FIELD BLASTING AT THE VOLUNTEER MINE.

BY L. S. CHABOT, JR., PALMER, MICH.*

One of the most important phases of the operation at the Volunteer mine is that of breaking the ore, a hard cherty hematite and carbonate, with the greatest efficiency; that is, to produce a breakage which will result in the least possible amount of secondary blasting. The Volunteer mine, operated by Pickands, Mather & Co., is located on the Marquette Range in the Lake Superior iron district and is a large producer of silicious ore.

The production for the first year of operation, 1926, was obtained by keeping three churn drills at work drilling single and double rows of holes along the face of the cut, ahead of the loading shovel, and by blasting these rows as needed for the operation. This method was found to be unsuitable because of the many delays arising in removing track, and replacing drilling and excavating equipment before and after each blast.

In 1927 it was decided to change the method of blasting and to resort to the area or field blast, that is, to break the ore needed for the entire shipping season all at one time. This was purely experimental work and presented many interesting and difficult problems. No large blasts of this kind had been put off in the Marquette district, consequently a detailed study of the formation, powder factors, fragmentation, and spacing of drill holes was necessary.

Six small blasts were put off in 1926 and two area shots in 1927. The data from these blasts were carefully recorded by the Engineering Department, and from a study of these results were determined the loading factors and drill hole spacings which have been used for the area blasts of 1928 and 1929.

In 1928 the Volunteer mine was made a two-shovel operation, one shovel operating on the 1,400-ft. bench and another on the 1,440-ft. bench, each shovel being given a working face approximately 40 ft. in height. This change in pit layout necessitated two field blasts which occurred on April 16 and 26. The secondary blasting required was very little. The results from the field blasts of 1927 and 1928 were very satisfactory and proved quite conclusively that field blasting is the only solution in economically breaking the ore.

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Accordingly, drilling for the 1929 season's blast was started in the late fall of 1928 at the close of navigation and continued throughout the winter and spring. The relative positions of the two benches, the 1,400-ft. and the 1,440-ft., which were to produce the season's tonnage, made it advisable to shoot them at the same time, for if either were blasted alone, the detonation would cause a portion of the drill holes on the other bench to collapse and would render them unfit for charging with explosive.

FIG. 1—LAYOUT OF HOLES ON BENCHES AND METHOD OF CONNECTION FOR SHOT

The remainder of the paper will deal principally with the field blast of April 18, 1929, since it was the largest in the experience of the Volunteer mine, involving more ore tonnage, diverse churn drilling, and the use of more explosive than heretofore handled at one time, in addition to being the largest blast ever put off in the history of the Lake Superior iron district.

DRILLING.

The areas laid out to produce the tonnage for the year's operation of 1929 were on the 1,400-ft. and 1,440-ft. benches. The production from the 1,400-ft. bench was to come from an area approximately 1,000 ft. long with a width of 300 ft. on the East end tapering to a width of 100 ft. on the West end, while the tonnage from the 1,440-it. bench was to come from an area approximately 400 ft. long and 100 ft. wide. The layout of the two benches is shown in Fig. 1.

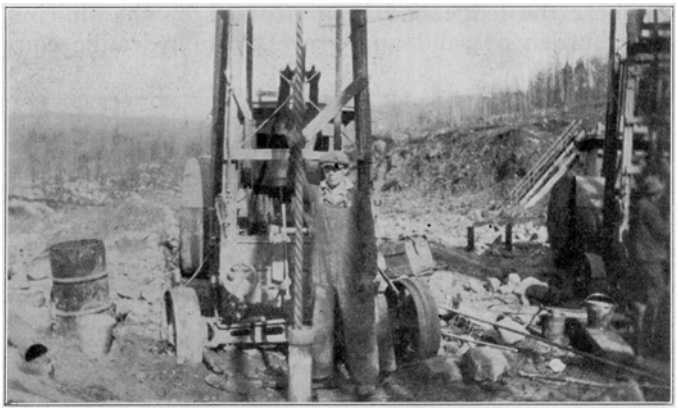


FIG. 2—FRONT VIEW OF SANDERSON-CYCLONE DRILL

The material on these two benches varies greatly in composition and hardness. The formation has an average dip of 45 deg. to the Southwest with a Northwest-Southeast strike, and has two distinct ore layers characterized by their color. The formation on the 1,400-ft. bench consists of a red, banded, cherty hematite yielding a reddish sludge from churn drilling. Drilling in this ground is comparatively easy. The formation on the 1,440 ft. bench is a hard, gray, cherty iron carbonate yielding a gray sludge in drilling. Drilling in this ground is difficult and slow because of the great hardness of the ore and the sliding of the drill bit on fracture planes and slips.

The equipment used in drilling for this blast consisted of six Sanderson-Cyclone No. Super 14 electrically driven, traction churn drills. Two of the drills were placed in the 1,440-ft. bench area, while four were placed in the 1,400-ft. bench area because of the greater amount of drilling required in this territory.

Each drilling machine is equipped with a string of tools consisting of rope socket, middle section, and drill bit, having a total weight of 1,350 lb. The drill bit is of the chisel type, with a guage of 5¾ in. It is of special design developed at the Volunteer mine to cope with the excessive hardness of the ore in some portions of the pit. The diameter of the hole made by the bit is approximately 6 in., which accommodates a special explosive cartridge measuring 5 in. in diameter by 16 in. in length.

One of the most important details connected with drilling at the mine is the proper spacing of drill holes. Since the formation varies greatly in texture and hardness, the spacing of holes must also vary for different ground. From the experience of previous blasts it has been found that a spacing of 12 by 13 ft. is ideal in hard carbonate ore, and that a spacing of 15 by 17 ft. in the red cherty hematite gives best results for efficient breaking.

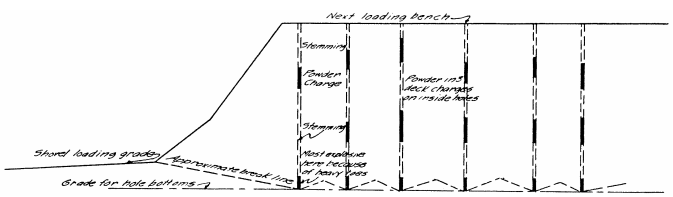


FIG. 3—CROSS-SECTION OF CUT SHOWING POSITION OF HOLES AND SCHEME OF DECK-LOADING

The holes in the 1,400-ft. bench area varied in depth from 15 to 60 ft., with an average of approximately 42 ft. The reasons for this large variation in depth are that the drilling occurred in an area where the ledge had been exposed by the sluicing away of the overburden of sand and gravel with hydraulic equipment, and the surface of the ledge itself was uneven and rolling. The holes in the 1,440-ft. bench area varied in depth from 54 to 60 ft. Holes adjacent to the faces of both benches were drilled 8 ft. below the shovel grade to take care of heavy toes, while all other holes were bottomed 5 ft. below the shovel grade to provide room for bottom charges and an even floor upon which to operate shovels. A cross-sectional view across the face of a cut showing the position of holes near the face, is shown in Fig. 3.

Due to the varying hardness of the ore in the areas of carbonate and hematite, different rates of advance in drilling were noted. The average footage per machine per shift of 9 hours in the 1,400-ft. bench area of red, cherty hematite was 30 ft., while in the 1,440-ft. bench of hard, gray, sideritic carbonate the average footage was 12 ft. The average footage per drill bit in the hematite was 15 ft. as compared with 4 ft. in the hard, cherty carbonate.

LOADING.

The next step in the sequence of preparation for the blast was the charging of the holes. Because of the softer drilling and additional equipment in the 1,400-ft. bench area, the drilling on this bench was completed first, and preparations were made immediately for charging or loading the holes. In computing the charge for each hole the factors taken into consideration were the spacing of holes, the depth and the characteristics of the material. In the lower bench there were 515 six-inch well-drill holes totalling 21,768 ft., with a burden of 231,850 cu. yds. of material, weighing 569,085 tons. On the basis of a factor of .67 lb. of explosive per cu. yd., the required explosive for the above burden was estimated to be 83,700 lb. of 40 per cent, 63,150 lb. of 60 per cent and 9,500 lb. of 80 per cent, a total of 156,350 lb. of Low Freeze Ammonia Gelatin. One gelatin cartridge as described above weighs roughly 17 lb. A log sheet of loading in this area as prepared by the Engineering Department is shown in Fig. 4.

Typical of the loading on the lower bench was hole No. 71 which had a burden of 680 cu. yds. and was loaded with 100 lb. of 60 per cent in the bottom and 350 lb. of 40 per cent for the remainder of the charge. In some parts of the 1,400-ft. bench area hard spots were encountered in drilling. These were marked on the maps by cross-hatching, and in loading, 80 per cent gelatin was used for the bottom charge and 60 per cent gelatin for the remainder of the charge. Greater shattering, which is very desirable in breaking the harder formation is obtained by using 80 and 60 per cent gelatin.

On the upper or 1,440-ft. bench there were 116 six-inch well-drill holes totalling 6,533 ft. and having a burden of 65,690 cu. yds., or 161,238 tons. With a loading factor of .84 lb. of explosive per cu. yd. of material, the explosive required for the above burden was 2,850 lb. of 40 per cent, 10,350 lb. of 60 per cent and 43,150 lb. of 80 per cent, a total of 55,350 lb. of Low Freeze Ammonia Gelatin. It will be noted that the faster 80 per cent gelatin was used in greater quantities here than on the lower bench because of the greater toughness and hardness of the ore. A log sheet showing theoretical and actual charges for this area is shown in Fig. 5.

Engineering Dept.,
Palmer, Michigan,
April 18, 1929.

PALMER MINING COMPANY—VOLUNTEER MINE

1,400-FT. BENCH BLAST

Hole No.	Depth	Area	Cu. Ft.	Cu. Yds.	Theoretical Explosive	Actual Explosive	No. of Sticks		Remarks
							60%	80%	
39	50	255	12,750	472	307	334	14	6	Hard form.
38	50	255	12,750	472	307	334	14	6	" "
37	50	255	12,750	472	307	334	14	6	" "
33	50	255	12,750	472	307	334	14	6	" "
32	50	255	12,750	472	307	334	14	6	" "
31	50	255	12,750	472	307	334	14	6	" "
30	50	255	12,750	472	307	334	14	6	" "
29	50	255	12,750	472	307	334	14	6	" "
24	45	255	11,475	425	276	300	12	6	" "
23	45	255	11,475	425	276	300	12	6	" "
22	45	255	11,475	425	276	300	12	6	" "
21	45	255	11,475	425	276	350	15	6	" "
20	45	255	11,475	425	276	350	15	6	" "
12	45	255	11,475	425	276	300	12	6	" "
11	45	255	11,475	425	276	300	12	6	" "
211	45	255	11,475	425	276	300	12	6	" "
10	35	255	8,925	331	215	250	6	40%9	Soft form.
9	35	255	8,925	331	215	250	9	6	Hard form.
8	35	255	8,925	331	215	250	9	6	" "
7	40	255	10,200	378	246	284	11	6	" "
6	35	255	8,925	331	215	250	9	6	" "
5	30	255	7,650	283	184	217	7	6	" "
4	25	255	6,375	236	153	184	5	6	" "
3	20	255	5,100	189	123	150	3	6	" "
2	15	255	3,825	142	92	117	1	6	" "
							40%	60%	
389	47	255	11,985	444	289	300	12	6	Soft form.
390	48	255	12,240	453	294	300	12	6	" "
391	49	255	12,495	463	301	300	12	6	" "
392	47	255	11,985	444	289	284	11	6	" "
393	46	255	11,730	434	282	284	11	6	" "
394	50	255	12,750	472	307	300	12	6	" "
395	48	255	12,240	453	294	300	12	6	" "
396	49	255	12,495	463	301	300	12	6	" "
397	46	255	11,730	434	282	284	11	6	" "
398	50	340	17,000	630	410	417	19	6	" "
546	59	425	25,075	929	604	600	30	6	" "
494	53	357	18,921	701	456	450	21	6	" "
479	52	255	13,260	491	319	317	13	6	" "
480	52	595	30,940	1,146	745	700	36	6	" "

FIG. 4—LOG SHEET OF LOADING IN 1400-FT. BENCH AREA

Typical of the upper bench was hole No. 675 which had a burden of 397 cu. yds. and was loaded with 400 lb. of 80 per cent in the bottom and 50 lb. of 60 per cent in the top of the hole. As in the lower bench there were areas of harder and softer materials requiring different loading.

The loading of the lower or 1,400-ft. bench required 29 hours with six crews of two men each, while the upper bench required 10 hours with six crews of three men each, including the operation of stemming the holes with sand and gravel provided for that purpose.

The loading of the holes proceeded as follows: The powder charge for each hole was laid nearby. One man with a wooden; mallet broke open the cases, and the loading crews, equipped with a powder punch, a loaded dolly for tamping, and a marked lowering rope, began loading the powder distributed at the hole.

The first operation of a loading crew was to sound and check the depth of the hole against the foreman's sheet; the next was to lower a cartridge with a double-countered Cordeau-Bickford fuse attached (see Fig. 6). Then another cartridge was lowered to check the position of the first, the Cordeau being held alongside of the hole. In deeper holes, such as those on the upper bench, deck-loading was employed, that is, some of the powder was placed in the top portion of the hole, separated from the lower part of the charge by a wad of stemming or fill material. This deck-loading was done to overcome blocky or large fragments in the top of the holes when blasted. In the shallower holes all of the powder charge was placed near the bottom. A cross-sectional view of a deck-loaded hole is shown in Fig. 3.

Engineering Dept.,
Palmer, Michigan,
April 18, 1929.

PALMER MINING COMPANY—VOLUNTEER MINE

1,440-Ft. BENCH BLAST

Hole No.	Depth	Area	Cu. Ft.	Cu. Yds.	Theoretical Explosive	Actual Explosive	No. of Sticks		Remarks
							60%	80%	
158	55	260	14,300	530	424	400	0	24	Hard cherty
157	55	260	14,300	530	424	450	3	24	carbonate
680	56	234	13,104	485	388	450	6	21	"
156	55	221	12,155	450	360	450	3	24	"
681	56	195	10,920	404	323	350	3	18	"
682	57	540	30,780	1,140	912	950	9	48	"
672	55	195	10,725	397	318	450	3	24	"
673	55	195	10,725	397	318	450	3	24	"
674	55	195	10,725	397	318	450	3	24	"
675	55	195	10,725	397	318	450	3	24	"
676	57	195	11,115	412	330	450	3	24	"
677	55	195	10,725	397	318	450	3	24	"
678	56	588	32,928	1,220	976	950	9	48	"
665	56	195	10,920	404	323	400	3	21	"
666	55	195	10,725	397	318	400	3	21	"
667	56	195	10,920	404	323	550	6	27	"
668	57	195	11,115	412	330	350	3	18	"
669	56	195	10,920	404	323	500	6	24	"
658	56	195	10,920	404	323	400	3	21	"
659	55	195	10,725	397	318	350	3	18	"
660	56	195	10,920	404	323	450	3	24	"
661	57	195	11,115	412	330	450	3	24	"
662	56	195	10,920	404	323	550	9	24	"
663	56	195	10,920	404	323	450	3	24	"
664	55	595	32,725	1,212	970	900	9	45	"
460	57	156	8,892	329	263	250	3	12	"
155	60	156	9,360	347	278	250	3	12	"
461	55	156	8,580	318	254	250	3	12	"
462	56	156	8,736	324	259	250	3	12	"
154	60	156	9,360	347	278	400	6	18	"
464	57	156	8,892	329	263	350	3	18	"
465	56	156	8,736	324	259	250	3	12	"
467	56	684	38,304	1,419	1,135	1,100	12	54	"

FIG. 5—LOG SHEET OF LOADING IN 1440-FT. BENCH AREA

The extra explosive from holes adjacent to the face, which called for more explosive than they could hold (because of heavy toes in front), was placed in holes directly back of them.

