For certain kinds of spray painting and in processes such as drying sand, respirators should be used to protect against particles of foreign material entering the lungs by way of the nose or mouth.

When doing electrical or arc welding the powerful light, which is given off, is very injurious to the sensitive nerves of the eyes and in these processes it is necessary to secure a large reduction of the radiant energy before allowing the eye to behold it. There are different types of helmets equipped with varying shades of glass to care for different intensities of light. In most cases as the work calls for special training the information concerning proper eye protection is cared for in that training. Safe Practices Pamphlet No. 23 of the National Safety Council on Gas and Welding contains information on this feature of eye protection.

Burner men and small oxy-acetylene outfit operators are subjected to excessive brightness of light which can be reduced by the use of certain types of goggles. This holds true for firemen who are required to frequently examine intense fires in boilers. Another field where much pioneering has already been done by a certain operator in. this district is that phase of the safety program which covers corrective vision. We wash to quote here in part from a paper read to the Lake Superior Section of the National Safety Council at the Duluth meeting in. June of this year by Mr. B. D. Shove, Safety Engineer of the Oliver Iron Mining Company:

> "A physical examination of your employees will reveal many startling defects. This has led one mining company to insist that every man whose loss of vision is over 25 per cent wear corrective goggles while at work. * * * Think of a man working in or around a mine whose eyes have a rating of 20/200, as determined by the Sellens standard chart. This man sees at 20 feet what he should see at 200 feet. According to all standards he is industrially blind. * * * Think of a man running a double drum tugger who cannot see the breast 50 feet away. Every company has a few men working whose eyesight is such that he is a decided accident liability and I believe an investigation along this line would startle you. Would it not be a step in the right direction to bring the vision of these men up to normal by providing corrective goggles and making sure that they are worn while at work?"

We feel that this company in enforcing the use of corrective safety goggles is to be congratulated for being the first to start this practice and that it has approached the ideal method in putting a protective wearing apparel program across to the men. There are no figures available to show just what per cent of mine employees have faulty vision, but the figures must be large, and when goggles are insisted upon where they serve a dual purpose, eye protection plus corrective vision, that fact alone has a tremendous psychological effect on the men in putting the program across. As pointed out by Mr. Shove the dangers connected with faulty vision are enormous and it is to be hoped that more operators will add this feature of corrective vision to their safety programs.

Another newcomer in the field of protective apparel in comparatively recent years, which has been through considerable experimentation in the variable and trying conditions in our mines, is the hard-toed shoe or boot in rubber or leather.

We have observed a wide variation in the percentages of feet and toe accidents to the total number of accidents in our mines from year to year, the variation running from 3 to over 40 per cent. Unlike finger and hand injuries the percentage of infections for toe and feet injuries is very small, possibly 4 to 8 per cent. It appears, however, that the old saying "He who injures his feet or leg is a beggar, while he who injures his hand or arm is a gentleman," is true and reflected in the disability which ensues from feet and toe injuries. The variation in the per cent of disability due to feet and toe injuries of the whole disability because of accidents we have found to range from 10 to nearly 70 per cent. In most cases then probably because of the feet and toe working more as a unit than do the hand and fingers, we find similar injuries to toes and fingers will cause considerably more disability to the former, hence it becomes more evident that good protective footwear is practical and efficient.

Probably the greatest problem the manufacturer has today in supplying good, comfortable, safe and economical shoes or boots is that of properly fitting those in the industry who have unusual feet. Much attention has been given to this problem, as also to the problem of supplying a shoe or boot that will stand up under the wet conditions in most of our mines. In the case of hard-toed shoes and boots we feel that a good deal of the experimental work is behind us and that further development will consist chiefly of minor improvements.

There is, however, an urgent need for a device which can be worn without interfering with a man's efficiency and comfort and which at the same time will protect his instep and ankle from rolling or falling objects in our mines. Injuries to the instep and ankle are more serious than toe injuries and while they are not as frequent, when seeking protective equipment, the ankle and instep

should not be overlooked. Glass, hot metal, and tin plate workers use a sort of spat of different materials depending on the hazard involved to protect instep and ankles and grizzlymen or others working at the bottom of vertical or inclined faces of chunky material in mines could be equipped with a device adapted to meet the kind of hazard encountered there.

Many of the older men in the Lake Superior District remember the old Michigan resin hat or cap which probably was designed to improve the hard stiff felt hats used for head protection in the Baden District in Germany many years ago. These hats were a step in the right direction and undoubtedly saved many an injury and possibly some lives, but they were very crude when compared to the modern hard hat, which is functioning very well in many of the mines in the Lake Superior District today. We are convinced that in at least two instances the hard hat has saved men in our mines from skull fractures and we have as a matter of record several instances where the hard hat has prevented what might have been serious head injuries. As falls of .material or objects are the greatest single item in the cause of accidents in our metal mines, it is important that to reduce the number of head accidents and the disability due to them, any safety program must include the hard hat.

A check up of accidents in our mines over a period of years will show/ that many serious injuries could have been prevented through the use of a safety belt. Quite often in the past when it was deemed necessary to offer some sort of protection for slipping or falling hazards, a plain rope or sling was used. When the slip or fall occurred with this type of protective device the usual result was a broken rib or ribs. There are several types of belts in the market today which are so constructed so as not to injure the body in case the slip or fall does occur. To conform to safe practice the component parts of a safety belt should be constructed of the very best of materials and as in the case of all protective apparel, the belt should allow freedom of movement to the wearer. It can also readily be seen that equipment of this type demands frequent and rigid inspection both as to belt and fastenings.

That phase of protective equipment in the mines of this district dealing with rescue apparatus has been very thoroughly covered in several papers presented to the Institute in recent years. The men who have written these papers are experts in the field of rescue apparatus and we merely wish to add to what they had to say about the, importance of this apparatus in our mines. When we learn that metal mines fires are fifth in order of causes for fatalities in the United States, we can see just how important it is to have our underground mines fully equipped with rescue apparatus. We are repeating what has been said by previous writers on this subject when we say that rescue apparatus should be of an approved type, kept in repair, and ready for emergency use at all times. Physically fit trained crews maintained to put this apparatus on in order to go safely underground to fight a fire where there is a deficiency of oxygen are also necessary.

In closing we wash to state that we have not been specific regarding when and where certain types of protective equipment should be used because hazards surrounding certain classes of work vary greatly from mine to mine. In all cases, however, of determining upon a policy of protective equipment when it is learned that a definite hazard exists even though no accidents have occurred, the fact that they could occur should determine the policy of protecting with the equipment for the particular hazard involved. After the rule is laid down for protective equipment the way for its introduction to the men should be paved by an educational program showing the benefits to be derived from that particular piece of equipment. Considerable of the protective equipment in our mines today is in the compulsory stage and for some men it will always be in that stage, but education will bring this element to a minimum.

Employees can be educated to work safely through many channels such as by example, through rules, bulletins, movies, general safety meetings, serving on safety committees, etc. Philosophers tells us that man endowed with a free will walls to do good. Even though he errs, man in the act of committing that error sees some apparent good in it and it is this apparent good which appeals to him. Take the sad case of suicide and we find illusion and sentiment making up the apparent good that appeals to the one who commits this error. The illusion is that suicide ends all while the sentiment is the desire to shake off the worries of this earth, and be at ease. For most of us having been given life, man's first yearning is to preserve that life. Of all of man's treasures it is life which he surrenders last, casting from him joys, wealth, power, ambition and honor to hold on to that precious thing called life. Instinctively man will put out his hand before him as he enters a dark room thus showing that he is willing to sacrifice pan of his body rather than lose the vibrating whole, his life. If then man wills good and yearns for life and in the course of his labors does not possess the truth and education necessary to carry on without accident as Mr. Channing pointed out, it is our duty "to continually exert our influence for right" and it becomes a moral duty to see that this education is given to him.

Following the educational program we must have careful, competent supervision and just discipline with reference to protective wearing apparel and equipment, if we are to fulfill our duty in the matter of eliminating accidents. The use of protective equipment is growing by leaps and bounds and it is to be hoped that more operators in the Lake Superior District will take an active part in the development of present and future protective wearing apparel and equipment.

THE DEVELOPMENT OF THE ROCK DRILL AND ITS RELATION TO THE LAKE SUPERIOR MINING DISTRICT.

BY E. L. HAWES, DULUTH, MINN.*

Being human beings, we are inclined to accept the existing order of things as they are without remembering the many trials and failures preceding the eventual success of some certain line of endeavor. We have only to read the following brief history of the development of the rock drill from its inception to the present time to realize what a great debt we owe the pioneers in this industry, as well as the present manufacturers of rock drills, for the remarkable advance made during the last twenty years. Think of trying to drive a drift in hard rock using the hammer and drill. It is inconceivable, and still we are apt to consider rock drills as necessary evils and not as an indispensable cog in the great machine of progress.

The modern rock drill as it is found operating in your mines today has been a gradual development. In the variety of models and types in which it appears we can trace the ideas of many ingenious designers, as well as the influence of some particular mining district or engineering project. Oftentimes some special requirement led to the development of a particular machine which has since become standard for certain conditions the world over.

The first borer was designed by J. M. and John A. Singer, one of them the inventor of the Singer Sewing Machine, who in 1838 experimented with a drop drill on the Illinois and Michigan Canal about thirty miles below Chicago. A dozen machines of this type were used there and later some were used during the enlargement of the Erie Canal at Lockport. These were simply drop drills, restricted to vertical holes and striking the blow through gravity alone.

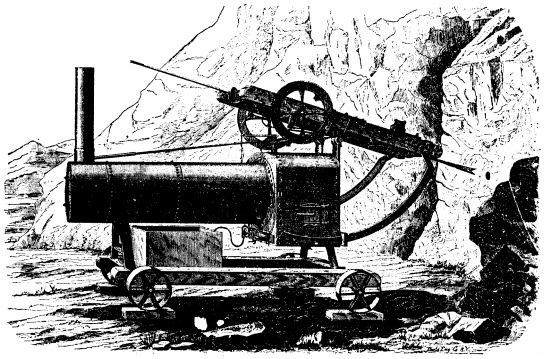
In 1854 Mr. Nasymith, an Englishman who was the inventor of the steam hammer, built a drill that operated on the same principle. Steam was used on one side of the piston only and there was no provision for rotating the drill.

The first European rock drill was patented in France in 1851 and was known as Cave's rock drill and was worked by compressed air. However, as the drill was reversed as well as rotated by hand, no motion was automatic and the drill was slow of action and a failure from a practical point of view.

*Engineer, Ingersoll-Rand Company.

The first practical percussion drill ever made was invented by J. J. Couch of Philadelphia in 1849. It consisted of a boiler mounted on four wheels, on the top of which was a wooden frame carrying the drill. The steel carrying the bit was thrown or disengaged from the frame, acting by momentum alone against the rock. There was an arrangement for rotating the drill by a ratchet wheel. While the drill was used only experimentally, it was the first instance of the use of a percussion type of rock drill, where the blow was struck independently of gravity and where the valve of the drilling engine worked automatically.

J. W. Fowle, who was assistant to Mr. Couch in the building of this drill, conceived the idea that the correct principle in rock-drill construction was to impel the drill by the direct action of steam or air on the piston and not by means of an auxiliary engine. He abandoned the Couch idea of throwing the drill like a lance. Fowle attached the drilling tool directly to the crosshead of the engine and provided a ratchet and pawl method of rotating the wheel. This was the most important invention in rock drill design up to that time and the Fowle type of drill was adopted by the Italian and French Governments for the construction of the Mount Cenis Tunnel through the Alps.



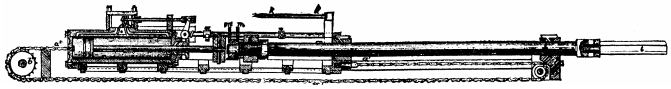
THE COUCH ROCK DRILL—THE FIRST POWER ROCK DRILL

Authentic records of the performance of the drills on this project appear to be conflicting. But in 1874 Mr. E. Gybbon Spilsbury of New York City writing for the American Institute of Mining Engineers says, "In the Mount Cenis Tunnel in 1864 it required 70 of these drills to keep 8 at work and necessitated a staff of 25 men in the repair shops, while in 1867 they required 200 machines to keep 16 constantly at work.

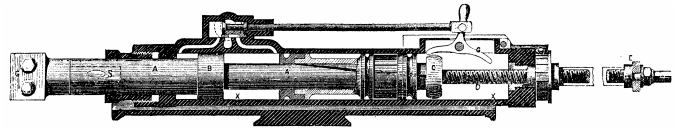
In 1866 during the construction of the Hoosac Tunnel in Massachusetts, Brooks, Gates and Burleigh built a drill of the Couch type, modified by attaching the drill to the piston, thus following the Fowle improvement. About forty of these machines were used in this tunnel. They weighed 240 pounds each and struck about 200 blows per minute. They were found to be too expensive on account of breakages and were abandoned, being superseded by what became known as the Burleigh Drill which was used throughout the construction of the tunnel. In constructing his machine, Burleigh dispensed with the cross-head and intermediate drill bar, attached the steel directly to the piston rod and rotated the steel by rotating the piston.

Regarding this, Spilsbury says, "In this country, at the Hoosac Tunnel where the Burleigh Drill was used, experience showed that the average life of each machine without repairs did not exceed 50 hours and that it required four machines to keep one at work. Almost every new drill that is invented shows great

improvement in this regard. Thus at Ausable Forks, N. Y., where the Ingersoll Rand Drill is being used, it is found that three machines will keep one at work, and at the Bethlehem Tunnel (New Jersey) on the Easton and Amboy Railway where the same drills are used, the average has been lowered to two to one."



FOWLE'S FIRST ROCK DRILL—CAVEAT FILED MAY 9, 1849



THE BURLEIGH DRILL

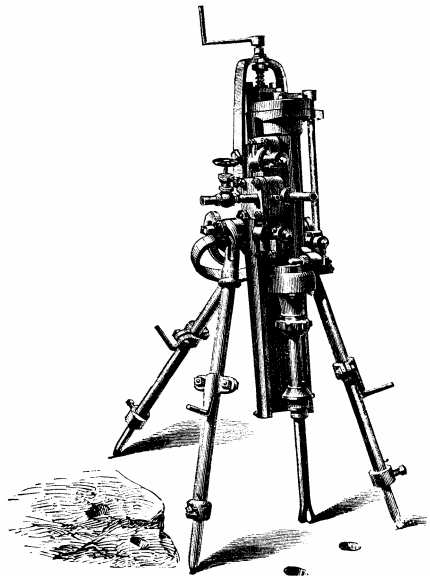
All the drills referred to in the foregoing were designed for mining or tunneling and were generally mounted on carriages. Simon Ingersoll was the first to develop the tripod form of mounting, using weights to hold the tripod down. Ingersoll's drill, constructed about 1871, was built fundamentally on the Fowle-Burleigh patents, which it became necessary to purchase, and the Ingersoll Rock Drill Company was then organized. About this time still other similar drills such as the Wood, Halsey, Sargent, Waring and Githens made their appearance. Man's primitive hand methods of rock drilling faded rapidly, giving way to the reciprocating piston type drill, which comprised a cylinder carrying a piston with a projecting end to which the drill steel was rigidly fastened.

The Michigan or Wood Drill was considered an infringement on the Burleigh and was not used in the Hoosac Tunnel. The Ingersoll drill was first employed to any extent in the Musconetcong Tunnel of the Lehigh Valley Railway.

Henry S. Dunke, E. M., of Philadelphia, writing in the Transactions in 1875, states, "Rock was encountered in the heading in May 1874. Four Burleigh Compressors were used, each to run nine drills. The art of manufacture of rock drills has progressed to such a point that the drills adopted were found to run for months with little ore no repairs necessary, and what repairs were needed were generally more in consequence of wear than breakage, the parts giving out first being usually the feed pawls and ratchets."

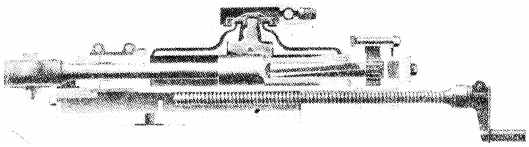
About 1875 the Rand Little Giant Drill with a tappet valve action controlled by the motion of the piston was developed by A. C. Rand and George Githens. With this machine, side rods first made their appearance. These drills were very popular in the Lake Superior District until they were largely replaced by the Sargent Auxiliary Valve Drill which was invented in 1884. The release rotation was also a feature of this particular machine.