The stemming crew followed the loading crews and filled the holes with sand and fine gravel, leaving a foot of empty casing pipe to prevent fouling the Cordeau-Bickford fuse sticking out of the hole.

After the loading and stemming were completed, the area to be blasted was cleared of all refuse such as powder boxes, extra casing pipes, lumber, and other material, in preparation for connecting and blasting.

FIG. 6—LOADING A HOLE

BLASTING.

The connecting of the holes prior to detonation was carefully done as follows: The men employed as loading crews laid out the branches of plain Cordeau-Bickford fuse and connected the stubs of fuse protruding from the holes to these branches under Supervision of powder technicians. Parenthetically, it may be said that Cordeau-Bickford fuse consists of a continuous lead tubing filled with compressed TNT, and when covered with cotton thread is called "double-countered." Thirty-six man hours were required to connect all holes to the branches, and the men were then released from the area. The mains were then strung along the faces of the two areas and the various branches were connected to them, this operation being followed by a close, final inspection of all connections. A sketch of the hole layout and fuse hook-up is shown in Fig. 1.

FIG. 7—BEFORE THE BLAST

FIG. 8—THE SHOT

The amount of double-countered Cordeau-Bickford fuse for the entire blast was 33,078 ft, while the mains and branches required 11,781 ft. of plain fuse, making a total of 44,859 ft or approximately eight and one-half miles of fuse.

The Cordeau was detonated by two No, 8 electric blasting caps connected in series and placed at the East and West ends of the main on the lower bench. The shot was fired by a 1-50 hole blasting machine placed under an electric shovel 200 ft. in front of the center of the lower bench face.

The great speed of detonation of Cordeau-Bickford, over 17,-000 ft. per second, resulted in a practically instantaneous blast. The broken material was thrown straight up, the casing pipes from some of the holes attaining a greater height than the main curtain of the shot (see Fig. 8). The buildings and equipment in a radius of from 200 to 900 ft. were not touched by flying fragments. The force of the shot appeared to be vertical, and, as a consequence, very little material was thrown horizontally. The operators who fired the shot from under the No. 125 Marion electric shovel on the lower bench, only 200 ft. away from the blast, were not bothered except by smoke and dust. They reported that very few fragments hit the shovel and that no windows were broken.

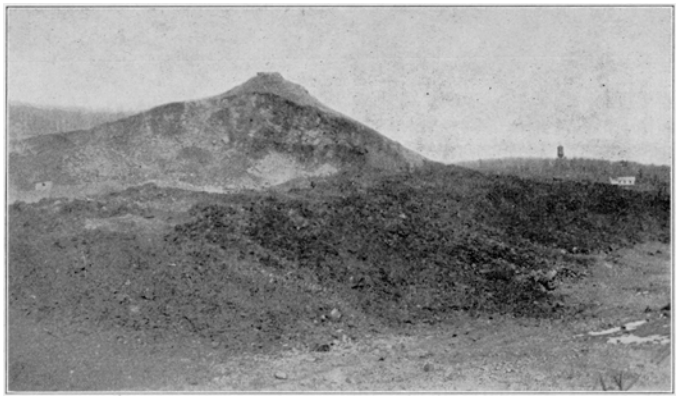


FIG. 9—A VIEW OF THE PIT AFTER THE BLAST

The fragmentation resulting from the blast was very good. Shovels loaded in the blasted areas throughout the shipping season with practically no secondary blasting required except in the case of an occasional large fragment. The material was ideally broken for economical shovel operation.

VIBRATION TESTS.

A study of the vibrations resulting from the blast was made to determine the effect of field blasting on buildings in the vicinity of the mine. The following is an excerpt from the report published in the "Explosives Engineer" of July 1st, 1929: "Vibration recording instruments were located in a building 1,470 ft. east from the center of the area to be blasted. This building consists of a combined office and warehouse, ground dimensions 15 by 31 ft, set upon cedar posts spaced 5 ft. apart each way upon which were laid the 2 by 8-in. floor joists spaced 16 in. centers. The building is made of timber frame, wood sheathed, and one story high. From the surface of the ground to the rock ledge underground is about 10 ft. The elevation of the surface of the ground is 1.461 ft.

The elevation of the top of the shot on the upper bench was 1,485 ft., with the shovel floor at an elevation of 1,440 ft.; the top of the shot on the lower bench was 1,440 ft., with the shovel floor elevation at 1,400 ft.

"In the building were located the following instruments: Vertical vibrograph which recorded a maximum double

amplitude of .08050 in. with a period of five vibrations per second at that point, it taking 2-1/10 seconds for the large waves to subside; a horizontal vibrograph which recorded a maximum double amplitude of .10388 in. with a period of 3½ vibrations a second at that point and taking 2-8/10 seconds for the large waves to subside.

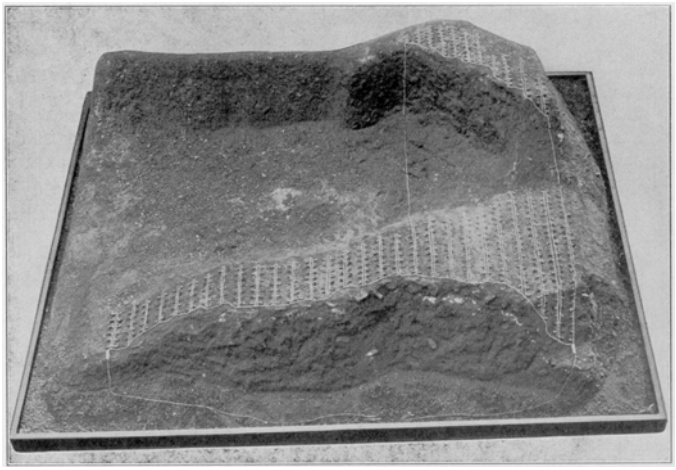


FIG. 10—MODEL OF BLAST OF APRIL 18, 1929, MADE BY THE HERCULES POWDER CO. FOR EXHIBIT AT THE MEETING OF THE LAKE SUPERIOR SECTION, NATIONAL SAFETY COUNCIL, IN DULUTH, MINN., JUNE 27 AND 28, 1929

"The pin set-up consisted of 8 steel pins, each ¼-in. in diameter and of the following lengths; one 5 in., one 5½, one 9 in., one 11 in., one 15 in., two 16 in., and one 18 in. The following pins fell down: one 5½ in., one 9 in., one 11 in., and two 16 in. The following pins remained standing: one 5 in., one 15 in., and one 18 in.

"A water glass set-up consisted of the following: One glass filled level full with water, and one glass filled within 1/16 in. from the top with water. No water was spilled out of either glass. Before the blast it was noted that the bricks on the top of the brick chimney of the building were loose. These were not disturbed by the blast. The same results were obtained on the setups by slamming the door."

ADVANTAGES OF FIELD BLASTING.

The advantages of field blasting, in the opinion of Volunteer mine officials, are many and certainly warrant this type of blasting. In the first place, the frequent removing of track and the placing and replacing of drilling machinery and shovels before and after each small blast are done away with, and a costly delay is thus eliminated. Secondly, the drilling operation is concentrated in one period and permits greater efficiency in drilling, as has been very well demonstrated at-the Volunteer mine. Third, better breakage results from an area blast because the mass of the material in motion helps to crush the fragments and to further reduce their size. Fourth, the blasting hazard, which is a great one at any open pit or quarry, is reduced to a minimum. Careful patrolling of the vicinity before field blasts assures safety to the public. Since the annual production is blasted all at one time, the one blast is the sum total of the blasting for the season.

Because of all these things, field blasting has a great appeal, and has been adopted at the Volunteer mine as the best practice in breaking ore for shipment.

THE X-RAY LABORATORY AT THE MICHIGAN COLLEGE OF MINING AND TECHNOLOGY FOR THE STUDY OF THE GROSS STRUCTURES AND MICRO-STRUCTURES OF MATERIALS.*

BY ROY W. DRIER, HOUGHTON, MICH.**

A description is given of the three types of X-ray units, the radiographic, the General Electric, and the gas tube, now being installed in the new X-ray laboratory at the Michigan College of Mining and Technology. The radiographic unit will use the recently developed Kenetron tube method of rectification and will include an oil immersed condenser for partial elimination of current pulsations. A Coolidge tube and a Muller helium-filled tube will be used. The General Electric diffraction unit and the gas tube unit are differentiated. A descriptive list of auxiliary apparatus is given, which includes modern dark room equipment, three types of spectrographs, a Moll microphotometer, an intensometer, an ionization spectrometer, new types of cameras, and safety apparatus. Included also are illustrations of apparatus, diffraction patterns, and radiographs.

Since time immemorial man's progress has been linked with his power to magnify. In time primeval it was a mental magnification, that is, imagination. Man's first tools and implements were essentially products of his imagination—the magnifications of ideas. In a like manner when man began to investigate natural phenomena, his progress paralleled his ability to magnify. The development of science—physics, astronomy, chemistry—has been in proportion to the growth of ability to magnify both physical things and man's abstract ideas. The modern concept of atomics is but a glorified idea whose proof has been made possible by the latest method of super-magnification, the diffraction of X-rays.

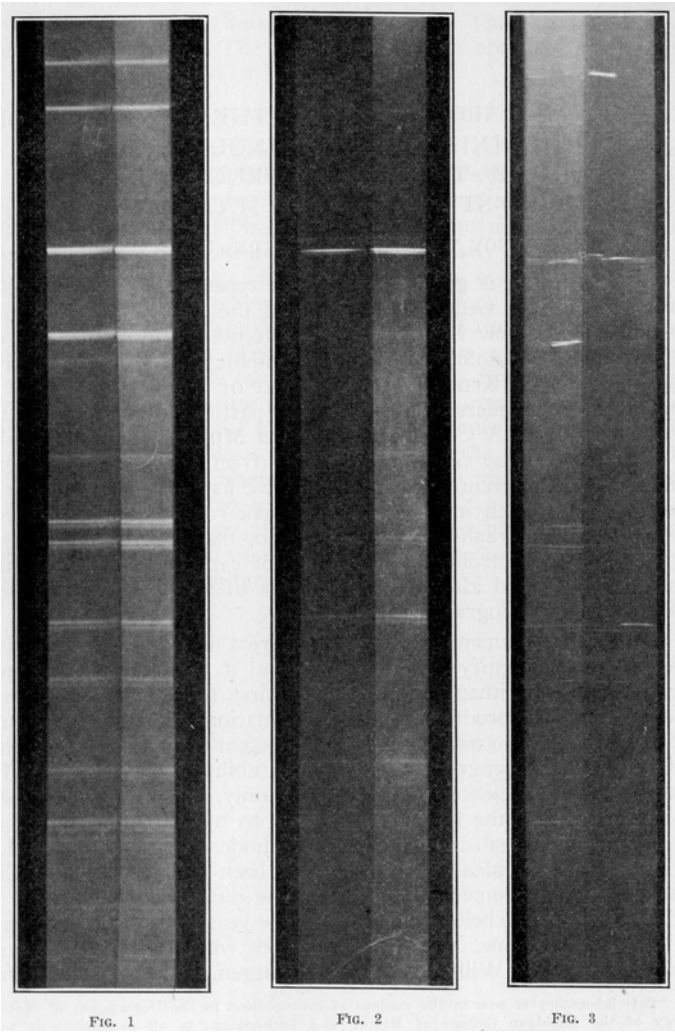
*This laboratory is now in the process of construction in the Department of Metallurgy of the Michigan College of Mining and Technology; in all probability it will be practically completed by the time this description is in print.

The College is indebted to Dr. G. L. Clark of the University of Illinois for his valuable suggestions regarding equipment and layout, and to Professor A. T. Sweet whose vision and untiring efforts have made the laboratory possible.

**Department of Metallurgy, Michigan College of Mining and Technology.

It is difficult to believe that only a few years ago the X-ray really deserved its name, X-ray, the ray about which little was known. In the year 1895 Wilhelm Conrad Roentgen, while experimenting with cathode rays, discovered the radiation which hears his name, the Roentgen Ray, or as it is more commonly known in this country, the X-ray, a radiation with exactly the same properties as ordinary light with the exception of wave-

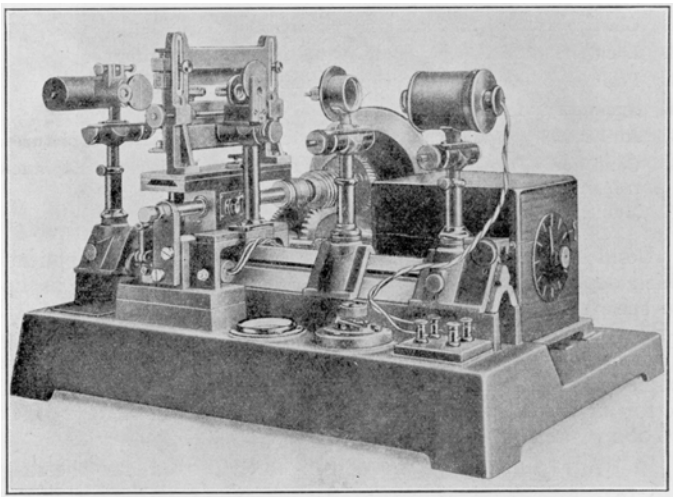
length. X-rays are of the order 10^{-8} centimeters or ½50,000,000 of an inch, a length which gives them their outstanding characteristic attribute, the ability to penetrate solid matter.



HULL TYPE OF X-RAY SPECTRA, OF COLD DRAWN COPPER WIRE
Fig. 1—Surface Condition of Wire.
Fig. 2—Core Condition of Wire, Showing Preferred Orientation.
Fig. 3—Annealed Copper Wire, Indicating Recrystallization.

The medical fraternity, quick to grasp the possibility of any aid which would permit visual examination without the necessity of operating, seized this tool as their own, and so until 1913 the popular mind connected X-rays with medicine, the fractures of bones, and the locating of bullets and other foreign bodies. These applications all depend upon the penetrating qualities of X-rays and this branch of the science is called radiography, known in metallurgy as metal radiography.

Metal radiography has had two important applications in routine metallurgical tests, especially in the examinations of foundry products. One is the testing, without destruction, of castings or other metal objects for cracks, blow-holes, cavities, inclusions, and other structural variations which would make the article unfit for use. The other application is, as a control in foundry technique, in the field of research.