Thus we see that during this period many details were conceived which are still being used by the present-day designers of rock drills. From that date we find that many new drills of this type were introduced to the mining fraternity. Sullivan, Rand, Wood, Sargent, Ingersoll, Chicago, McKiernan-Terry and others were used in the various mining districts. These machines varied in weight from about no pounds to as much as 900 pounds, each having certain features that appealed to their respective operators.

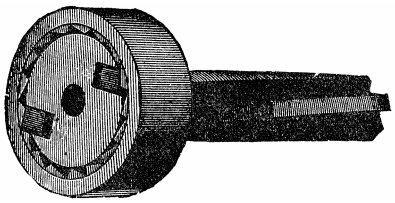


THE INGERSOLL DRILL

During this period, from the time of the invention of the first rock drill until the hammer drill came into prominence about 1910, the Lake Superior Iron and Copper Districts were being opened up. Before drill machines were in general use, even the larger mines drilled their ground with the hand hammer and drill. In the old workings of many of the mines of the Copper Country, the small short holes may be seen in the sides of the drifts, and sometimes even a hole unblasted in the breast.



CROSS SECTION OF THE RAND LITTLE GIANT

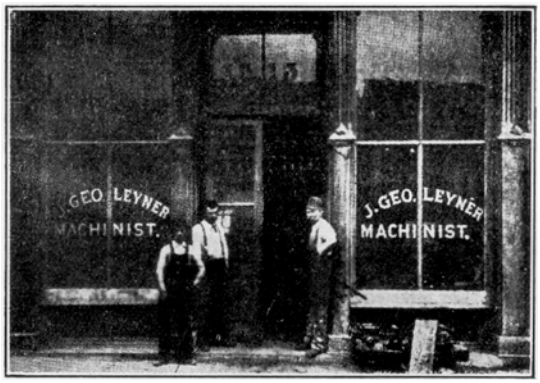


SARGENT RELEASE ROTATION

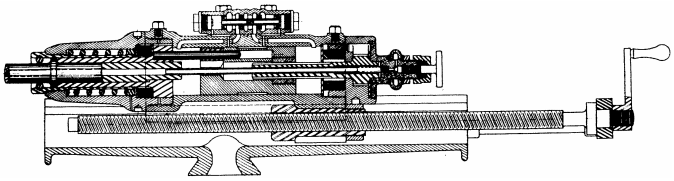
As time went on and drill machines became the topic of conversation in mining camps all over the country, the larger mines installed air compressors, ponderous, slow speed, steam driven machines, and put a few heavy rock drills to work. The hammer and drill was still used in the smaller mines, or for cutting hitches, drilling pop holes, or raising in the larger ones. As the art of

manufacturing rock drills progressed, they came into more general use, until by about 1900 most hard rock mines had installed air compressors and were using the piston type machines. The soft ore mines of the Michigan and Minnesota Iron Ranges depended on the hand auger and the pop bar or jumper, occasionally using the hammer and drill if a hard seam of ore or rock was encountered.

In the meantime, about 1894 J. George Leyner opened up a shop in the City of Denver for the repair of mining machinery. This led him into numerous experiments with the power rock drill, finally culminating in the invention of the first hammer drill about 1897. In this type the piston moves freely in the cylinder and strikes upon the drill steel instead of being attached to it as in the reciprocating type of machine, a direct reversion to the principle involved in the primitive method of single jack and steel. In the invention and development of the hammer drill George Leyner accomplished the introduction of water and air through hollow drill steel for cleaning the hole, automatic lubrication, enclosed in the machine throttle control, and mechanical-rifle-bar-rotating-drill-steel chuck, in fact all the hammer drills of the present day, irrespective of maker, have borrowed their most important features from the Leyner Hammer Drill.



J. George Leyner's First Machine Shop in the Old Business Section of Denver. Mr. Leyner is the Center Figure in the Doorway. This Photograph Was Made in the Early Nineties.



Leyner Drill—The First Hammer Drill With the Water Feature

During 1906, Mr. C. H. Shaw of the Shaw Pneumatic Tool Company also of Denver, showed his inventive genius by creating the Stoper Drill, which depended for its success upon an air feed attachment to a drill cylinder. This was followed rapidly by the Waugh Slugger, also an air feed type of machine, the Crown Air Feed Drill, the Hardscog Wonder, the Sullivan, Chicago, Cleveland, and the Leyner Stoper.

These stopers of various types and makes were really the first hammer drills to be introduced into the Lake Superior District. They were used principally in raising, and as a mine only boasted of one or two of these machines, they were carried from place to place as need arose.

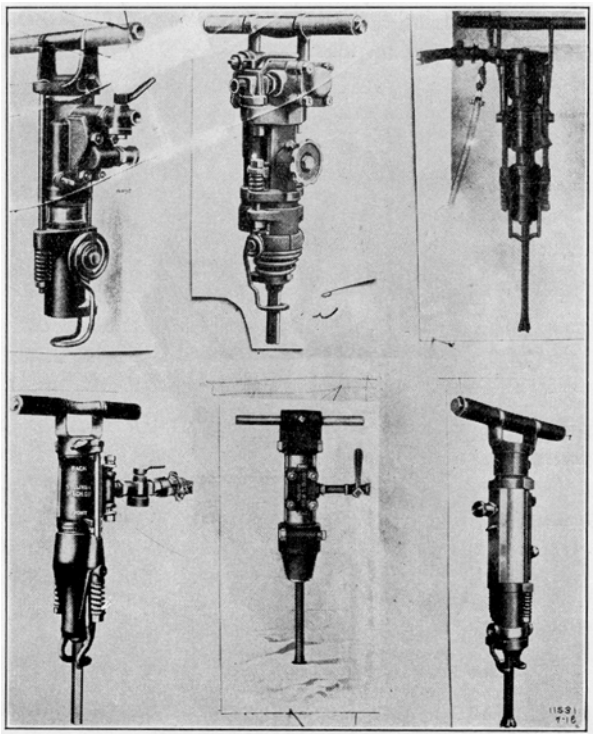
The majority of the early hand hammer drills (excepting plug drills) were largely patterned after the air feed stoper, the air feed being replaced by a handle. In fact, the manufacturers of the early stoper advertised the interchangeability of handle and air feed as a great asset. This early practice of interchangeability was, however, soon abandoned, for while good in theory, it proved impractical, and the Little Jap Drill, the Sullivan Hand Hammer Drill, the Hardscog Little Wonder, the Cleveland and the Leyner Brownie soon put in an appearance.

The First Self-Rotating Hand Hammer Drill

In the year 1909 Mr. Leyner conducted experiments with a Leyner drill cylinder removed from its shell. He placed a T handle at the back and additional handles half way down the cylinder and built several of these machines, more particularly for shaft sinking. Shortly after this, the Ingersoll Rand Company obtained a license to manufacture and sell under the Leyner patents, and about 1911 the "Jackhamer," the first self-rotating hand hammer drill employing the Leyner rifle bar and sleeve chuck rotation, was placed on the market. It proved such a success that other manufacturers brought out modified designs.

During this period many mining men of the Iron Country were giving a great deal of thought to improving the methods of drilling in the soft ore mines. Some mines were using the light piston drills, weighing about no pounds. These had to be mounted on a post or bar and at best were slow in drilling speed, even in the softer ground. Other mines used the hand augers and pop bars or jumpers. Various suggestions were made and experiments tried, to improve on this practice. A coal

puncher was tried out in one mine. The idea was to undercut the breast clean out the broken ore and lay down steel sheets for sollars to make easier shoveling. This proved to be a tedious job. It was hard to scrape out the ore from the undercutting and even after this was done the face had to be drilled with the hand auger to get holes for blasting. So this scheme proved impractical.

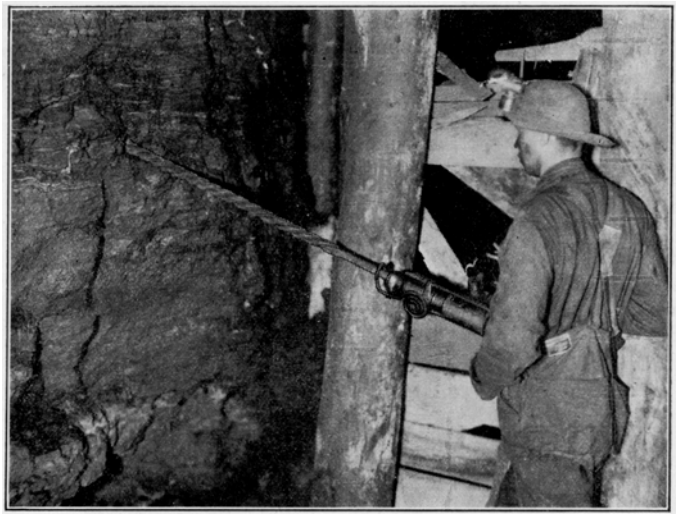


Another experiment was also tried. A regular pneumatic drill, such as is used in machine shops, was rigged up and fitted with auger steel. This furnished the rotative power while a common riveting hammer was used to pound the end of the feed screw, to make the auger bite the ground. This also proved cumbersome and impractical although we know they were on the right road.

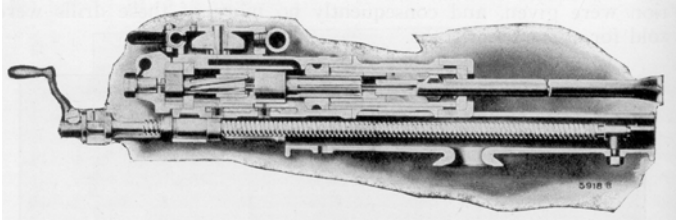
Early in 191.2 the "Jackhamer" was first introduced in the Lake Superior mines. This was the first machine of its type and used hollow hexagon steel. It was enthusiastically received by the mining fraternity and some eighty machines were purchased by the various mines that year. Then came the usual kick back. Immediately one hundred and one objections were raised by men of every rank as to why the "Jackhamer' could not be used. Miners complained it was hard to hold and this objection was overcome by putting a bushing in the intake with a 3/16-inch diameter hole in it to take away the kick. Other reasons too numerous to mention were given, and consequently no more of these drills were sold for about ten months.

During this period the manufacturers had not been idle and brought out an experimental drill called the "Jackhamer" Auger. The piston diameter of this drill was greater and the stroke shorter than the standard drill, giving greater torque and a little lighter blow.

Demonstrations were carried on in all mines and during 1913 the mining companies of the district purchased about 190 of these machines, an indication that the "Jackhamer" Auger Drill had arrived. This machine was developed entirely for use in the soft ore mines and so we see the influence of one mining district on the development of a rock drill.



The first hundred machines were built in the special production department of the manufacturer. In this much tedious labor was involved, as entire interchangeability had to be assured. It was necessary to be absolutely sure the machine was a success before going to the great expense of making dies, jigs and fixtures used when a drill is put into quantity production.

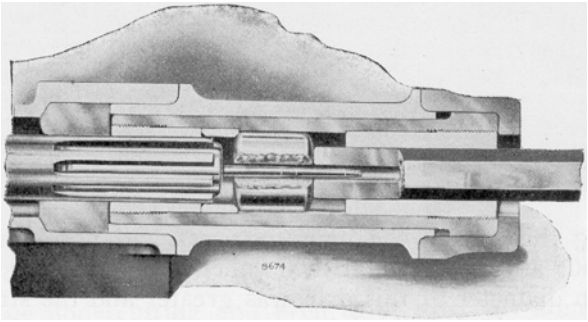


The original auger was an upstroke machine; that is, it rotated on the up stroke of the piston. Later in 1917 it was changed to a down stroke machine, giving a much stronger rotation and lessening the force of the blow. Still later the number of pawls was increased and other minor changes made, always with the idea of bettering its performance.

While this development was going on in the hand held type of machines, progress was also being made in the mounted or Leyner type of drills. In the Copper Country where the greatest number of heavy drifters were used, the Water Leyner was first introduced in 1912. Even with the great difficulties attending such a radical change in design and construction over the old piston drills, a machine was perfected that swept through the district like magic. The advantages to be gained by its use were so marked that mine managers were keen to equip their properties with this wonderful new drill.

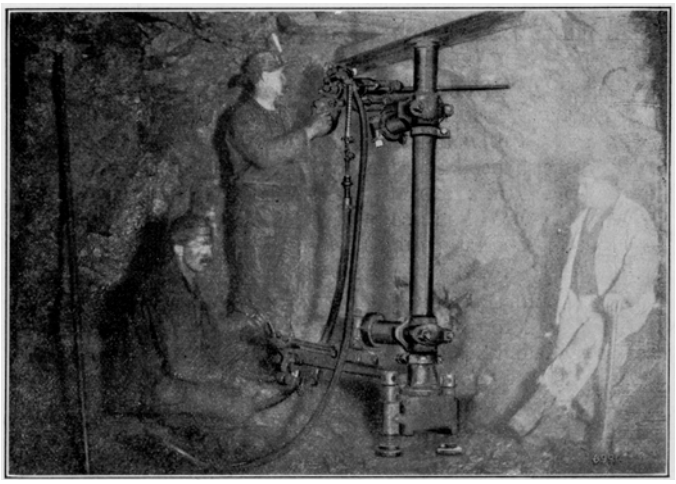
Here we find the influence of the Copper Country on the design of a Rock Drill. In other districts standard

machines use what is known as the Leyner Lug Shank on round steel, the lugs serving to lock the steel against rotation in the chuck and assist in backing or pulling the steel out of the hole. With this type of chuck the piston hits the steel directly on the end of the shank.



THE SPECIAL ANVIL BLOCK CHUCK FOR NO. 18 LEYNER-INGERSOLL DRILLS

For use in the Copper Country where the ground is uniform and not so inclined to be fitchery and hamper the withdrawal of the steel from the hole, an anvil block chuck was developed. Hollow Hexagon or quarter octagon sections of steel are used with a straight shank without lugs. A chuck was constructed using a small block of steel or anvil block, floating as it were in the center of the chuck, between the piston and the steel. The piston hits the anvil-block which in turn hits the steel. This lowers the drilling speed somewhat, but has the advantage of a perfect face for the piston to strike and a straight shank without lugs which is easily kept in condition.

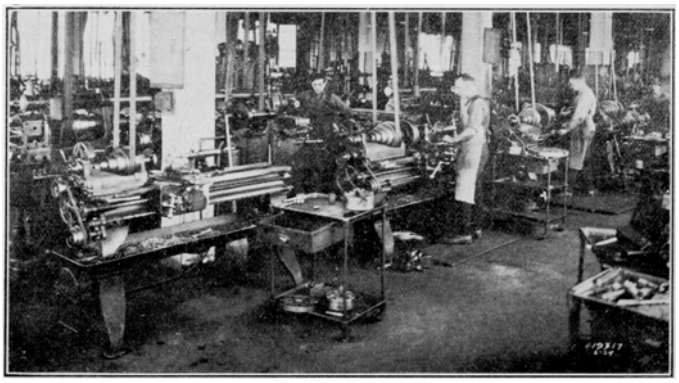


TWO LEYNER-INGEKSOLL DRILLS ON THE FIFTEENTH LEVEL, SOUTH NO. 4 SHAFT, WINONA MINE, WINONA, MICHIGAN

One very interesting point in connection with the production of a successful drill at this period was the part science had in its perfection. George Leyner conceived and constructed a drill whose performance eclipsed anything heretofore dreamed of, and still his drills were a rank failure from a practical viewpoint, as it was impossible to get them to stand up and stay on the job. After its manufacture had been taken over by a company with large resources and much talent at its command, practically the same drill made of selected materials, properly heat treated, was an unqualified success. This is a lasting tribute to science in comparison with "rule of thumb methods."

From the time the Hammer Drills of all types were first constructed on a manufacturing basis, there has been a constant demand made on the manufacturer to increase the drilling speed of each machine and still keep the weight within a certain well defined limit. Each designer strives to perfect a drill that can be produced on a manufacturing basis and will be lighter in weight. superior in drilling speed and have a lower upkeep cost.