MICROPHOTOMETER

The following is a list of information to be obtained from X-ray radiographic examinations; and some of the applications dependent upon the penetration of X-rays:

1. Presence of internal cracks, gas cavities, pipe cavities, sand and slag inclusions, porosity, and segregations in castings.
2. Condition of drawn wire—whether over—or under-drawn.
3. Soundness of welds.
4. Uniformity and soundness of ball-bearings.
5. Control of thickness of rolled metal sheet.
6. Control of coal washing processes.
7. Interior condition and arrangement of grenades, shells; insulation of wire, effect of vulcanizing in tires.
8. Presence of cracks, knots, and other harmful structural variations in materials used in aircraft and automobiles.
9. Internal diameter of pipes and height of capillary rise of liquids.
10. Metallic inclusions in insulators.
11. Classification of minerals and pigments.
12. Location of hidden pipes and wires in walls; contraband.
13. Position of electrodes in vacuum tubes.
14. Symmetry of core of golf balls.
15. Authenticity of old paintings; retouchings, superimposed pictures.
16. Condition of museum specimens such as mummies, fossils; ancient trepanning.
17. Medical and dental radiography.

Besides these radiographic uses, X-rays have an application which depends not so much on their penetrating powers as upon the specific length of the rays. It is in this application that an X-ray diffraction unit deserves the name of the Supermicroscope of science. With it can be measured distances as short as ½50,000,000 of an inch in length, and since this measurement is accurate to the third decimal place, the limit is more nearly ½50,000,000,000 of an inch.

In 1913 a German physicist, von Laue, proved that the length of X-rays was of the same order of magnitude as the distance between atomic planes in crystalline matter, 10-8 centimeters or approximately ½50,000,000 of an inch. This meant that crystalline matter could be used as diffraction gratings for X-rays, and conversely that with X-rays of known wave-length much could be

learned of an unknown crystalline material if it were used as the grating. It is in this way that we learn the size of the unit cells of metals, alloys, and other crystalline matter; the nature of alloys, and the effects of mechanical and heat treatment. It is this application which is of greatest interest and value to the metal industry.

The following is a list of some of the information obtainable from X-ray diffraction examination:

1. State of matter being examined, whether crystalline or amorphous.
2. Lattice structure of crystals and position of atoms and molecules on the lattice; also size, shape and volume of the unit cell.
3. Single crystal or aggregate,
4. If an aggregate, is orientation random, (chaotic), preferred or fibered.
5. If fibered or preferred, to what degree, also the degree of deformation in fabrication (rolling, drawing, torsion, impact, pressure, electrodeposition, etc.) The qualitative analysis of the mechanism of deformation or of fibering. Interpretation of practical effects of deformation.
6. Size of particles, whether micro-crystalline or macro-crystalline.

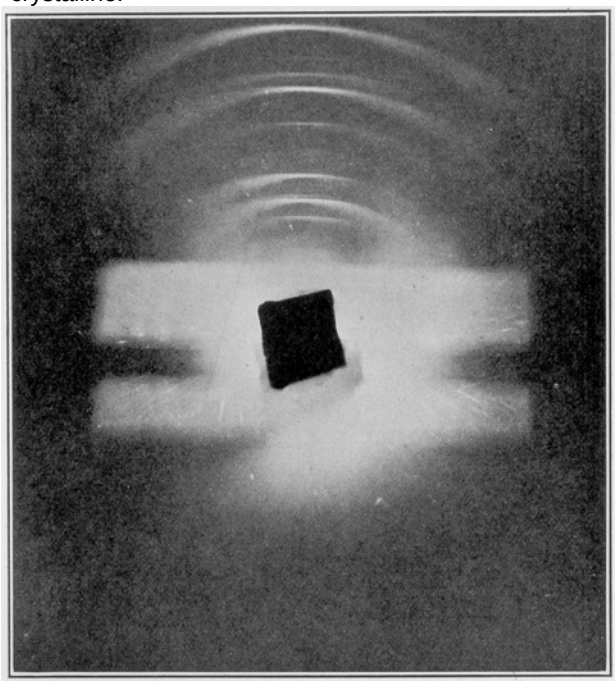


FIG. 4—PINHOLE SPECTRA OF COLD DRAWN COPPER—SURFACE OF WIRE

7. Chemical identity, homogeneous or heterogeneous; that is, element, compound, mixture, solid solution, adsorption complex phase, etc.
8. Transformations and allotropic modifications.
9. Effect of cold working, hot working, heat treatment, and pressure on crystal orientation, internal strain, transformations, grain size and nature of recrystallization.
10. Difference between internal and external structure, (especially of worked metals).
11. Measure of physical properties—density, co-efficient of expansion, electrical properties, atomic and molecular forces.
12. Uniformity of ultimate structure in different lots of material, in the same lot and in the same piece.
13. Final fundamental differentiation between satisfactory and unsatisfactory materials.
14. Properties and thickness of films, such as parafins and those formed by lubricating oils and greases.
15. Qualitative and quantitative analysis.
16. Changes due to chemical treatment.
17. Discovery of new elements.

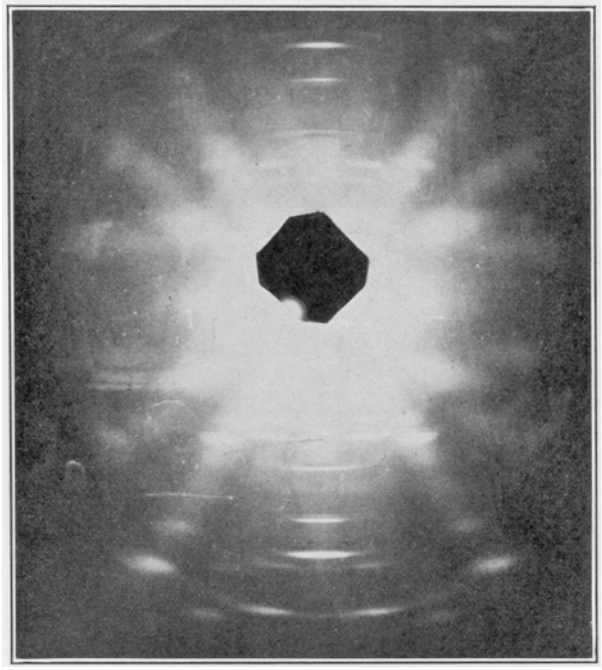
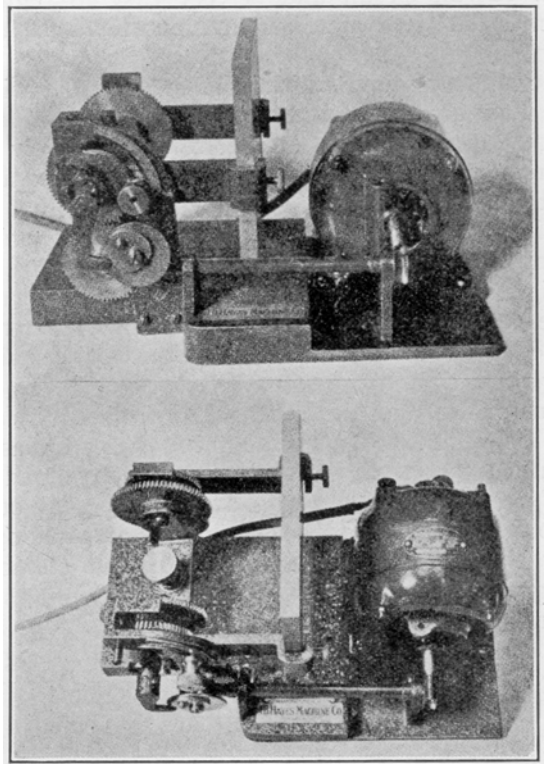


FIG. 5—PINHOLE SPECTRA OF COLD DRAWN COPPER—CORE OF WIRE, INDICATING EXTREME FIBERING

RADIOGRAPHIC EQUIPMENT.

Radiography is dependent upon the penetrating power of X-radiation which in turn is a function of the voltage across the X-ray tube. There are two parts of a radiographic circuit which are of equal major importance—the high tension transformer and the X-ray tube. The transformer is a piece of apparatus which transforms a low voltage to a high voltage or vice versa. In this case it will receive a 220-volt feed and will deliver up to 230,000 volts. This is alternating current and before it can be used by the X-ray tube, it must be made unidirectional or rectified. In the apparatus to be placed in the new laboratory at the Michigan College of Mining and Technology, this rectification will be accomplished by means of a series of oil-immersed kenetron tubes. These are highly evacuated tubes which permit an electric current to flow through them in one direction only. In the transformer circuit will also be included the number of oil-immersed condensers necessary to give the rectified current as uniform a voltage as possible; in other words, the condensers will make the X-ray tube more efficient by flattening out the sine wave which corresponds to the pulsations of the current. This type of transformer will make it possible to increase the voltage above 230 kilovolts merely by the addition of auxiliary units—an increase which will be very helpful in the future if tubes are built which will withstand higher voltages and currents.



A Clark-Hayes Spectrograph Equipped With An Oscillating Table

There will be no rectifying switches or rotating discs in the kenetron rectifying circuit, and as a result a great deal of noise will be eliminated, the laboratory will be safer, the corona will be diminished to a great extent, and there will be no radio interference in the neighborhood.

The laboratory will be equipped with two types of X-ray tubes for radiographic work. One will be the type of tube designed originally for deep therapy by Dr. Coolidge, of the General Electric Company's research staff. It is capable of withstanding a voltage of 220 kilovolts and a current of 5 milliamperes. The cooling of this tube which is by radiation will be aided by forced draft ventilation in the tube box. The current through the tube depends upon the temperature of the cathode filament. This filament is heated by a 12-volt circuit and is very easy to regulate. The anode is a massive piece of tungsten supported by a molybdenum cylinder.

The other type of tube which will be available will be of the hot cathode type also, that is, the current across the tube will be a function of the number of free electrons emitted by the cathode filament which in turn is a function of the temperature of the filament. It will differ from the Coolidge tube in that it will have a straight line focus instead of a spiral and will permit pressure water cooling of the anode. As a result, the use of higher currents and higher voltages will be possible which in turn will shorten exposures and will allow thicker sections to be rayed. The straight line focus gives better definition for certain types of radiography.

The transformer and the tube will be placed in a lead-lined room, their operation being visible through lead glass windows. The tube and tube box will be so placed and arranged that radiography will be possible from any angle. The layout has been planned also with the purpose of making stereo-radiographs possible in any position. When viewed through a stereoscope these stereo-radiographs give the same sensation of depth as that which one experiences when looking through the common, small, hand stereoscope. To eliminate as much as possible the fogging of films by secondary radiation, a rotating, spiral Bucky-Diaphragm is being designed.

Auxiliary radiographic equipment will include bakelite front cassettes with double intensifying screens, film exposure holders, fluoroscopes, and the necessary dark-room equipment.

Diffraction or Spectroscopic Equipment.

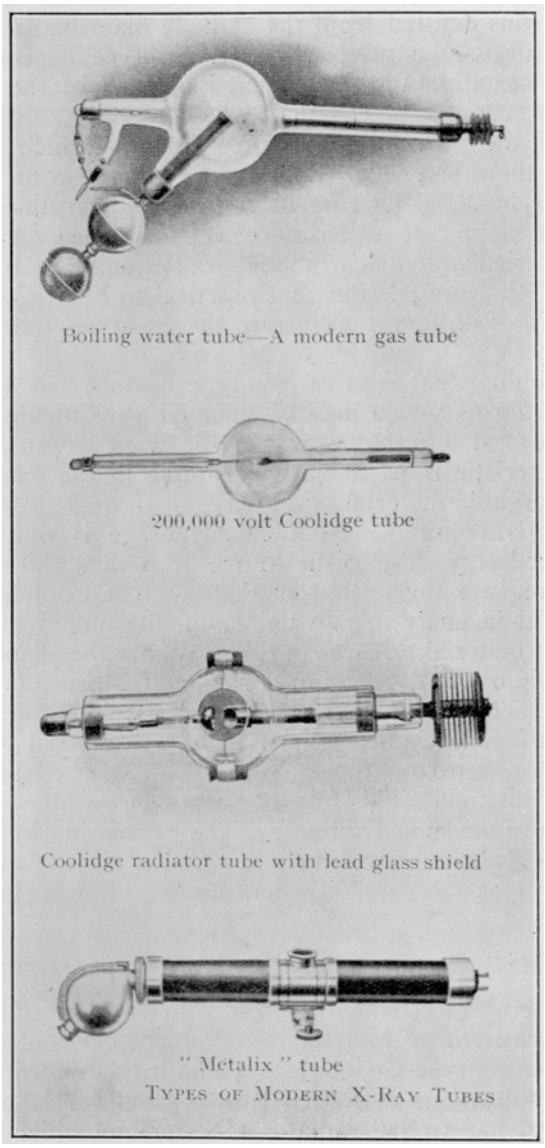
In the diffraction type of circuit, as in the radiographic, the high tension transformer and the X-ray tube vie for major honors. For this kind of work the transformer will differ from the radiographic transformer in two ways; voltages over 50 kilovolts will seldom, if ever, be used, and the transformer will be of the single high-tension terminal type. This type of transformer has one grounded terminal, and this characteristic permits the use of pressure water from the city mains for cooling the anode. In the case of the radiographic tube the pressure water for cooling the anode has to be in an isolated and insulated circuit.

For diffraction work two types of tubes will be available. One wall he a Coolidge tube, similar to the one already described with the additional advantage of being water-cooled, and the other tube will be a metal Hadding-Siegbahn type or gas tube. The Coolidge tube, like the one mentioned previously depends upon the number of electrons emitted from the cathode filament for the amount of current across the tube, while the gas-type depends upon the degree of evacuation and subsequent ionization of the residual gas for its tube current.

Each of the two tubes has some features which are superior to those of the other. The Coolidge tube has a constant vacuum, is self-rectifying, and its current can be predetermined and regulated by the setting of a resistance; it is capable of emitting only one characteristic (monochromatic) radiation, that of the target material. If it were possible and practical to build Coolidge tubes with anodes of different elements, the gas-type tube would not be necessary.

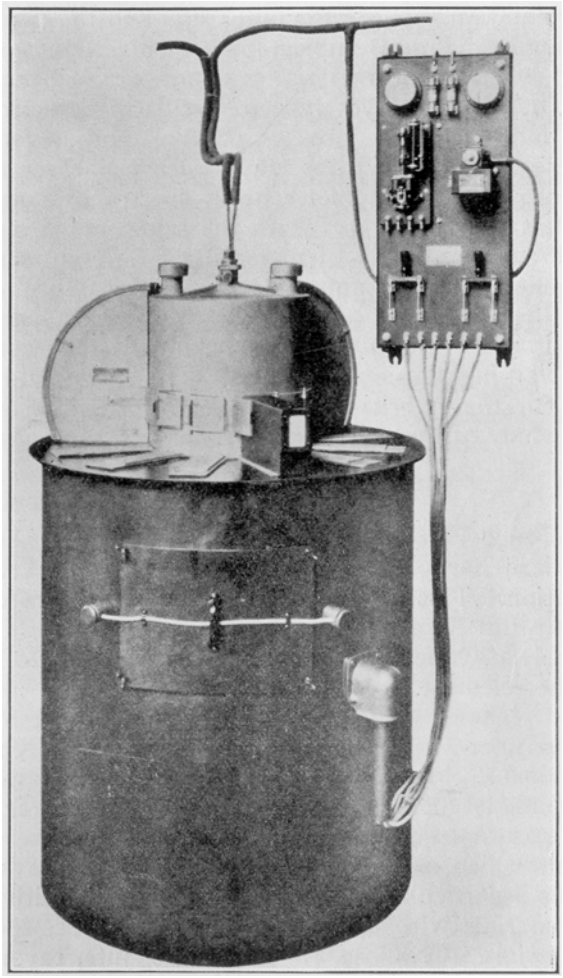
The Hadding-Siegbahn or gas-type of tube has the desirable feature of a target which may be changed, thus making it possible to obtain several different characteristic wave-lengths, as desired. This characteristic is particularly desirable in the examination of thin films, organic material and all types of work in which a real long X-ray is required. Another advantage is that the sample may be placed very close to the source of X-rays and consequently the exposures are

much shorter than with a Coolidge tube. It is also useful in analyzing an unknown, the unknown being used as the target material. It was in this way that the elements illinium (61), Hafnium (72), Rhenium (75), and Masurium (43) were discovered. The gas tube is not self-rectifying and so requires some type of rectification. A 50 kilo volt Standard X-ray transformer with a kenetron tube in series will be used to supply the current for this unit. This tube has a pressure water cooled anode and a pressure air cooled cathode. The evacuating system for the Hadding-Siegbahn tube will include a Cenco Hyvac backing pump, a Langmuir type mercury diffusion pump, and a McLeod vacuum, gage.