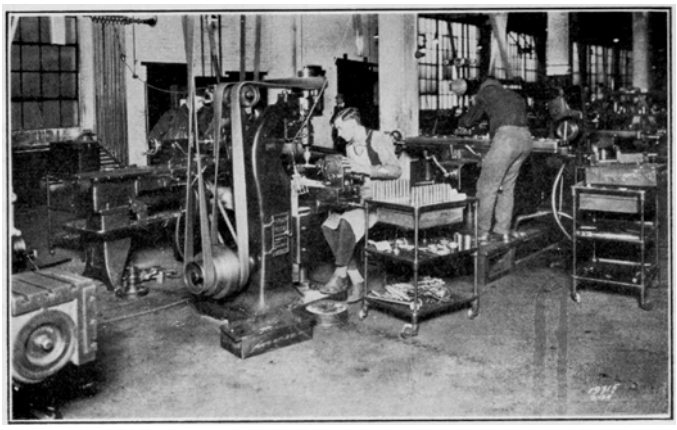
To accomplish this end the manufacturer must build his organization. We will assume that the field men have found a demand for a rock drill of a certain weight and drilling speed. This is reported to the proper officials who take it up with the designing department. A round table discussion is held and the needs outlined and various possibilities suggested. One of these very able men who has had years of experience in this work is delegated to make a trip into the territory and get first hand information on the requirements.



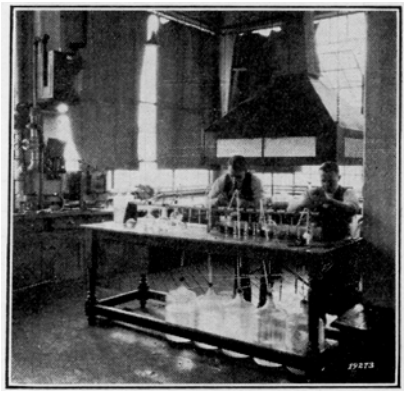
Having gathered all the data possible which might have a bearing on the design and construction, the designer returns to his desk and begins the very tedious process of creating on paper a suitable machine. He probably has certain fundamental ideas in mind and starting with these as a basis and correlating them with the wide fund of information about experiments that have been tried previously, he eventually hands the Experimental Department the drawings of a machine that he thinks will do the work required.

In this department the new drill is made out of solid metal. All parts have to be machined, heat-treated and

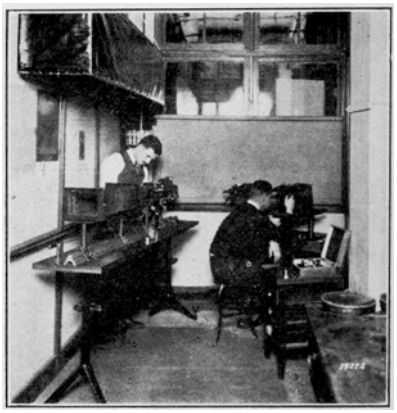
ground to fit to a nicety. The parts are then assembled and the drill sent to the testing department for a trial run. Afore often than not certain changes have to be made that entail more machine work, and further trials. Sometimes the machine does not come up to expectations and radical changes have to be made. Eventually in a year or so after the designer first started his work, a drill is sent into the territory for a trial at the various properties. Here it is watched very closely by the representatives of the company. Trials are run against existing tools, and if its performance under working conditions is such as to warrant it, the drill goes back to the factory with a favorable report. Perhaps minor changes have to be made to more nearly fit the needs of the operators, until finally the perfected drill is sent to the special production department where perhaps 25 or 50 are made by hand. These machines are then sent out into the various territories all over the country and tried out under all sorts of conditions to finally determine if as a standard machine it may be put in production.



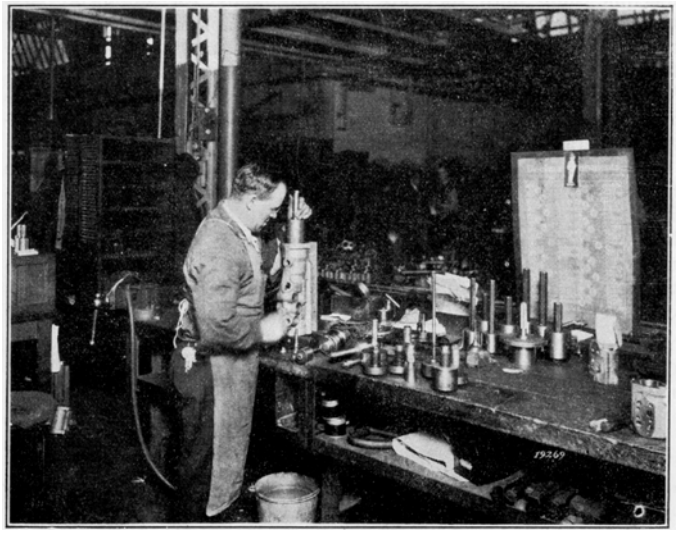
By this we mean that many thousands of dollars must be spent to make dies for the forging hammers and jigs and fixtures for the automatic machines which will insure absolute duplication of parts. This work is done by tool room men skilled in particular jobs of this kind. Much of the success that follows depends on the extreme nicety exercised, and the ingenuity shown in devising these numerous facilities.



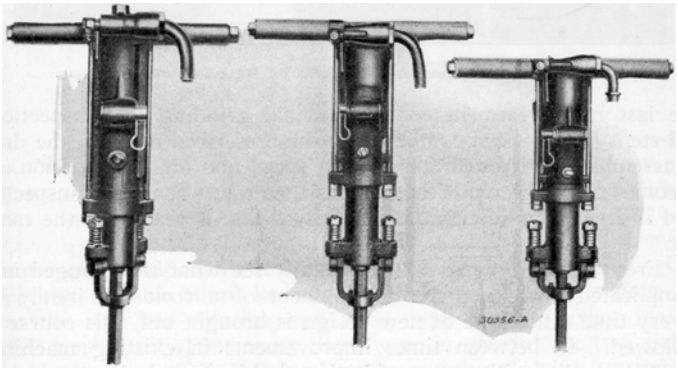
All Steels Are Given A Thorough Chemical Analysis to Make Sure They Are Up to I-R Specifications.



One Corner of the Metallurgical Testing Laboratory Where All Materials Going Into I-R Machines Are Carefully Tested.



Each Part of the Drill is Inspected After Each Operation. Limit Gauges Are Employed. They Assure Accurate Fit and Interchangeability of Parts



"Jackhamers" of Latest Design

The next step is to provide suitable material from which the various parts are to be made. Only special alloy steels are used which are purchased from reputable concerns. The drill manufacturer has inspectors in the various mills and their scrutiny is supplemented by exhaustive laboratory tests by the Metallurgical Department after the metal reaches the plant. Also they

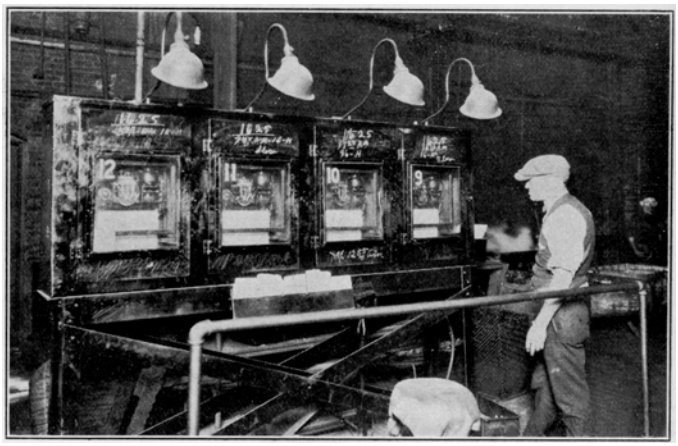
must be experimenting continually with new materials in an effort to improve the product.

As an example, the stock from which cylinders are made is a low carbon steel of special alloy which lends itself to the making of drop forgings and heat treatment which-imparts distinctive quality at points where hardness and added strength are required. The rough or original billet for a certain drifter cylinder weighs about 150 pounds. The finished cylinder, on the other hand, weighs 46 pounds, or in other words, 104 pounds of steel are scrapped in the making of it.