THE GENERAL ELECTRIC DIFFRACTION UNIT.

The General Electric Diffraction Unit consists of a high tension transformer of 30 kilovolt capacity, a water-cooled, self-rectifying, diffraction type Coolidge tube and a tube housing which allows the simultaenous raying of twelve samples. The housing, a lead cylinder, has twelve radial apertures into which may be inserted blocks containing slits of three sizes varying from .02 x .02 in. (pinhole) to .07 x .50 in. These slits serve to define the X-ray beam in such a manner that the resulting beam consists of parallel rays. The spectra resulting from the use of the slits are recorded on films which are contained in cassettes in the form of a quadrant of a circle, the center of which is the specimen being examined. These cassettes are made with a Zro2 filter as an integral part. This material absorbs all but a sensibly monochromatic radiation. This is the Hull method of obtaining X-ray spectra.



X-RAY DIFFRACTION APPARATUS—VIEW OF ASSEMBLY

The pinhole slit is an exception; it is not used with the quadrant cassette. The pinholes may contain a Zro_2 filter in which case the method is called the monochromatic pinhole method, or the filters may be removed and the pinhole used for the classical Laue method. These spectra are recorded on duplitized X-ray films, 3¼ x 4 in. (5x7 may be used), which are contained in flat cassettes held at an angle of 4 deg. to the vertical. These cassettes, both quadrant and flat may he fitted with intensifying screens. The work for which this unit is best suited is the examination of powders and materials such as metals, ores, inorganic compounds, mixtures which may be powdered, rolled materials, and wires. It is especially adaptable to the determination of any variation in structure and orientation between the outer skin and the core of a wire.

The pinhole diagrams indicate whether fibering or strain is present and whether the material is course-grained, crystalline or amorphous. A Clark-Hayes type of oscillating spectrograph will enable thin films of waxes, greases, parafins, and surfaces of sheet metal to be examined. With a Hayes Debye-Shearer type of circular camera with a goniometer head, spectra of single and rotating crystals can be made. With the same unit a small electric furnace will permit a study of materials at different temperatures. In this manner optimum annealing and recrystallization temperatures may be determined. With a small tension apparatus it will be possible to study strain distribution and crystal orientation and size under varying tension conditions. This may aid in finding the reason for the embrittlement of boiler plate. It will also be used in the study of hysterisis and core loss in transformer steel.

THE GAS TUBE UNIT.

The gas tube unit consists of a Hackling-Siegbahn gas tube and a Standard X-ray transformer equipped with a kenetron tube for rectification. This tube is of metal and has three windows or ports of exit for X-rays permitting three exposures to be made simultaneously. These windows are made of a thin foil aluminum or some other element of low atomic number.

Slits and pinholes will be a part of the equipment for this unit and with a Hilger-Muller spectrograph all types of X-ray spectra will be obtainable. With it can be made Lane diagrams, monochromatic pinhole diagrams, 360 deg. Debye-Shearer diagrams, and rotating crystal diagrams.

This unit which usually employs characteristic rays of copper or iron, finds a particular useful application in quantitive measurements of materials with large unit cell dimensions, such as most organic materials. Cellulose, rubber, ramie, jute, rayon, silk, and proteins are examples of such materials,

AUXILIARY APPARATUS.

The dark room will be equipped for tank development. Hot and cold water connections will enable the solutions to be kept at any desired temperature. The latest type of direct and indirect illumination will aid in making the dark room light safe. Facilities for printing will include an Eastman auto-foscusing enlarging camera.

A Kipp and Zonen, Moll type of microphotometer will be very useful in the determination of the exact position of density maxima of diffraction lines. This feature is particularly advantageous in the study of alloys, solid solutions, and particle size.

To aid in the study of alloys the laboratory will include also three Siemens-Bohlin cameras of the focusing type. These three cameras, when used together will make possible the study of practically the whole diffraction range. They permit greater dispersion without lengthening the exposure.

For physical measurements of the radiation, that is, the density and intensity, an intensometer will be used. This instrument will be calibrated in “R” units. This unit was recently adopted by a world congress of roentgenologists in Stockholm. Besides its value in the metallurgy laboratory this instrument will be available for the standardization of transformers used in X-ray therapy. It is planned to add an ionization spectrometer to the equipment as needs develop for it. This not only will be of great value in determining intensity of X-ray beams but will enable more precise measurements to be made of interplanar distances, which in turn will make possible diffraction investigations by the Bragg and the Clark-Duane methods.

For heat treatment and the forming of alloys and solid solutions an electric furnace laboratory is available. The equipment includes Westinghouse furnaces with automatic temperature control, an Ajax induction furnace, a Leads-Northrup hump furnace, a transition point indicator and an Epstein apparatus for the study of hysterisis and core loss in transformer steel.

Because these units will be operated continuously it is essential that the X-ray tube receive an ample supply of cooling water at all times; Mercoid automatic pressure control switches will be a part of the cooling water circuit. These switches insure the opening of the primary electric circuit should the cooling water drop below a predetermined quantity and pressure. Pressure gages in the cooling water line allow the pressure to be read at any time. To make certain that the tube is not receiving a current greater than its rated capacity, Cutler-Hammer starting boxes, which act as thermal relay cutouts, will be used. The General Electric Unit comes equipped with a stabilizer which prevents the current through the tube from fluctuating. A Kelley-Koett stabilizer is available for the stabilization of either of the other units.

RAPID CROSSCUTTING AT THE EUREKA MINE.

BY N. E. NILSEN* AND A. E. FOSS,** RAMSAY, MICH.

A hard rock crosscut in the Eureka Mine, at Ramsay, Mich., (Gogebic Range) was advanced 924 ft. in 31 consecutive days. The Castile Mining Company considers this an accomplishment only because it was done in conjunction with the hoisting of 32,000 tons of iron ore by way of the same shaft through which the rock was hoisted. During those operations not one of the men employed at the mine suffered an injury.

This work was done on the 24th level, which is 2,315 ft. below the collar of the shaft. The shaft is in the footwall, with the formations inclined about 70 deg. from the horizontal. This necessitates longer crosscuts on each new level as the shaft is deepened. The crosscut was driven on a line normal to the strike of the formations, and at a grade of one-half of 1 per cent in favor of the loaded cars.

AN S-70 DRIFTER VIEWED FROM THE RIGHT OF THE COLUMN

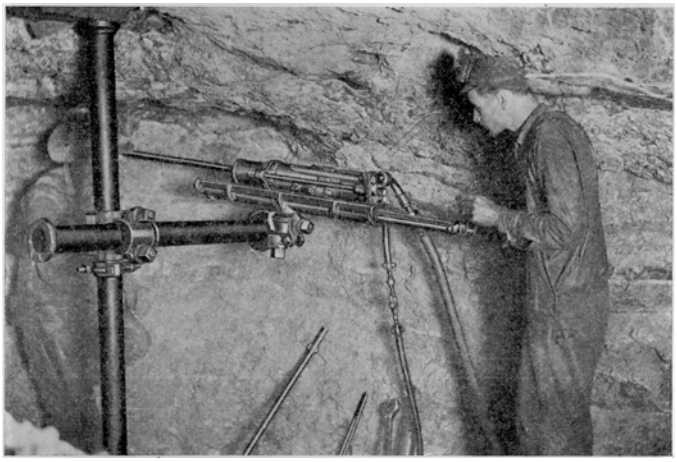
The rock through which this crosscut was driven consisted of 227 ft. of hard unaltered granite, 408 ft. of thin bedded quartz slate, 235 ft. of hard massive quartzite, and 54 ft. of iron formation and ore. While in granite, the crosscut was advanced an average of 27.3 ft. per day; in quartz slate, 37.1 ft. per day; and in quartzite and iron formation, part of which was timbered, 23.5 ft. per day.

*Foreman Rock Development and Shaft Sinking.

**Chief Engineer.

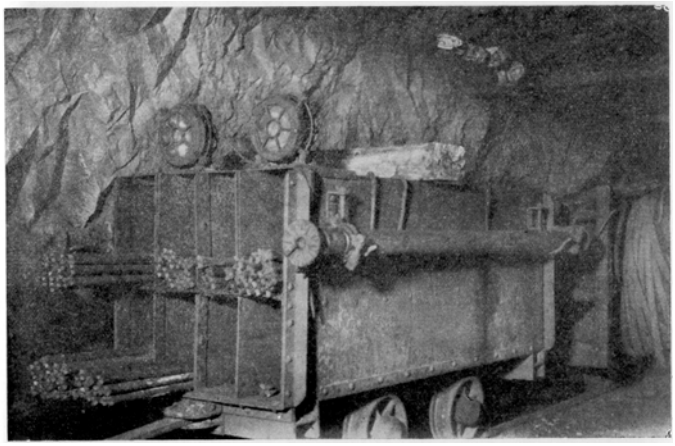
The best advance made in one day of 24 hours was 45 ft., or five 9-ft. cuts; and the best week netted 267 ft. of advance. This was done in the quartz slate. If enough of this rock had been available, and there had been no interruptions due to other activities in the mine, an average daily advance of 40 ft. could easily have been maintained, resulting in a monthly advance of 1,240 ft.

The crew at the heading under consideration consisted of 32 men, as follows: two bosses—one day shift and one night shift, 24 miners divided up into three shifts of eight men each, one electrician and a helper, two trackmen, and two ditchmen. When work on this program of intensive rock cutting was started, the breast of the crosscut was 275 ft. in from the storage pocket at the shaft station.

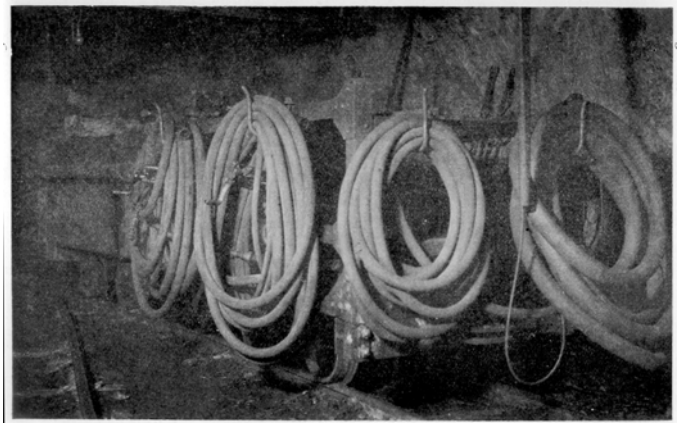


AN S-70 DRIFTER VIEWED FROM THE LEFT OF THE COLUMN

The equipment used consisted of one modified Osana type scraper slide provided with a 10-h.p., double-drum electric hoist with a rope speed of 200 ft. per min., six Ingersoll-Rand S-70 wet drifting machines, two single-jack drill posts, one drill truck, one equipment truck, two 4-ton electric locomotives, two 60-cu. ft. rocker dump cars, and one 20-in. Jeffrey universal blower fan with 400 ft. of 12-in. galvanized piping. Compressed air at 90 lb. pressure was furnished; and this was conveyed down the shaft through an 8-in. column, and through a 4-in. pipe line on the level.



DRILL TRUCK IN THE 24TH LEVEL CROSSCUT WITH THE EQUIPMENT TRUCK AT THE RIGHT

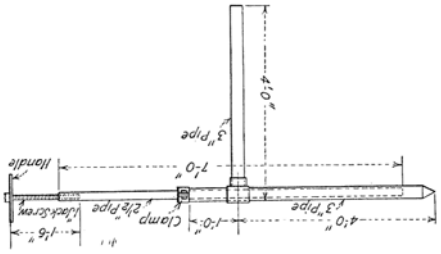


THE EQUIPMENT TRUCK EMPLOYED BY THE CASTILE MINING CO. IN DRIFTING THE CROSSCUT

The equipment truck, which is shown in one of the accompanying illustrations, carried air and water manifolds on its bottom deck. From these manifolds a 2-in. hose, extending rearward, connected with the 4-in. air pipe and a 1-in. hose with a 2-in. water line. Each drifter was at all times attached by suitable hose lengths to the air manifold on the equipment truck, which was fitted with line oilers—one for each connection. After a round had been drilled, the hose was detached from the machines and coiled up and hung on the sides of the equipment truck, as illustrated. The trucks were run on 50-lb. rails laid in 15-ft. lengths so as to facilitate handling and to permit the track to be laid closer to the breast.

The time schedule for a cycle at this heading was, for example, from 7 a. m. to 11:45 a. m., as follows:

	Hrs.	Min.
Rigging machines		25
Drilling 24 holes, average depth 8.4 ft.	1	40
Removing machines and blowing holes		15
Charging holes and blasting		25
Ventilating		15
Moving in loader		5
Mucking 26 cars	1	35
Removing loader and moving in equipment and drill trucks		5
Total time to complete average cut	4	45



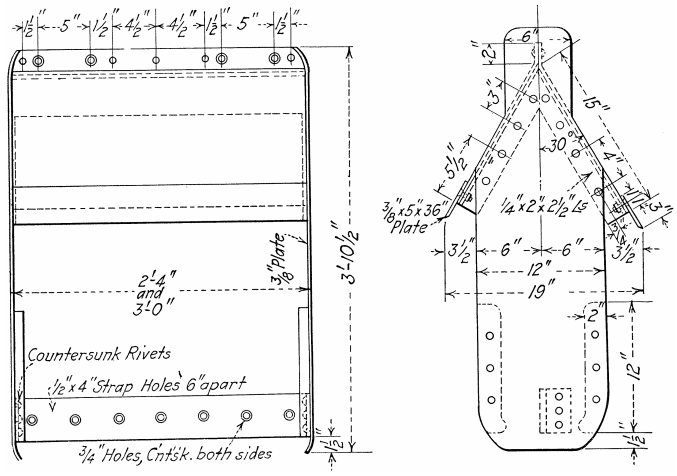
EXTENSION BAR FOR DRILL STAGING

Four wet drifting machines, mounted on 4-in. by 8-ft. vertical posts equipped with clamps and arms, were used at the heading throughout the work. Staging was provided for the men operating the upper machines. Two miners were assigned to each machine and were required to drill six holes. One and one-quarter inch, hollow, round steel was employed in lengths of 3, 5, 7, 9, and 11 ft. While mucking was in progress two miners oiled the machines and arranged the steels in the proper compartments on the drill truck. On its way to the working face, the drill truck preceded the equipment truck—its two electric headlights serving to illuminate the breast. Wherever track and trolley wire were needed, they were installed while drilling was going on.