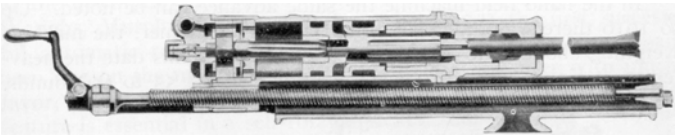
From the time half a hundred cylinder forgings enter the machine shop until they are finished, ready for shipment, is a matter of five or six months. This seems a long time, but there are no less than one hundred different operations from start to finish in the making of a cylinder.

In like manner, the billet of a piston weighs 15 pounds before being forged and 9 pounds when finished, requiring 45 separate operations in its manufacture.

Heat treatment between the various operations and before the final grinding plays an extremely important part in this work. This is carried out by the heat treating department of the plant. Oil heated furnaces controlled by both indicating and recording electric pyrometers, calibrated at frequent intervals, heat the parts to the required temperatures, after which they are quenched in baths of water, brine, or oil, according to the results required. After the last heat treatment comes the final grinding and inspection. All steps having been completed in the prescribed manner, the drill is assembled and tested for drilling speed and air consumption. If it comes up to the requirements it is then taken apart and inspected and if free from defects, is reassembled, and is ready for the market.



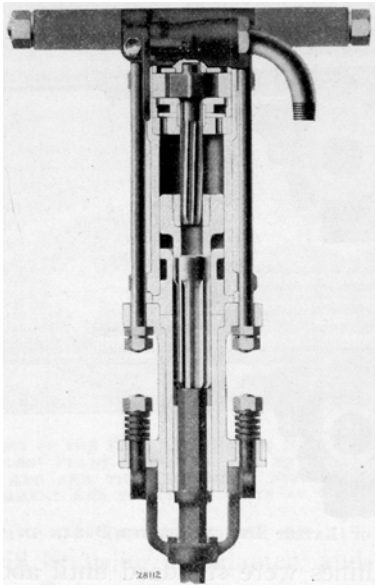
INDICATING AND RECORDING PYROMETERS ON HEAT-TREATING FURNACES



CROSS-SECTION OF MODERN HIGH SPEED DRIFTER

From the foregoing, we can readily see what a prolonged and complicated procedure the development of a rock drill really is. Every time a machine of new design is brought out, this course is followed. In between times improvements in existing machines must keep pace with any trouble that develops, and all patents and suggestions of the mechanically inclined all over the country must be patiently and thoroughly investigated.

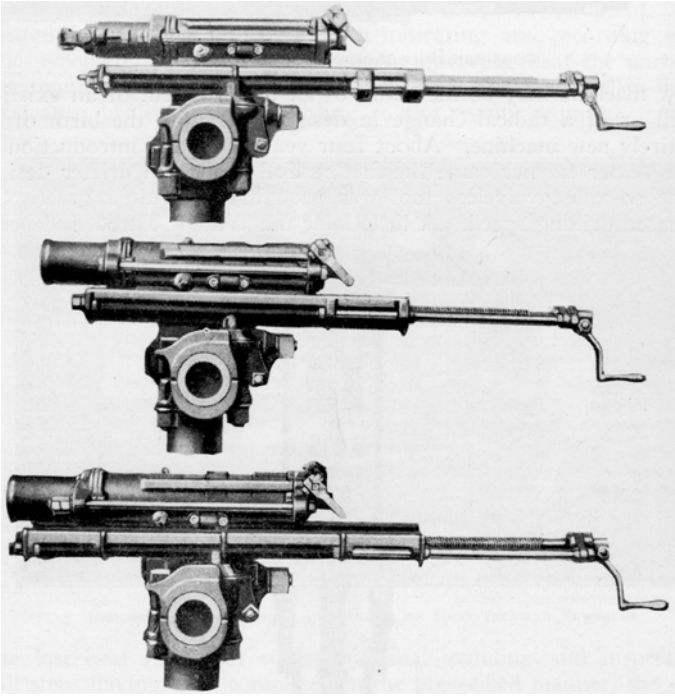
It has been in this manner that the present day high speed drills of all types have been developed, from the meager beginning in the George Leyner shop in Denver. In an individual case, the new machine may be the result of an improvement of an existing drill or of a radical change in design, presaging the birth of an entirely new machine. About four years after the introduction of the Water Leyner came the first radical change in drifter design. The so-called valveless tool was brought out with a greatly increased drilling speed. A little later the Waugh Turbo, independent motor rotation drifter, and Waugh-Hammer appeared. Competition became more keen and eventually the type swung back to the rifle bar rotation and valve type drill. During most of this time, until about 1922, there were in general use two sizes of drifters, the so-called Baby Leyner, weighing about 100 pounds, and the standard drifter, weighing about 150 to 160 pounds. In 1922 a still heavier drifter was developed, weighing about 200 pounds, for jobs where extra hard ground was encountered or where it was necessary to drill extra long holes. Since that time the three types have been standard.



CROSS-SECTION OF MODERN HIGH SPEED "JACKHAMER"

In the hand held machine the same advance can be noted. Up to 1916 there was practically one type of Jackhamer, the machine weighing about 42 to 45 pounds. Shortly after this date the heavier shaft sinker was introduced, weighing about 55 to 60 pounds, and these two machines were standard until about 1928 when the heavy sinker, weighing about 80 pounds, was made for some special conditions. This latter type was probably the direct result of some one taking a drifter off

the shell, equipping it with a handle, and using it for shaft sinking in very hard ground or for quarry work where deep holes were required. This was first tried out in 1909 by George Leyner and was really one of the first "Jackhamers."



THREE SIZES OF LATEST DESIGN DRIFTER DRILLS IN COMMON USE

PART OF THE EXHIBIT OF THE LAST 25 YEARS OF ROCK-DRILL DEVELOPMENT AT THE PHILLIPSBURG PLANT. THIS IS AN EXAMPLE OF THE RESTLESSNESS OF THE ART AND THE CONTINUAL EFFORT OF THE COMPANY TO ACHIEVE BETTERMENT AND TO KEEP ALWAYS AT THE FOREFRONT.

Although the Lake Superior District is not a stoper territory, still there are a sufficient number of this type to deserve mention. Stopers were really the first hammer drills in the district. Gradually the designs were changed to get increased drilling speed, all of the machines being hand rotated and called variously, stopers, Waughs, Murphys or wiggle-tails. About 1921 the first successful automatic rotation stoper put in its appearance. There had been one on the market in 1914 but this did not meet with much favor, probably because it did not have an air feed control. This feature is essential in a self-rotated stoper and its proper performance will determine whether or not the machine is a success.

About 1918 some of the mines put an air feed on the "Jackhamer" Auger Drill by using an adapter, and these Monkey-Stopers, as they were called, were very useful machines for raising in ore. Drill manufacturers, acknowledging the logic of such an arrangement, are now doing the same thing with their standard "Jackhamers" and augmenting the arrangement with an air feed control.

In conclusion, we want to bring out the fact that there has been steady progress during the first thirty years of this century in this industry so vital to the mining" companies. This has been possible only through the close co-operation between them and the drill manufacturers. Perhaps the best way to show this progress is to tabulate the different steps in design, giving the weights and drill speeds under uniform conditions, with comments on distinctive features, if any. It is a far cry from the hand auger to the present "Jackhamer" Auger and from the old piston machine weighing 300 pounds and striking 200 blows per minute with 60 pound air pressure to the super Leyner weighing 165 pounds and striking 1,800 to 2,000 blows per minute with 100 pounds air pressure and separate air motor feed.

This age is essentially one of progress, and who can say but that there will be as much progress in this direction in the next twenty years as there has been in the last?

APPENDIX.
Comparison of Various Types of Rock Drills With Relation to Their Performance.

Type	Date	Weight Pounds	Average Drilling Speed Inches Per Minute 80-Lb. Pressure	Remarks
DRIFTERS:				
Piston drill to	1912	250	3.0	Light drifters
Type No. 1	1913	99	5.0	
"	1925	100	10.0	
"	1929	117	16.2	
Type No. 2	1912	153	6.25	Independent rotation introduced.
"	1916	149	10.2	
"	1923	164	16.25	
"	1925	125	13.4	Medium weight drifters.
"	1928	144	20.3	
Type No. 3	1922	196	16.5	Independent rotation.
"	1922	207	14.5	Heavy drifters.
"	1925	205	18.0	
"	1928	214	20.5	Rifle bar rotation.
"	1929	179	23.5	Air motor feed.
"JACKHAMERS":				
Type No. 1	1912	43	2.0	Non-rotating plug drill.
Type No. 2	1911	47	4.2	Rifle bar rotation, wet or dry.
"	1912	47	4.2	
"	1923	43	5.6	
"	1925	42	7.9	Hand held or mounted.
"	1929	43	9.7	Also air blower type.