Before deciding on the use of vertical posts in preference to cross-bars upon which to mount the machines, considerable discussion arose as to the safety of the different methods. It was finally concluded that two vertical posts, equipped with a safety collar to prevent the upper drills from falling the full length of the post, presented the safest and most efficient means of supporting the machines. The upper drills were at all times kept above the arms; the lower ones below the arms. To move the machines up or down, the arms were slid along the post.

A total of 24 holes was drilled for each cut; and the average time required to put in a round was 1 hour and 40 minutes. In granite the average drilling time was 8.1 in. per minute, in quartz slate it was 16 in. per minute. After drilling, the holes were blown out and all equipment transferred to the drill and the equipment trucks, which were then taken back to the shaft and prepared for the next cut. Immediately after blowing, the holes were charged. Five sticks of 1-in., 80 per cent gelatin were placed in the bottom of each hole—the space remaining being filled with 1¼-in., 60 per cent gelatin. All blasting was done by means of electricity from a 250-volt direct-current line. As soon as the holes were fired, a valve at the shaft was opened and the breast ventilated with compressed air discharged from a 2-in. nozzle. At the same time a 1-in. valve was opened, allowing water to enter the air line and thus to wet down the muck pile. In addition to this the fan was started. This sucked the smoke from a point a considerable distance back from the breast.

CREW OF MINERS WHO DROVE THE 24TH LEVEL CROSSCUT IN THE EUREKA MINE



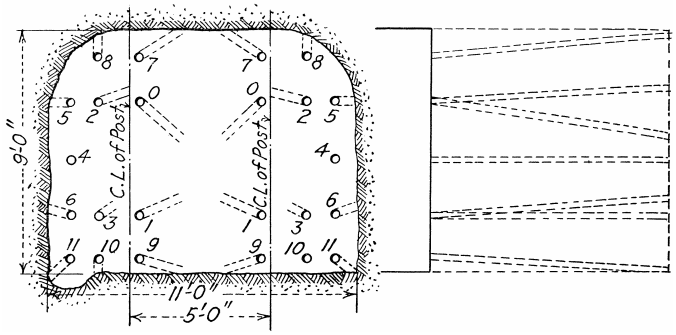
ASSEMBLY OF UNDERGROUND SCRAPER

Fifteen minutes were allowed for ventilating the breast. Following this, while the scraper slide was being moved in, a split iron wedge with a ring attached was driven into a hole in the side of the crosscut; a block attached; and mucking begun. Another hole on the opposite side of the heading permitted moving the block to that side; and two holes in the upper corners of the breast, with a chain between them, made it possible to place the block in any desired position. The holes in the sides of the crosscut were put in about 1-ft. back from the breast while drilling the cut just blasted, and the holes in the upper corners were the bottoms of two extra long holes previously driven into the cut and into each of which a short wooden plug had been inserted before blasting.

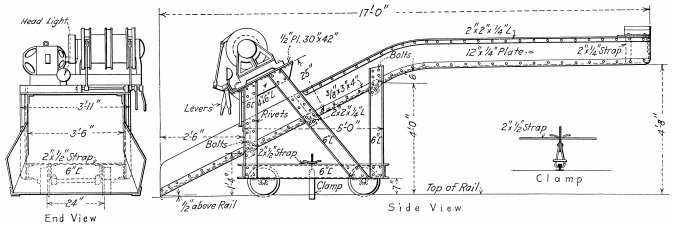
The outstanding feature of the mucking operation was the scraper slide, several of which have been built at the mine shops in recent years at a cost of not more than $1,500, including the hoist. This simple loading device was so efficient that a 60-cu. ft. car of rock, loaded in

about 1¼ minutes, would be on its way to the shaft within five minutes after the miners had entered the place. The wide lip on the slide, with two 4-ton locomotives behind it permitted the loader to be used like a snow plow. The scattered rock on the track was carried to the main muck pile. The slide was equipped with an arrowhead-type, bottomless, box scraper. One switch track was near the shaft; and when the crosscut had been advance 500 ft. it was slightly widened for a distance of 35 ft, thus providing another point where two trains could pass.

While mucking was in progress the crew of eight miners was engaged as follows: one man operating loader, two men tending scraper, two men rearranging drill and equipment trucks at the shaft, two men operating electric locomotives, and one man throwing switch. The two miners whose duty it was to look after the drill truck and to oil the drifters while the six others did the mucking were also required to extend the air and the water lines as the work progressed.



DRILL ROUND USED IN ADVANCING THE HARD-ROCK CROSSCUT



MODIFIED OSANA LOADER EQUIPPED WITH 10-HP. HOIST

In addition to stringing trolley wire and lengthening the blasting line, the electrician and his helper had to install the fan piping, to oil the locomotives and the loader hoist, and to change the cables on the hoist whenever this was necessary. These men worked only on day shifts. When drilling, the bottom corner holes were inclined sufficiently to permit the ditch to be dug' without additional blasting. The two ditchmen were required to clean up alongside the track and to dig the ditch while on an 8-hour night shift. The two trackmen were employed on day shifts.

From 7 a. m. to 7 p. m., the work was under the supervision of N. E. Nilsen, and under Jacob Kettula from 7 p. m. to 7 a. m. All shifts were changed at the working places. The 24 miners in the crew were paid a contract price of $6 per foot of advance, resulting in a rate of approximately $1.03 per hour. All other labor received a daily rate of pay.

After the heading had been driven 712 ft. in the first 22 days, an area of faulted and dangerous ground was struck. This necessitated the installing of timber and forepoling. Progress was therefore considerably retarded; but no chances were taken for the sake of speed. However, the heading was advanced a total distance of 924 ft. in 31 days in spite of the difficulties encountered towards the end of the work.

To quote our superintendent, John M. Price: "The performance in this place was obtained by the operation of four dominating factors. First, supervision; second, organization of the crews so that there was no lost time and no overworking of the men; third, proper equipment; and last, but not least, active cooperation of all departments and the sustained enthusiasm of the entire organization."

LAKE SUPERIOR MINING SECTION, NATIONAL SAFETY COUNCIL.

The following addresses were delivered at the eleventh annual conference held at Duluth, Minn., June 27 and 28, 1929, and have been reprinted by permission of the officers of the Council:

SAFETY AND EFFICIENCY.

BY CHARLES J. STAKEL, ISHPEMING, MICH.*

What is this safety movement all about? Why do we talk safety every day, every time we get together? Is it just a phase of our daily lives, or does it have a greater significance?

In my judgment, the safety work in which we have all been engaged and in which the mining industry has been so outstandingly successful is the most important work of mankind.

Certainly nothing could be more important than safe-guarding our own lives, safe-guarding the lives of our employees, safe-guarding the lives of our associates, safe-guarding the lives of the citizens of the community in which we live to the same extent that we want every one with whom we come in contact to safe-guard our wives, children and ourselves. No more important work can be done by human beings.

As an evidence of the fact that the importance of safety work is generally appreciated, let us reflect that the government and the heads of industries have been and are giving that subject greater thought than any other.

Safety also has its financial aspects, but the prime motive must be the humanitarian viewpoint. An excellent safety performance protects our individual safety and earning power, gives us greater assurance of the success of the business we are engaged in and actually declares dividends for us and our employees.

*Superintendent, Cleveland-Cliffs Iron Co.

In this paper, I am going to endeavor to bring out the relation between productivity and safety.

Let us go back twenty years when the organized safety movement was first started in this country. Prior to that time, there was a deplorable loss of life and limb. Coincident with the beginning of the safety movement the hazards in industry were immediately seduced. Both frequency and severity rates were reduced up to the time we entered the World War. During that period, a great many skilled men entered the service of their country, unskilled workers taking their place. As a result when pressure was brought to bear by the government to increase production, injuries increased. At the close of the war, however, the accident rate continued downward until 1921. Following 1921, as industry gradually increased its pace, accidents went up by leaps and bounds. Casualty insurance companies reporting to the New York insurance department showed in their workman's compensation business in the United States during the years, 1923, 1924, 1925 and 1926, a discrepancy of (44) forty-four million dollars between premiums available for the payment of losses and losses incurred. So unaccountable did this seem, that it was some time before the actuality and seriousness of the changing situation was recognized as well as the necessity for studying it and for taking steps to control it.

About two years ago, therefore, the National Bureau of Casualty and Surety Underwriters proposed to the American Engineering Council, that an investigation be undertaken of the industrial accident situation and that a study be made of the relation between safety and efficiency of production.

Let me just give you a simple example of what is meant by the relation between safety and productivity.

Suppose a piece of timber falls off a truck. The truck will be stopped and the timber replaced and possibly the load will have to be re-piled. That may happen ninety-nine times without hurting anyone and the one hundredth time somebody gets injured. Therefore, although there may be only one case of physical injury, there will still be 99 cases of inefficiency.

The country as a whole, has greatly increased in efficiency in all lines of manufacture, mining and railroading since 1921, but the accident rates have also increased in the last few years.

While there has been an increase in the number and severity of accidents, production has increased so much more rapidly that we produce a ton of ore, a barrel of flour, a pair of shoes, an automobile or a barrel of cement with less loss of life and limb than ever before.

This increased efficiency of production is due to four reasons:

First: Better management.

Second: Through standardization of products and processes.

Third—Through replacement of man power by labor saving devices.

Fourth: By better understanding between labor and management.

Efficiency has been increased in our mines by the installation of mechanical loading devices, such as scrapers which have done away with hand loading. A miner is not as liable to be hurt using a shovel as he is with a scraper outfit, and the use of scrapers with their ropes and blocks have introduced new hazards that must be guarded against.

The question then naturally arises, whether or not, there is a positive correlation between safety and efficiency. Is the safe factory or mine, the efficient one and is the efficient factory or mine, the safest one to work in?

If accidents occur, does it not mean that we have done the work in an improper way? If the right routine is not followed we are not getting the maximum efficiency and at the same time, running the risk of injuring employees.

The connection between safety and efficiency is very close. Any factory or mine that is properly organized should function properly in all its parts. It will be efficient because it is functioning properly. If it is functioning properly, it cannot help but be safe, because safety is characteristic of an industry that is functioning properly. The relation between those two factors is very close because they both spring from the same source. I mean by that, that both are due to good management. How are we going to make our mines function properly? One answer is standardization.

Standardization has been accepted as essential to the reduction of costs and the elimination of waste in industry. The United States Department of Commerce has brought about considerable progress in standardization and in the simplification of products and practices. The American Mining Congress has done a great deal for our own industry in this line. Some of the companies and corporations in the Lake Superior region have held conferences of their operating heads and foremen to fix standards for the operation and installation of the underground haulage system, for handling explosives, for operating scraping equipment, general mining practice, etc.

Although standardization plays its part, we can carry that to the extreme and standardization defeats its own purpose if we forget to try and improve the standards. When standardization becomes an end in itself, rather than merely a means to an end, there is grave danger to the industry. When it is permitted to stand in the way of adoption and use of needed new developments then standardization does more harm than good. Standardization conserves resources, eliminates waste and reduces cost. Research overcomes difficulties, improves the product and increases our knowledge. There must be a constant compromise between these two forces, otherwise there is danger of waste on one hand or stagnation on the other.

Safety and efficiency are also linked together by what is best described as continuity of operation. Everything must move smoothly and in an orderly manner. As an example of what can be accomplished in that line, let me tell you what the Simmons Bed Company has done. In 1919, when there were 700 punch presses operating in one department, (36) thirty-six fingers were taken off in accidents. After making changes in the methods of feed and stock removal, the injuries decreased to seven fingers in the first six months of 1920. In the four years following, not a single finger was lost and production per press had increased on an average of 60 to 65 per cent. The Simmons Company management state that whenever they made a job safe, they increased production from 15 to 150 per cent.

The Simmons Company also found that their presses were not equipped with the right tools and that these tools were not properly taken care of. Dull cutting tools not only will not do their work efficiently, but are more dangerous than sharp tools.

Did you ever watch a miner cut a piece of timber with a dull saw or one that has not been set properly? Improper or insufficient edge or set retards cutting by increasing the friction and, thereby, requires more power. That creates a natural tendency on the part of the operator to force the tool to do its work, thus subjecting both it and him to unnecessary strains. It

tires and provokes him, distracting his attention from the work itself and rendering him more liable to injury. It is likely to cause the material or tool to jam or bind, which in some situations, may be dangerous.

Another angle, essential to efficiency in production, is in the determination of the proper routine of an operation. Any circumstance that interrupts the routine of a normal operation and requires repairs, curtails production and increases the possibility of injury because of the peculiar hazards that accompany repair jobs. Is it not true that most of our bad accidents are due to emergency methods, due to correcting conditions that are not normal? An example of this kind is found in the experience of the Du Pont Powder Company, where most of the accidents, at a particular plant, were due to repairing transmission belts. Because of the accidents that were constantly recurring, a survey of the transmission belts was authorized, resulting in changes in equipment and correcting certain conditions which increased the life of the belts with corresponding reduction in maintenance expense and accidents. In one particular instance, the average life of a certain belt was increased from 9 to 154 days. In the same plant, the grinding equipment was changed and capacity increased 40 per cent. The survey recommending these changes cost $200.00 and resulted in a direct saving of $7,000.00. In the year 1922, 60 per cent of the severity rate of the dye works of the Du Pont Powder Company, was due to emergency methods, that is conditions constituting a departure from the normal.

Sometimes a human factor affects safety and production. The California Industrial Accident Commission reports this circumstance: At the Moccasin power plant of the Hetch Hetchy project a surge chamber 40 ft. in diameter by 160 ft. deep was being constructed of concrete. After the concrete had reached a height of 80 ft., it was decided to stretch a life net between the walls of the chamber to serve the double purpose of saving the life of any workman who might fall from the top and also provide protection for the men below from falling timbers. While the net was installed solely with the idea of affording protection, it actually resulted in reducing the cost of the work because of the added sense of security afforded the workmen which enabled them to speed up all operations in connection with the concrete lining, with the result that the time of concreting a five foot lift was reduced from 56 to 48 hours, an actual saving in labor cost of nearly 20 per cent.

This whole problem, of the relation between safety and efficiency, is summed up in the following questions:

1. Have industrial accidents under the conditions of intense production increased in severity and frequency?
2. If they have increased, are the number and severity of accidents proportionately greater or less than the increase in production?
3. Can accidents be controlled under modern conditions of production?
4. Does safety interfere with production?
5. Does a positive correlation exist between the safety performance and the efficiency of production.
6. Is the safe mine or factory, the most efficient one and the efficient one the safest?
7. Is safety an executive responsibility?

Let us take the first two questions, namely,—Have industrial accidents in the past few years increased in severity and frequency and if accidents have increased, are they proportionately greater or less than the increase in production?

A survey conducted by the American Engineering Council, covering 19 industrial groups comprising 914 different companies employing 513,-083 employees shows that in the past six years, there has been an average increase of production of 24.6 per cent, accompanied by a decrease of 29.8 per cent in accident frequency and 29.5 per cent decrease in accident severity rates.

Another group of 4,773 companies shows an increase of 54.5 per cent in efficiency with a decrease of 35.9 per cent in their accident severity rate, but an increase of 24.5 per cent in the frequency rate for the past eight years.

These two groups combined, covering approximately 83 per cent of all the employees included in the survey, show an average increase in productivity of 33.4 per cent coincident with reduction in both severity and frequency rates of 31.5 per cent and 10.9 per cent respectively.

Perhaps some of us do not know what our neighbors are doing in our own Lake Superior country and in order to show their excellent safety records and increase in productivity, some information regarding these various groups will be of interest.

Group No. 1, consisting of eight mines in Northern Michigan employing 1,425 men in the four-year period 1925-1928, shows an increase of 16.7 per cent in efficiency with a decrease of 66.6 per cent in frequency and 44.6 per cent decrease in severity rates.

Group No. 2, comprising all the mines (26 in number) in Iron County, Michigan, for the four-year period 1925-1928, shows an increase in tons per man of 35 per cent. The number of accidents decreased from 444 to 219, while the total number of compensable days dropped from 21,270 to 13,850 days.

Group No. 3, includes one of the largest operators on the Gogebic range. They show a remarkable decrease in both the number and severity of the accidents at their mines for the years 1925-1928. In four years, the number of accidents per 1,000 days worked dropped 80.2 per cent, while the number of compensable days shows a decrease of 72.8 per cent. During that same period, their tons per man increased 32.7 per cent.

Group No. 4, covers the production and safety records of all the Michigan mines on the Gogebic range. Comparing 1925 with 1928, we find an increase in efficiency of 29 per cent together with a decrease in the accident frequency rate of 37.7 per cent accompanied by a small decrease in the severity rate.

All of these records prove the same facts, namely, an increase in efficiency is invariably accompanied by a decrease in accidents and now only occasionally will you find an operator or manager who is so blind that he does not see the importance of the safety movement.

Whether accidents can be controlled under modern conditions of production and whether safety interferes with efficiency, can best be answered by citing a few more examples.

The United States Steel Corporation in the past thirteen years has decreased its accidents 85 per cent.

The shop employees of the Union Pacific Railway have a safety record five times as favorable as the average for the other large railway systems in the country and that railway company is noted for its high operating efficiency. The Clark Thread Company has a record of approximately 10,000,000 man hours without an accident. One of the plants of the Du Pont Company, employing 65 men, has gone eleven years

with but one minor accident. We have mines in the iron country that have gone approximately 100,000 man shifts with no disability accidents. Those instances I think prove that although modern industrial conditions are making it increasingly more difficult to control accidents, that although we are all driven by competition to intensify our efforts to make our plants more efficient, that despite all that, accidents are being controlled under our modern conditions by the same managerial skill that has made our plants and mines more efficient. Safety does not interfere with production but actually aids it.

Is there a positive relation between safety performance and efficiency of production and is the safest mine the most efficient one?

I don't believe that any of us doubt that increased production is the normal outcome of better and more efficient management and equipment. Is it not true that better safety records are the result of better supervision, a better understanding between the superintendent and captain between the captain and his bosses, and closer cooperation between all of them and the workmen? I believe the safest mine is the one where the bosses are strict but fair, where discipline is enforced and where the standards and rules are rigidly adhered to. I believe the safest mine is one where the bosses, themselves, take the initiative and correct faults without waiting for the captain or the safety inspector to call their attention to unsafe conditions. In the safest and most efficient mine, everybody is trained to keep his place in order at all times. There is no excuse for poor housekeeping because it is reflected not only in the accident record but in careless habits and poor work. Every man must become a watch dog for conditions that may cause accidents. The foreman must instill in his men, habits of cleanliness and orderliness for accident prevention.

Summing up the entire problem, I believe the whole situation revolves around the executive. We can't expect our safety inspectors single handed to make our mines and plants safe. It is up to all of us first to be sold on this safety idea and then teach the lesson to the men under us. It is sometimes difficult to give direct supervision, but past experience and the records of companies that have secured results, prove that better and closer cooperation between foremen and workmen, result in both better safety and production records. None of us can deny the fact that the working man is pleased to have the executive visit him while at work and his influence will be directly reflected in the results secured.

In order to get anywhere with this safety movement, the superintendent or manager himself, must give it his own personal attention. He can't evade the responsibility and let someone else do that job for him.

The results achieved by the companies making the best showing, have not been accidental or casual, but are due to the long continued careful effort on the part of the management.

I believe the hope of the safety movement of the future is in the hands of the chief executive himself. For some time this safety work had the knowledge and approval of executives, but really did not demand their interest or attention. Now they are beginning to realize its great importance and as a result, it has become the chief concern of the management.

For some of the material and figures I have given in this article, I am indebted to the committee on safety and production of the American Engineering Council and also to some of the safety inspectors of the Lake Superior country.

SAFETY WORK AND SAFETY PRACTICES IN METAL MINES.

BY D. HARRINGTON, WASHINGTON, D. C.*

Although metal mines in the United States have a somewhat better general safety record than have coal mines, safety achievements have lagged far in the rear of general mining progress in this country. However, while the past safety record in mining is by no means one on which mining men of the United States can pride themselves, there are at present many hopeful indications in so far as mine safety is concerned. Many of our mining men are now veering away from the almost universal attitude held practically up to the present that "it can't be done," when reference is made to the conducting of mining operations without the annual killing of 3 to 5 persons per 1,000 employed and the maiming of 25 to 40 or even more than 40 per 1,000 employed. One of the best signs of the trend of present-day thought on accident prevention in mines is the fact that there are several mining companies (some in coal, some in metal) that are now conducting all-year campaigns against occurrence .not only of fatalities or serious accidents but also against any kind of lost-time accidents, and some mining organizations have been able to work at full capacity for months without a single lost-time accident; one coal mine in Pennsylvania recently worked for a 17-month period involving 1,208,246 man hours of mine labor and produced over 1,000,000 tons of coal without sustaining a lost-time accident. The Morris-Lloyd mine of the Cleveland-Cliffs Iron Company, near Ishpeming, Mich., recently worked well over a year without any lost-time injuries, and there were nearly 68,000 man shifts involved.

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The cement industry has pointed the way in accident prevention, more particularly in prevention of lost-time accidents, and mining people might well "take a leaf out of the book" of the experience of that industry. In 1923 when it was decided by the Portland Cement Association to give a trophy for the permanent possession of any cement plant which operated through an entire calendar year without a lost-time accident, it was fully expected that none of the 105 plants which entered the contest would be able to take the trophy. When one plant won it in 1924 the opinion then was that this plant had established an all-time safety record for the cement industry, but upon continuing the trophy offer, two plants out of 118 competing took trophies in 1925; in 1926 out of 124 plants in the contest, two won it; and in 1927 there were 10 successful plants out of 136 entered. In 1928 there were 17 trophy winners out of 136 entered, hence exactly one-eighth of the plants entered were able to go through an entire calendar year's operation without a single lost-time accident. One plant has established the enviable record of having operated over three years, employing practically 200 persons, without a lost-time accident, and two others have had over two years' immunity from lost-time accidents. Here is another case illustrating the fact that, even when applied to accident prevention, "It can't be done" is an idea which is out of date in this age when we "pluck" music out of the air, have talking moving pictures, fly like birds, and do sundry other daily acts which 20, 10, or even 5 years ago would have been held impossible. While the cement companies have spent much time, effort, and money in their remarkably successful campaign looking to the elimination of accidents in their plants, they have found that not only has the money as well as the

time and effort expended all been returned in lives, limbs, and human suffering saved, but also the unit cost of the product and production per man has been changed to the definite financial benefit of the stockholders.

While there are a few isolated instances of safe operation of mining plants without the intervention of a working safety organization, these few instances are difficult to find, and by far the best safety results are secured where a definite safety organization has been perfected and kept in operation. There is no question that every mine, large or small, coal or metal, should at all times have an active safety organization directed by the management, but preferably the organization should be such that all classes who work in or around the mine may participate in some way.

The exact form of the safety organization is not nearly as essential as is the necessity to have a definite organization looking toward forwarding mine safety and with the correct spirit behind the organization. One of the essentials without which it is nearly impossible to get real results in mine-accident prevention work is that the mine officials, not only the lower operating ones but, fully as important, those in the higher positions, should be in full accord with the vital importance of mine safety; unfortunately it is often a decidedly difficult matter to secure real interest or cooperation in safety from those "higher up"; in fact, it is usually impossible to secure even their perfunctory interest. There is much foundation to the cynical statement frequently made that if the higher officials were forced to have their offices underground and the board of directors meetings were held monthly in the most dangerous place in the mine, there would be a decrease in accidents in mines amounting to 75 per cent or more. There is no question that the higher mine officials are far more likely to attend meetings relating to taxes, freight rates, or tariff schedules than those concerned with safety; in fact, the mining meetings advertised to discuss safety alone are almost invariably devoid of attendance of general superintendents, general managers, vice presidents or presidents, or members of the board of directors of mining organizations. It is significant that where in the few isolated cases, the "higher ups" are really interested in safety, their mines almost invariably have good safety conditions and good safety records. One of the main reasons that the cement industry has been able to accomplish its really wonderful accident-prevention record of the past few years is that its safety committees, safety meetings, and safety work have not only the financial and moral support of the higher officials but also their physical presence and participation; and curiously enough these higher officials of the cement companies find that this active interest in safety pays them and their companies not only in humanitarian results hut also in dollars and cents, the latter being reflected in decreased costs and increased output.

While efficient accident-prevention work in mining does not necessarily demand the employment of any person or persons solely for safety work, and while it is generally feasible to band the usual operating organization into a smoothly working safety machine, nevertheless there are very few going mining concerns which cannot well afford the so-called luxury of at least one full-time safety employee, as such a man, of the correct type, can much more than save his salary if placed in charge of ventilation, safety, and fire prevention work; all of these mine activities are so intimately connected that one person should logically direct all three. Comparative records of accidents in metal mines of the Tri-State zinc district of Oklahoma, Kansas, and Missouri, as issued by the Accident Prevention Organization of that district, indicate that the companies employing safety engineers produced over 40 per cent of the tonnage of the district and had but about 30 per cent of the fatalities. The report, after quoting statistics indicating material reduction in accidents both fatal and non-fatal, states:

"To those of us who have been watching the accident-prevention work in this district for the past three years, such figures are indeed gratifying and this office wishes at this time to acknowledge the good work of those superintendents, ground bosses, and mill foremen who, by their cooperation with the Safety Engineers, have made such gratifying reductions in accidents possible. We feel that such facts as these prove conclusively that the employment of safety engineers in the Tri-State district has been a decided success both from the humanitarian and the economic viewpoints."

The person placed in charge of safety work should preferably be technically trained, but it is of much greater importance that he should have had sufficient actual experience in mining to be able to know what can be done in the mine towards bringing mine practices as well as methods and installations into line with reasonable safety requirements. In other words, the person in charge of safety work should have a sufficient background of experience to combat the "it can't be done" attitude almost universally encountered when suggestions are made that unsafe but long established practices, methods or installations should be displaced by others which are different but which are likely to be safe. In addition to this background of experience, the man in charge of safety should preferably be physically able to go into all parts of the mine or mines under his jurisdiction, and he should by all means be familiar at all times with the mine or mines and with the personnel. It is futile to place a man in charge of safety and force him to be amenable to those in direct charge of mine operations, who are only too likely to take criticisms or suggested changes of mine safety features as personal affronts. While he should act in harmony with the local operating officials he should be employed by the higher officials, and his reports should go to the higher officials as well as to those in immediate operating charge. An ideal situation obtains where the safety man has operating authority, such, for instance, as being assistant foreman, or assistant superintendent, thus allowing him to enforce on the ground such of his safety suggestions as he judges to be of emergency nature; the safety man to whom this operating authority is given must have had a considerable amount of mining experience and must be possessed of much tact and diplomacy.

There are about as many forms of mine-safety organization as there are mines which have such organization, and while undoubtedly some are more efficient than others, all can do much toward making mining safer, more healthful, and probably more profitable than where no safety organization is in existence. Bureau of Mines Technical Paper 229, entitled "Accident Prevention in the Mines of Butte, Montana," and Technical Paper 452, entitled "Safety Organizations in Arizona Copper Mines," outline a number of well-established and successful safety organizations in copper mines of Arizona and Montana. Data are now being collected for a similar publication covering safety activity in iron mines of the Lake Superior region. Also the Bureau of Mines has issued in Information Circular 6045 a more or less standard form of mine-safety organization for coal mines which when modified to fit in with local conditions could be utilized by any mining company, coal or metal, looking to the establishment of a formal safety organization.

Having formulated a safety organization with at least one person delegated to head it—preferably, though not

necessarily, a full-time safety man—there are any number of different forms of functioning of the organization and of its personnel. Some companies have the safety procedure modelled after the proceedings of our national congress, with two working bodies corresponding to the senate and the house of representatives, the members and officials of which are partly mine officials, and partly representatives of various groups of workers. In other places the safety organization functions somewhat as the law enforcement body of a city or town, with police officials, judges, courts, etc. In some organizations there are committees of officials, in others the committees are composed partly of officials, partly of miners; in others there are committees of employees with or without the safety man as member; and in others the safety man or men shoulder all of the safety work, or there may be modifications or combinations in some form or other of two or more of the above; in all, however, the mine officials must constitute the court of last resort to determine final action taken.

It has been said that safety can be secured and maintained only by everlastingly keeping at it, and this is most certainly true; any relaxation in "keeping at it" is practically sure to result in at least a relative increase in accidents. There are various methods of maintaining safety work; some organizations give a salary bonus to shift or other bosses for good safety records held by the men under their jurisdiction; others assess penalties of one kind or another upon bosses for failure to hold the accident record to or above a certain standard, or there may be various combinations of bonus and penalty systems; in some cases the bonus or penalty is given the individual worker, or possibly to certain groups of workers. There are various competitive methods used, such as placing the safety records of various mines against one another or parts of mines against other parts, which appear to be highly successful, at least in some instances, as they appeal to sportsmanship in one form or another. There is much difference of opinion as to relative merits of bonus as against penalty systems, as well as much opposition to both; experience indicates that both have merit and both can be misused, and it is probable that the ideal system is one which, embodies both the bonus and the penalty idea applied not only to the officials but also to the individual employees.