Type—	Date	Weight Pounds	Average Drilling Speed Inches Per Minute 80-Lb. Pressure	Remarks:
"JACKHAMERS":				
Type No. 3	1912	38	4.8	"Jackhamer" auger drills.
"	1917	38	3.2	
"	1922	38	3.2	
"	1925	42	5.7	
Type No. 4	1911	53	4.0	Non-rotating.
"	1916	56	6.5	Medium weight sinker, wet or dry.
"	1922	55	6.9	
"	1924	56	7.0	Hand held or mounted.
"	1928	57	11.5	Air blower type also.
Type No. 5	1916	73	6.8	Heavy sinker, wet or dry.
"	1928	72	12.8	Also air blower type.
STOPERS:				
Type No. 1	1910	65	4.0	Hand rotated.
"	1911	75	6.3	
"	1914	78	6.5	Dry.
"	1916	101	8.7	Wet.
"	1924	105	8.7	
"	1929	97½	..	
Type No. 2	1916	88	4.2	Rifle bar rotation.
"	1921	98	8.2	Ind. motor rotation } With air feed control.
"	1926	108	12.9	Rifle bar rotation } With air feed control.
"	1929	88	9.7	Jackstopers } With air feed control.
"	1929	95	11.5	

In writing the foregoing, the author made frequent reference to authoritative articles by Mr. W. L. Saunders, Charles Austin Hirschberg and Robert G. Skerrett, appearing in the Compressed Air Magazine, as well as numerous references to the Transactions of the American Institute of Mining Engineers.

AMYGDALOID TAILINGS.

BY R. N. ADAMS, HOUGHTON, MICH.*

In the Lake Superior District copper occurs in the native state and is mined from two formations, conglomerate and amygdaloid, whose ores produce two very different types of tailings. This paper deals with some experimentation on the retreatment of the amygdaloid sands, satisfactory methods of retreating the conglomerates having already been perfected.

The extraction of copper from the amygdaloid sands has been relatively difficult and expensive, because the copper content of these sands has been low in comparison with that of the conglomerates. This difference in content has been due to the difference in occurrence of the copper in the ores: in the conglomerates it exists in a finely divided state and can be liberated from the gangue by a 200-mesh grinding; in the amygdaloids it is usually much coarser, most of the metal being liberated by a 65-mesh grinding.

An understanding of both the amount and condition of the copper in the sands is necessary in a study of the specific problem; this understanding can best be obtained, perhaps, by reviewing the development of amygdaloid ore treatment.

The early process for the concentration of native copper consisted of breaking the rock in Cornish stamps, and of treating the stamped material on jigs; the products of the jigs were concentrates, hutch, and tail. The hutch was then further treated in a hand huddle and was separated into concentrates and tails. No attempt was made to treat any of the overflow or slimes. The copper in the tails was of two kinds, flake and included, and varied in size, larger particles being produced by the jig and smaller ones by the buddle, which, however, produced the richer tail. Very fine particles existed in the slimes, but these were not recovered. The total tonnage treated by mills equipped with Cornish stamps was comparatively small.

The Levitt and Ball steam stamps replaced the Cornish stamp, giving increased capacity but no increased recovery, and hutch clean-up jigs replaced the buddle, decreasing the copper content of the retreated hutch tails.

*Fellowship Student—Michigan College of Mining and Technology.

Slimes were first treated about 1895; they were thickened in small V-tanks, and the spigot product was concentrated on round tables. This process decreased the amount of fine free copper in the tails, although no copper smaller than 200-mesh was recovered.

About 1900, the Wilfley table replaced the round table, effecting higher recoveries and more economical operation. It made possible larger V-tanks, which in turn resulted in the treatment of a greater portion of the slimes and decreased still further the amount of fine free copper in the tails.

The Chili mills were next introduced to further regrind some of the middlings from the rough and the hutch clean-up jigs before they went to the Wilfley tables. This regrinding reduced still further the amount of copper contained in the coarse tails, although so much copper still remained in them that new and more satisfactory methods of regrinding were being studied. Such a method was found by the use of the ball mill.

The ball mill treated all the middlings from the jigs and the tails from the hutch clean-up jigs and consequently effected a still further decrease of copper in the tails. This process, with minor refinements in classification, jigging, and tabling, constituted amygdaloid ore mill practice through the district until 1928, when it was discovered that flotation, which had already been successfully applied to conglomerate ores, could be applied to the amygdaloids and the current slimes.

Flotation feed consists of Dorr Classifier overflow, in closed circuit with the ball mills, and of primary slimes, and produces a final tailing of one to two pounds of copper per ton.

The tailing piles, accumulated during the years before these present methods of concentration were introduced, contain so much copper that their re-treatment is advisable. Flotation is the obvious method; it has proved its success on the amygdaloid ores and is already in successful operation on conglomerate sands. However, unexpected problems are encountered which arise from the inaccurate determination of the present copper content of the amygdaloid sands, and from the oxidation of that copper, oxidized copper being difficult to float.

The copper content of a tailing pile computed from the assays of the tailings during operation is inaccurate for several reasons. First, samples for assaying were usually taken when the mill was operating normally, and no consideration was given to losses due to accident, shut-downs, and careless operation. Second, the action of the lake water has tended to carry off some of the slimes and some of the soluble copper during the years since the samples were taken and the sands dumped.

A better method of determining the present copper content of a tailing pile is to sample it in its present condition. Such sampling may be done by laying out the pile and by drilling it at regular intervals to its entire depth. Results obtained from such tests on a few amygdaloid tailing piles indicate a valuable copper content, the amount varying from live to 12 pounds per ton.

The problem arising from the oxidation of the copper in amygdaloid sands is a serious one, as has been found by operators who have attempted to reclaim the copper contained in old amygdaloid tailings. These operators have concluded that some alteration which affects flotation takes place in the mineral or gangue. Because copper is so readily oxidized, it seems probable that oxidation is the explanation. To verify this assumption, samples from old piles were taken and assayed for total copper and copper oxide. The results are tabulated in Table No. 1, and show that the extent of oxidation in the sands varies from 30 to 50 per cent, the term oxide including all copper compounds soluble in 5 per cent cold Sulphuric Acid solution.

TABLE NO. I.

Sample No.	Copper Oxide Per Cent	Total Copper Per Cent
1	0.168	0.296
2	.182	.384
3	.152	.325
4	.190	.387
5	.166	.367
6	.192	.452

Part of the specific problem, then, is how to treat oxidized copper to make it susceptible to flotation. Experiments were made with various flotation reagents on a sample containing about nine pounds of copper per ton. A screen analysis of this sample is shown in Table No. 2.

TABLE NO. II.

SCREEN ANALYSIS—AMYGDALOID SANDS.

Product	Weight Grams	Corrected Weight	Per Cent Total Weight	Per Cent Copper	Grams Copper	Per Cent Total Copper
+ 10	1026.4	1011.5	50.57	0.562	5.681	60.81
+ 20	507.3	500.2	25.01	0.394	1.97	21.1
+ 35	305.0	300.0	15.00	0.384	1.152	12.33
+ 48	51.6	50.6	2.53	0.332	0.167	1.77
+ 65	36.5	36.0	1.8	0.372	0.099	1.06
+ 80	16.7	16.3	0.82	0.246	0.04	0.43
+100	17.5	17.3	0.87	0.248	0.042	0.45
+150	15.2	15.0	0.75	0.232	0.034	0.36
+200	11.3	11.2	0.56	0.254	0.028	0.3
-200	42.5	41.7	2.09	0.314	0.130	1.39
	2030.0	2000.0	100.00		9.343	100.0
Head*	2030.0			0.467	9.34	
Head**	2000.0			0.460	9.20	

*By products.
**By assay.