There is now a fairly widespread opinion among those who are most closely associated with intensive safety work in mining that while there are numerous factors which enter into attempts to secure and maintain reasonable safety in and around mines, by far the most important factor is education and by far the best method to provide widespread education among employees in and around a mine with minimum loss of time to avoid intervening loss of life and limb is the very effective combination of intensive intelligent supervision and careful rigid discipline. Preferably there should be always at or near places where men work a competent supervising official for not to exceed 25 men, and this supervising official should have full authority to enforce immediate execution of any or all instructions but especially those involving safety. Notwithstanding a more or less general feeling against printed safety rules, there is no question that every mining company owes to its employees, including officials as well as other workers, a definite printed statement giving to the various types of workers (drillers, muckers, timbermen, trackmen, mechanics, electricians, shift bosses, mine foremen, etc.) the minimum requirements that the company demands of each and every type of worker or official as to safety. Preferably these safety rules should be issued in pamphlet form, possibly in several languages, and every employee should not only be supplied with a copy of the pamphlet but also be held responsible for having a working knowledge of the data in it. Generally the pamphlet should also contain the essential safety requirements of the State law but since nearly all State laws are woefully inadequate and probably 10, 20, or more years out of date, the company requirements should be much more rigid than those of any State if mines or miners are to be even reasonably safe. Some mining companies now subject employees to regular examination at least once per year as to company rules and the essential features of State law; this or some similar practice should be instituted and kept in operation by all mining companies. One very good method of acquainting the mine employees with current safety requirements is the issuance weekly, or as occasion demands, of multigraphed letters signed by the general superintendent or general manager and the distribution of a copy to every worker at his working place; this method (as well as numerous other good safety practices) was used for years by a large mining company, which issued over 1,000 letters on as many subjects and as a result can show a wonderfully fine accident record for more than half a dozen mines. These are but a few of the numerous effective means of educating mine workers, but by far the best and most definitely productive method is that of intensive supervision and rigid discipline, as there is absolutely no question that if the worker in and around mines is to be kept even reasonably safe, he will be compelled to make any number of changes from past general practice, and about the only feasible method of bringing this about within a reasonable length of time is by discipline.

Since the "proof of the pudding is in the eating" it is likely that specific instances of good safety records will give a fair intimation concerning the relative effectiveness of various safety methods; and at least in some cases this is substantiated. One of the outstanding records in mine accident reduction in recent years is that of the Phelps Dodge Corporation in its four metal-mining operations—the Morenci and Copper Queen branches, together with the Old Dominion and Moctezuma Copper Companies (the Moctezuma Copper Company properties are in Old Mexico). The record is as follows:

Year	Total lost-time accidents	Lost-time accidents per 1,000 shifts
1924	2,386	1.047
1925	1,394	0.629
1926	499	0.228
1927	263	0.123
1928	133	0.064

This record of accident reduction is remarkable not only in number of lost-time accidents but is even more significant in the year-by-year reduction of lost-time accidents per 1,000 shifts; this ratio in 1928 (0.064) was but 6.1 per cent of the figure for 1924 (1.047). Surely a reduction of over 93 per cent in the accident rate in a five-year period is full justification for the elaborate safety organization and intensive attention paid to safety by the Phelps Dodge Corporation from the highest to the lowest official. One of the most significant features of the Phelps Dodge Corporation's exceptionally good record is the fact that the best record of the four component parts of the organization is held by the Moctezuma Copper Company, which is located in Old Mexico and worked almost wholly by Mexican labor, largely under supervision of Americans; the lost-time accident record per 1,000 shifts worked for the Moctezuma Copper Company in 1928 was 0.042, as against the rate of 0.064 for the entire Phelps Dodge Corporation (metal mining). Here is an admirable exemplification of the fact that non-English-speaking miners can be worked safely under rational competent supervision.

The 1928 annual report of the mine inspector of St. Louis County, Minn., has on page 6 a tabulation which indicates that

accident prevention in mining has made remarkable progress, at least in this iron-mining area of the Lake Superior region. This tabulation condensed into periods of years is given herewith:

Years		Average No. Employed	Average No. Killed Per Year	Fatalities Per 1,000
*1905-10	(5)	14,521	72.6	5.00
*1910-15	(5)	15,890	48.0	3.02
*1916-22	(7)	13,240	32.9	2.48
**1923-28	(6)	9,983	18.7	1.87

*Fiscal year July 1 to June 30.
**Calendar year January 1 to December 31.

The foregoing table shows the remarkable reduction in fatalities from 5.00 per 1,000 employed during the years 1905-10 to 1.87 per 1,000 during the years 1923-28. On page 3 the very pleasant information is given that "1928 stands out as a record-breaker for the conservation of life in the industry with which our department has to do." It is stated that during 1928 there were but nine fatalities in the mines of St. Louis County, the best previous record being 15 in 1926; the rate per 1,000 employed in 1928 was but 1.12, which compares most favorably with the rate of approximately 3.5 for the metal mines of the United States. There were produced during the year in St. Louis County 7,179,030 tons of ore from underground mines and 22,525,744 tons from open-pit mines.

Notable recent individual records of metal mines in the United States are rather numerous and a few are given herewith. The fact that the Morris-Lloyd mine of the Cleveland-Cliffs Iron Company near Ishpeming has been able to operate over 380 days for over 68,000 man-shifts without a single lost-time accident is sufficiently noteworthy to allow of repeating this record here. Recently the Berkshire mine of the Brule Mining Company, having worked an average of 177 men throughout the calendar year 1928, a total of 403,487 man hours without a lost-time accident, was awarded the Sentinels of Safety trophy for metal mines for 1928. In the contest three other metal mines were given honorable mention for having operated through the calendar year 1928 without a lost-time accident—the Rogers mine of the Munro Iron Mining Company, Iron River, Mich., the Jay Bird zinc mine of the Commerce Mining & Royalty Co., Miami, Okla., and the Webber zinc mine of the same company in Cherokee County, Kan. Among quarries and open-pit mines the Sentinels of Safety Trophy for 1928 was won by the Wakefield iron mine of the Wakefield Iron Company, Wakefield, Mich., for having worked an average of 125 men a total of 283,680 man hours without a lost-time accident.

The Dunwoody mine of the Orwell Iron Company, Chisholm, Minn., operated its open-pit and underground iron ore property with an average of 150 employees a total of 1,212,386 man hours, producing 2,347,-737 tons of ore, during a recent three-year period without a fatality and with but three lost-time accidents totaling 99 days. This is a wonderful record. Another safety record worthy of particular note is that of the East Vulcan mine of the Penn Iron Mining Company, Vulcan, Mich., where about 200 men worked a total of 925,000 man hours from January 26, 1927, to January 26, 1929, producing 424,109 tons of material from an underground iron ore mine, with no lost-time accidents. The Lucky Bill mine of the Federal Mining & Smelting Co., of Cardin, Okla., operated for a recent three-year period without a fatality and with but four lost-time accidents. Some excellent safety records of mine officials have been brought to light recently. Mine Foreman Muir of Walsenburg, Colo., operated a coal mine from July 27, 1915, to February 21, 1929, with production of 2,475,555 tons of coal without a fatality, and in so far as information is at hand the good record has not yet been broken.

Mr. F. E. Middleton acted as mine foreman or mine superintendent in Pennsylvania for 24 years with but one fatality among the 200 or more men under his jurisdiction.

Numerous other good safety records of various kinds are at hand concerning mining operations, and undoubtedly there are good records which have not been made available outside of the mine or company involved. Unfortunately many mining companies, even in this generation, have the mistaken attitude of secretiveness in connection with their operations, and this foolish policy is applied not only to costs, methods, etc., but also to safety—-including safety practices, equipment, and even good safety records. On the other hand the results of good safety work of many progressive metal-mining companies have been given to the public freely and with benefit not only to the wide-awake organizations studying the information but also to those which released it. Among the many metal-mining companies which have well-established safety organizations in their plants and have accomplished definitely good results, a few are here mentioned: The Tri-State Zinc and Lead Ore Producers Association in and around Picher, Okla., the Phelps Dodge Corporation in Arizona and Old Mexico; the American Zinc Company in Tennessee; the Cleveland-Cliffs Company in Michigan; the Pickands, Mather & Co., in Minnesota.

CONCLUSION.

Volumes could be written pertinent to the subject of this paper, but it appears that safety work and safety practices in metal mines, if made even reasonably efficient, depend primarily on the existence of a definite safety organization (preferably with at least one full-time man in charge) and with education as one of the main features of the method of attacking the problem of accident prevention. The best, or at least the most readily effective, mode of education is through careful competent supervision and rigid but just discipline. Efficient aids toward prevention of accidents in mines are the giving of bonuses to officials or to employees for good records; and in some instances penalty methods assessed against both bosses and workers for infraction of safe practices are of aid; a combination of bonus and penalty systems seems logical. Each company should place in printed pamphlet form its minimum safety requirements with respect to practically each class of workers such as foremen, shift bosses, timbermen, machinemen, trackmen, pipemen, electricians, etc., and preferably these printed pamphlets should also contain the essential requirements of the State laws as to safety; in addition, some methods of examination of all employees as to knowledge of these safety rules should be kept in effect. There should be discussed from time to time the correct procedure in case of fire or similar disaster, and there should be an agreed plan as to the method of handling such affairs with especial regard to safeguarding lives of workers. Every person working in or around a mine should be familiar with standard methods of giving first-aid to the injured. Metal-mining companies should by all means take more precautionary measures toward prevention of fires than have been taken in the past; among these precautions should be careful installation and active supervision of mechanically controlled ventilation, elimination of open lights and substitution of up-to-date electric lights, and more careful installation and use of electricity with especial reference to trolley wires, locomotives, etc. There should be periodical meetings to discuss safety matters brought out by selected speakers or by reports of safety committees; and preferably these meetings, committees, and speakers should include not only mine officials but also the mine workers. Metal-mining practice with explosives is lax in the extreme, and much greater care and much better system should be put into effect in connection with

practically all phases of storage and use of explosives in and around metal mines. All metal-mining organizations should require a thorough physical examination of applicants for employment and should also have all employees physically examined at least once annually, taking suitable action by change of employment or otherwise toward safeguarding the health and safety of those found to have physical defects. The introduction of mechanical loading devices brings to the fore new and different probable causes of accidents in and around mines, and especial thought should be given the safeguarding of the mine worker as well as the mine wherever mechanical equipment (and especially electrically operated mechanical equipment) is placed in mines. These are but a few of the problems and methods of meeting problems connected with safety work and safety practices in metal mines; while dozens of other suggestions might be made concerning what should be done, the main requirement looking to the protection of the health and safety, and even the lives, of mine workers remains in supervision and discipline. It should not be forgotten that not only public sentiment but laws now place upon the employer the main responsibility for protection of the employee.

ESTIMATED IRON ORE OUTPUT IN THE UNITED STATES FOR 1929.

The iron ore mined in the United States in 1929, exclusive of ore that contained 5 per cent or more of manganese in the natural state, is estimated by the United States Bureau of Mines, Department of Commerce, at 73,283,000 gross tons, an increase of 18 per cent as compared with that mined in 1928. The ore shipped from the mines in 1929 is estimated at 75,589,000 gross tons, valued at $197,007,000, an increase of 19 per cent in quantity and of 26 per cent in total value as compared with the figures for 1928. The average value of the ore per gross ton at the mines in 1929 is estimated at $2.61; in 1928 it was $2.46. The stocks of iron ore at the mines, mainly in Michigan and Minnesota, apparently decreased from 9,190,061 gross tons in 1928 to 7,102,000 tons in 1929, or 23 per cent.

The Bureau of Mines estimates are based on preliminary figures furnished by producers who in 1928 mined about 99 per cent of the total iron ore. They show the totals for the principal iron ore producing states, and, by grouping together certain states, the totals for the Lake Superior district and for groups of southeastern, northeastern, and western states.

LAKE SUPERIOR DISTRICT.

About 86 per cent of the iron ore shipped in 1929 came from the Lake Superior district, in which approximately 63,059,000 gross tons was mined and 65,129,000 tons was shipped, increases of 20 and 21 per cent, respectively, as compared with the quantities mined and shipped in 1928. The ore shipped in 1929 was valued at the mines at $174,717,000, an increase of 29 per cent. These totals include the ore from all mines, but exclude manganiferous ores amounting to approximately 1,048,000 gross tons in 1929 and 1,077,705 tons in 1928 that contained 5 per cent or more of manganese in the natural state. The ore is chiefly hematite. The stocks of iron ore in this district apparently decreased from 7,926,199 gross tons in 1928 to 6,101,000 tons in 1929, or 23 per cent. The stocks at the end of 1929 were about 3,000,000 tons less than the average for the preceding five years. The shipments of iron ore by water from the Lake Superior district in 1929 (including manganiferous iron ores), according to the Lake Superior Iron Ore Association, amounted to 65,204,600 gross tons, an increase of 21 per cent as compared with these shipments in 1928. The average value of the ore at the mines in the Lake Superior district in 1929 was $2.68 a ton; in 1928 it was $2.51.

SOUTHEASTERN STATES.

The southeastern states, which constitute the second largest iron ore producing area, including the Birmingham and Chattanooga districts, mined approximately 6,794,000 gross tons of iron ore in 1929, an increase of 2 per cent as compared with 1928. The shipments of iron ore from mines in these states in 1929 amounted to 6,975,000 gross tons, valued at $13,790,000, increases of 8 and 10 per cent, respectively, in quantity and value as compared with 1928. The ore is mainly hematite; brown ore and magnetite come next in order. The average value of the ore produced in these states in 1929 per gross ton was $1.98; in 1928 it was $1.94. The stocks of iron ore at the mines in this group of states, mainly in the Birmingham district, decreased from 1,019,667 gross tons in 1928 to 839,000 gross tons in 1929. These stocks are about 300,000 tons less than the average for the preceding five years.

NORTHEASTERN STATES.

The northeastern states, which include the Adirondack district, New York, and the Cornwall district, Pennsylvania, in 1929 mined 2,235,000 gross tons of iron ore and shipped 2,290,000 tons, valued at $6,897,000, increases of 12 per cent in quantity mined, 7 per cent in quantity shipped, and 3 per cent in value of shipments compared with 1928. The stocks of iron ore in this group of states decreased from 232,030 gross tons in 1928 to 150,000 tons in 1929. These stocks are considerably less than usually carried over at these mines, being about 229,000 tons below the average for the preceding five years. The average value of the ore in these states in 1929 per gross ton was $3.01; in 1928 it was $3.13. Most of this ore is magnetite.

WESTERN STATES.

The western states that ordinarily produce iron ore named in order of their importance are Wyoming, Utah, New Mexico, Colorado, Montana and Washington. Occasionally California, Idaho, and Nevada contribute small quantities. All the ore from Wyoming and Colorado and most of that from Utah and New Mexico is used for the manufacture of pig iron. Much of the remainder is used as a flux in smelting copper and the precious metals. It is estimated that the western states mined and shipped in 1929 approximately 1,195,000 gross tons of iron ore, valued at $1,603,000, an increase of 14 per cent in the quantities mined and shipped and of 3 per cent in value of shipments as compared with 1928. The ore comprises hematite, magnetite, and brown ore.

IMPORTS AND EXPORTS.

The imports of iron ore reported for the eleven months ended November 30, 1929, amounted to 2,853,279 gross tons, valued at $7,369,823, or $2.58 a ton. The imports for the year 1928 were 2,452,646 gross tons valued at $5,428,019, or $2.21 a ton. The reported exports of iron ore for the eleven months ended November 30, 1929, amounted to 1,302,019 gross tons, valued at $4,762,475, or $3.66 a ton, as compared with exports for the entire year 1928 of 1,282,306 tons, valued at $4,797,881, or $3.74 a ton.

The following table shows the quantity and value of the iron ore mined and shipped in the United States by the principal

producing states. The figures for 1928 are final, but those for 1929 are subject to revision.

ESTIMATES OF IRON ORE MINED AND SHIPPED IN THE UNITED STATES IN 1929 AND ACTUAL OUTPUT IN 1928.