The results of three representative tests are shown in Tables 3, 4 and 5. Table No. 3 shows the results obtained by the use of the Xanthate combination of reagents which is in use in present flotation practice in this district. This test gave a recovery of about 78 per cent. Table No. 4 shows the results from the 208 and Aerofloat combination of reagents which is also in use at present. This test gave a recovery of about 73 per cent. Table No. 5 shows the results obtained from the use of Sodium Sulphide in addition to the regular Xanthate combination of reagents. This test gave a recovery of about 84 per cent.

TABLE NO. III.

SAMPLE — Amygdaloid Sands.

PREPARATION — 2000 grams ground through 65 mesh with 50 per cent solids. Metallics discarded and assayed separately.

MACHINE — 2000-gram Fahrenwald.

REAGENTS — Sodium Carbonate 0.2 pounds per ton; Potassium Xanthate 0.2 pounds per ton; Yarmour Pine Oil 0.1 pounds per ton

FLOTATION CONDITIONS — Density 25 per cent Solids; Temperature Normal

Product	Weight Grams	Per Cent Total Weight	Per Cent Copper	Grams Copper	Total Per Cent Copper
Concentrates	31.0	1.57	16.0	4.96	54.3
Metallics	.....	.....	.....	2.21	24.2
Tailings	1962.0	98.43	0.1	1.96	21.5
Feed*	1993.0	100.0	0.47	9.13	.....
Feed**	2000.0	100.0	0.449	8.98	.....

*By products.
**By assay.

TABLE NO. IV.

SAMPLE — Amygdaloid Sands.

PREPARATION — 2000 grams ground through 65 mesh with 50 per cent solids. Metallics discarded and assayed separately.

MACHINE — 2000-gram Fahrenwald.

REAGENTS — Sodium Carbonate 0.29 pounds per ton; 208 0.022 pounds per ton; Aerofloat 0.127 pounds per ton; Yarmour Pine Oil 0.100 pounds per ton

FLOTATION CONDITIONS — Density 25 per cent Solids; Temperature Normal

Product	Weight Grams	Per Cent Total Weight	Per Cent Copper	Grams Copper	Per Cent Total Copper
Concentrates	25.9	1.32	17.0	4.40	48.0
Metallics	.....	.....	.....	2.30	25.1
Tailings	1970.0	98.68	0.125	2.46	26.9
Feed*	1995.9	100.0	0.459	9.16	100.0
Feed**	2000.0	100.0	0.455	9.10	.....

*By products.
**By assay.

TABLE NO. V.

SAMPLE — Amygdaloid Sands.

PREPARATION — 2000 grams ground through 65 mesh with 50 per cent solids. Metallics discarded and assayed separately.

MACHINE — 2000-gram Fahrenwald.

REAGENTS — Sodium Carbonate 0.2 pounds per ton; Potassium Xanthate 0.2 pounds per ton; Yarmour Pine Oil 0.1 pounds per ton; Sodium Sulphide 1.0 pounds per ton

FLOTATION CONDITIONS — Density 25 per cent Solids; Temperature Normal

Product	Weight Grams	Per Cent Total Weight	Per Cent Copper	Grams Copper	Per Cent Total Copper
Concentrates	30.2	1.51	18.0	5.44	59.2
Metallics	.....	.....	.....	2.26	24.7
Tailings	1964.0	98.49	0.075	1.47	16.1
Feed*	1994.2	100.0	0.459	9.17	100.0
Feed**	2000.0	100.0	0.458	9.13	.....

*By products.
**By assay.

These tests indicate that a recovery of from 70 to 85 per cent of the copper content may be expected when amygdaloid tailings are re-treated by flotation. Sodium

Sulphide aids in producing a higher recovery. It is thought that the recoveries obtained in these experiments warrant mill tests to determine the commercial possibility of such reclamation of amygdaloid sands.

SOME GASES ENCOUNTERED IN THE IRON MINES OF THE LAKE SUPERIOR REGION.

BY STEPHEN E. QUAYLE, IRON RIVER, MICH.*

It is not our intention of pretending to name and classify all the dangerous gases which might be met with in our mines, but to list what have been encountered and studied to some extent.

Each locality or range in the district may have fumes which might be thought of as foreign to some other range, but still the operations are so nearly alike and conditions so similar that what applies to one locality might apply to another. The sulphur fumes emanating from the decomposition of the pyritic slates of the Menominee Range however are peculiar to that district. Every mine has its own problem with ventilation, whether the movement of the air be natural or whether the mine is equipped with fans and blowers.

If we start with the most common poisonous gas encountered we think we should name carbon dioxide. Carbon dioxide is generated in mines by the breathing of the men, the decay of the timbers, the burning of open lights and blasting. When the carbon dioxide content of air reaches 3 to 4 per cent, man feels distressed and breathing becomes affected. When this content reaches 10 per cent severe headaches are felt, breathing is rapid, the heart throbs and stupefaction occurs. Carbon dioxide is approximately 1½ times as heavy as air and is often encountered in the bottoms of winzes. So-called "dead-air" probably contains considerable carbon, dioxide which should be in a higher percentage along the bottom of a drift than the top. As the carbon dioxide content increases the oxygen content of air decreases and air containing 4 per cent or over will not support life for long periods of time, which periods will shorten as the dioxide content increases.

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Carbon monoxide is closely allied with carbon dioxide and they are often found together. However, this is not always the rule and we may have one without the other. Carbon monoxide is a very deadly gas and 1/10 of 1 per cent will prove fatal to man if he is exposed for several hours. We notice the Bureau of Mines list the dangerous content to be 2/10 of 1 per cent. This gas is generated in mines mainly by tires and blasting. It has practically the same specific gravity as air and is found anywhere. The backs of all raises are especial places for its presence, however; and we think nearly all cases of gas poisoning- in raises is due to carbon monoxide. Both carbon dioxide and carbon monoxide are practically colorless, odorless, and tasteless. A miner's lamp can be used to detect the presence of carbon dioxide by the yellowish color or lack of flame, but carbon monoxide cannot be detected in this manner since it may be present in deadly proportions but the flame show no change.

The next important fumes on the Menominee Range are the sulphur fumes. The writer can find no analysis of any of these. The Bureau of Mines took samples of these fumes several years ago at the Zimmerman and Hiawatha mines. These samples were taken from behind bulkheads on what could be called the fire side. They showed some carbon dioxide and some carbon monoxide. However, the sulphur gases were disintegrated and analysis could not be made. In talking with various men, the following conclusion was drawn by the writer, namely, that the gas would be considered as mainly sulphur trioxide, containing some sulphur dioxide and also traces of the deadly hydrogen sulphide; along with carbon dioxide and monoxide. An atmosphere containing as low as 1/10 of 1 per cent of either sulphur dioxide or hydrogen sulphide is dangerous. The fumes of the sulphur oxides are very pungent and easily recognized and guarded against. They are over two times as heavy as air. The hydrogen sulphide is easily recognized by its very disagreeable odor. It is about 1.2 times as heavy as air. While we have fought these gases successfully in the past, they must not be treated too lightly. They are very deadly and must be avoided without the protection of breathing apparatus, or at times when the oxygen content of the air is good the All-Service gas mask may give adequate protection.

There is one other gas which occurs or is apt to occur naturally in our mines, and that is marsh gas. Marsh gas is a mixture of carbon and hydrogen CH_4 and when mixed with air is very explosive. This, of course, is the curse of the coal mines, and fortunately is rare in our mines. However, we cannot absolutely disregard it for we have seen what was termed marsh gas in an iron mine. This mine broke into an old abandoned top-slice mine and water coming therefrom carried a gas with it which would readily ignite. So we believe that it is possible to get enough of this gas coming from such a place to collect in a poorly ventilated room in quantities sufficient to cause an explosion of such size as to badly burn a man.

As a rule, throughout the entire district, the most poisonous fumes are usually generated by blasting. In every blast gases are liberated, many of which are poisonous. When the detonation is perfect the poisonous gases are in very small percentages. However, in the case of blown-out shots, burned charges or incomplete detonation, the noxious gases liberated are plentiful and very deadly. In practice when blasting is done on a large scale under the every day conditions met with in the mines, all the charges are not ideally detonated and poisonous gases are apt to result. Therefore, we should consider all powder fumes whether fresh or old as being deadly and use every precaution to