District—	Ore Mined (gross tons) 1928	Ore Mined (gross tons) 1929	Ore Shipped 1928 Gross tons	Ore Shipped 1928 Value	Ore Shipped 1929 Gross tons	Ore Shipped 1929 Value
Lake Superior:						
Michigan	13,676,984	15,560,000	14,241,102	$ 37,039,644	16,843,000	$ 47,679,000
Minnesota	37,564,005	45,878,000	38,129,018	94,258,899	46,496,000	122,188,000
Wisconsin	1,284,592	1,621,000	1,394,371	3,700,797	1,790,000	4,850,000
	52,525,581	63,059,000	53,764,491	$134,999,340	65,129,000	$174,717,000
Southeastern States:						
Alabama	6,307,844	6,435,000	6,159,863	11,599,176	6,616,000	12,646,000
Georgia	73,052	63,000	73,052	209,877	63,000	192,000
Missouri	94,899	164,000	94,899	377,847	164,000	647,000
North Carolina	.....	34,000	.....	.....	34,000	94,000
Tennessee	128,928	98,000	128,478	286,524	98,000	211,000
Virginia	27,902	.....	27,970	83,114	(a)	(a)
	6,632,625	6,794,000	6,484,262	$ 12,556,538	6,975,000	$ 13,790,000
Northeastern States:						
New Jersey	250,332	278,000	350,616	1,357,877	281,000	1,170,000
New York	712,757	830,000	767,743	2,906,055	861,000	2,857,000
Pennsylvania	1,023,870	1,127,000	1,013,791	2,441,114	1,148,000	2,870,000
	1,986,959	2,235,000	2,132,150	$ 6,675,046	2,290,000	$ 6,897,000
Western States	1,051,923	1,195,000	1,051,923	1,577,733	1,195,000	1,603,000
Grand total	62,197,088	73,283,000	63,432,826	$155,788,657	75,589,000	$197,007,000

(a) Virginia reported shipments of 232 gross tons, valued at $631.

COMPARATIVE STATEMENT OF IRON ORE SHIPMENTS FROM UPPER LAKE PORTS TO CLOSE OF SEASON 1928 AND 1929.

(Extract from Report of Lake Superior Iron Ore Association—By Permission.)

Port and Dock—	Season 1928	P. C. of Total	Season 1929	P. C. of Total
Escanaba—C. & N. W.	3,884,690	7.20	4,445,775	6.82
Escanaba—C. M. & St. P.	1,602,866	2,97	1,902,798	2.92
Marquette—D., S. S. & A.	758,736	1.41	875,843	1.34
Marquette—L. S. & I.	2,652,166	4.91	3,572,545	5.48
Ashland—C. & N. W.	4,574,275	8.47	5,358,139	8.22
Ashland—Soo Line	1,906,883	3.53	2,261,921	3.47
Superior—Great Northern	13,469,476	24.95	17,355,736	26.62
Superior—Soo Line	1,135,600	2.10	1,373,871	2.10
Superior—Northern Pacific	808,618	1.50	893,532	1.37
Duluth—D. M. & N.	17,454,063	32.34	20,562,705	31.54
Two Harbors—D. & I. R.	5,733,501	10.62	6,601,735	10.12
Total	53,980,874	100.00	65,204,600	100.00
1929 increase	.....	.....	11,223,726	20.79

Season—		Season—	
1920	58,527,226	1925	54,081,298
1921	22,300,726	1926	58,537,855
1922	42,613,229	1927	51,107,136
1923	59,036,705	1928	53,980,874
1924	42,623,572	1929	65,204,600

TONNAGE OF LAKE SUPERIOR IRON ORES ON HAND AT FURNACES AND LAKE ERIE DOCKS JANUARY 1ST, 1929 AND 1930.

	Central District Furnaces	Eastern Furnaces	Lake Front Furnaces (a)	All-Rail Furnaces	Total
Ore on hand at furnaces January 1st, 1930	14,684,883	795,909	15,368,092	654,423	31,503,307
Ore on hand at furnaces January 1st, 1929	13,481,329	701,981	14,519,956	748,602	29,451,868
Ore on Lake Erie docks January 1st, 1930	6,022,317	120,247	.....	.....	6,142,564
Ore on Lake Erie docks January 1st, 1929	5,669,624	25,596	.....	.....	5,695,220
Total ore on hand at furnaces and Lake Erie docks January 1st, 1930	20,707,200	916,156	15,368,092	654,423	37,645,871
Total ore on hand at furnaces and Lake Erie docks January 1st, 1929	19,150,953	727,577	14,519,956	748,602	35,147,088
Total number of furnaces represented above, 1930	127	31	90	11	259
Total number of furnaces represented above, 1929	133	27	97	11	268
Number in blast on last day of December, 1930	64	15	53	7	139
Number in blast on last day of December, 1929	88	11	64	8	171
Decrease December 31st, 1930	24	4*	11	1	32

(a) Including Canadian Furnaces. *Increase.

BALANCE OF IRON ORE ON DOCK AT LAKE ERIE PORTS APRIL 1, 1929—RECEIPTS FOR THE SEASON—BALANCE ON DOCK JANUARY 1ST, 1929 AND 1930.

	Dock Balance April 1st, 1929	Receipts for Season, 1929	Dock Balance January 1st, 1929	Dock Balance January 1st, 1930
Buffalo, North Tonawanda, Port Colborne	2,470	5,411,640	3,433	32,817
Erie	59,645	1,410,016	59,645	121,810
Conneaut	1,320,318	9,570,557	1,734,035	1,871,955
Ashtabula	1,279,618	8,872,566	1,996,654	2,062,972
Fairport	188,090	2,415,771	298,610	400,107
Cleveland	922,498	11,148,363	1,081,366	1,123,802
Lorain	60,224	3,847,799	71,538	120,157
Huron	343,434	1,183,879	387,225	364,959
Toledo	47,051	1,911,981	62,714	43,985
Total	4,223,348	45,772,572	5,695,220	6,142,564

BENEFICIATED ORE—SEASON 1929.

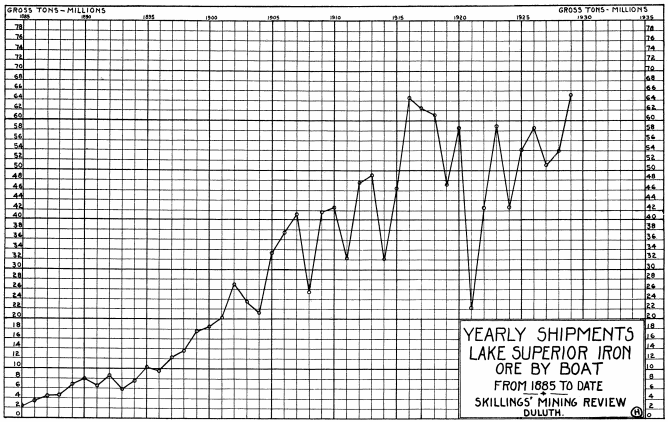
Method of Beneficiation—	Minnesota	Michigan and Wisconsin	Total
Washing	5,874,028	.....	5,874,028
Jigging	84,000	.....	84,000
Drying	341,759	.....	341,759
Sintering	224,063	.....	224,063
Total concentrated	6,523,850		6,523,850
*Crushing and screening	9,455,553	6,960,358	16,415,911
Total beneficiated	15,979,403	6,960,358	22,939,761

*Improves physical structure only.

SHIPMENTS FROM LAKE SUPERIOR COPPER MINING COMPANIES FOR YEAR 1929.

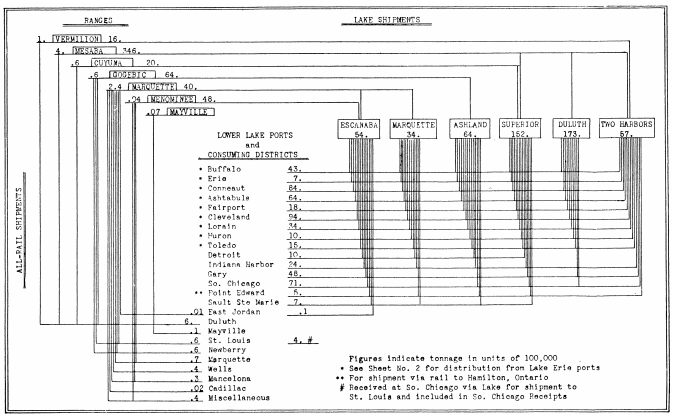
	Pounds
Calumet & Hecla Consolidated Copper Company (including Isle Royale Copper Company)	134,694,085
Copper Range Company	25,146,698
Mohawk Mining Company	13,926,450
Quincy Mining Company	4,459,426

NOTE:—The figures given above are shipments from smelters, and not production. The Quincy Mining Company has been working on a development program, and has done a very limited amount of mining.



The year 1929 witnessed the largest amount of Lake Superior iron ore shipped to lower lake ports by boat that has ever been freighted: 65,195,595 gross tons. The previous high record for lake transportation was during the war (1926) when 64,734,280 gross tons of iron ore was carried down the lakes.

DISTRIBUTION OF LAKE SUPERIOR IRON ORES FROM RANGES THROUGH UPPER LAKE PORTS TO LOWER LAKE PORTS AND DIRECT ALL-RAIL TO CONSUMING DISTRICTS—SEASON 1928



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BIOGRAPHICAL

FRANK. CARBIS

Frank Carbis was born at Tremar Coombe, Cornwall, England, August 29th, 1850. His early work underground began in the copper mines of Cornwall, where he was first employed at the age of nine years.

Captain Carbis migrated to the United States in the year 1869, landing in Cleveland on July 4th, from where he went direct to the Copper Country, in Michigan, securing employment at the Quincy mine where he remained about one year. He later worked in the mines in Pennsylvia and Virginia and spent some time in the gold mines in Nevada, finally coming to Michigan and locating in Iron Mountain, in 1882, where he procured work as a miner in the Chapin mine. He later was employed as mining captain by the Hamilton Ore Company operating the Hamilton mine at Iron Mountain and remained at this property until it was flooded in the fall of 1892. Subsequent to this period and up to the year 1923, at which time he retired from active work, Captain Carbis was in charge of operations as superintendent at the Traders mine, an open pit property just outside of Iron Mountain, Mich.

During his residence in Iron Mountain he held many public offices, was a much respected citizen and had many friends. He died April 9, 1929.

FRANCIS HARVEY COHOE

Francis Harvey Cohoe was born at New Durham, Oxford County, Ontario, Canada, on May 4th, 1868, of Quaker parents. His father owned a farm at that place and Mr. Cohoe was raised thereon. In 1891 he was married to Elsie Clarabel Kelley and during the following eleven years operated a farm of his own in the same community as that of his father.

In 1902 Mr. Cohoe sold his farm and with his family came to Minnesota, locating at Hibbing and going to work for the Oliver Iron Mining Company at the Hull mine as supply clerk and timekeeper. He continued in the employ of the Oliver Company from June, 1904, to August, 1914, when he went with the Arthur Iron Mining Company at Chisholm. In July, 1917, he became general superintendent for the Hanna Ore Mining Company in the Hibbing-Chisholm district where he was employed up to the time of his death. Mr. Cohoe contracted pneumonia on May 10, 1929, and died at his home at Hibbing on May 18, 1929.

ROBERT W. CREER

Robert W. Creer was born in Onchan Village, Isle of Man, England, on February 15th, 1866. He attended the village school until the age of 14, when he started to work as a blacksmith apprentice, serving a term of five years, then continued working at the trade, with the same employer for three years. He then moved to another part of the island where he was employed as blacksmith at one of the lead mines, for a period of four years.

He then, in 1892, came to the United States, going to Ishpeming, Michigan. He went to work as miner at the Salisbury mine, where he worked for nine years. He then went to work at the Mansfield mine at Crystal Falls, Michigan, as shift boss, working there until the mine closed. He then returned to Ishpeming and worked as miner at the Lake Angeline mine, for a period of six years. He then accepted a position as mining captain for the Oliver Iron Mining Company, at the Mississippi mine at Keewatin, Minnesota, where he was employed for a period of two years. Mr. Creer was then

employed by the M. A. Hanna Company at Chisholm, Minnesota, as mining captain in charge of shaft work.

He was transferred by the company in the fall of 1911 to Crystal Falls, Michigan, to take the position of mining captain at the Carpenter mine. He held this position until 1925, when he, on account of his health, was retired. He resided in Crystal Falls until the date of his death, January 8th, 1929.

Mr. Creer was always interested in community affairs and always willing to assume any duties required of him.

SOLOMAN S. CURRY

Born June 12, 1839, at Lancaster, Ont.

He received as much of an education as the local schools afforded and at twenty years of age worked as an apprentice in a blacksmith shop and learned that trade.

In the book entitled "The Calumet Conglomerate," by Edwin J. Hulbert, he speaks of having with him in 1859 exploring for the Calumet & Hecla mine, Soloman Curry as chainman. A picture taken in 1863 shows Mr. Curry in a party of explorers for the St. Mary's Canal Mineral Land Company at Marquette.* This party was under the direction of Henry F. Q. d'Aligny who was in charge of the Company's affairs at that time and who also is in the group. These facts seem to show that Mr. Curry was very active in the explorations being made in the Lake Superior region during the years 1859 to 1865.

About 1865 he moved to Ishpeming where he was employed driving team, oxen and horses, at the open pit of the Lake Superior mine. At this time the ore was hauled out of the pits with teams instead of machinery. The panic of 1873 caused the closing of the mine, leaving him with his equipment on his hands. He then went into the grocery business which also turned out disastrously.

In 1879 he went to the then new Menominee Range and opened the Curry mine. He was also interested at about the same time in the Beaufort and Titan mines on the Marquette Range.

In 1881 Mr. Curry went to the new Felch Range and opened the Metropolitan mine. Eventually he became president of the Metropolitan Iron & Land Company. In 1885 this Company acquired the Norrie mine at Ironwood from A. Lanfear Norrie and commenced operating that property as well as the East Norrie mine, and later the Pabst, Davis and Puritan mines.

He made Ironwood his home, remaining there after the mines in which he was interested were sold to other interests.

Probably few men were as long connected with the development period in the Northern Peninsula as he. He always had the courage to follow his judgment and back the same with his money and effort and in doing so reaped a rich reward. In politics he was a Democrat of the old school, representing Marquette County in the State Legislature at one time and becoming his party's candidate for Lieutenant Governor in 1886.

In his long life he made many staunch friends and associates and retained them until the end.

He died at Ironwood, Michigan, July 29, 1929.

*NOTE—This photograph is published in Vol. XIX, 1914.

ALTON L. DICKERMAN

Born in Stoughton, Mass., in 1850. Graduated from Tufts College in 1869 and completed his education as mining engineer at Friburg, Saxony. Upon his return to the United States he joined the Northern Pacific Railway as consulting mining engineer.

His first active connection with the mining industry of the Lake Superior region was when he came to Ironwood in 1888 as a representative of Charles L. Coulby. He had charge of the various mines of the Penokee & Gogebic Development Company and later was interested in mines in Washington and Montana.

In 1890 he was given general charge of all of the Rockefeller mining interests along the line of the Northern Pacific and the Michigan Ranges, being interested in the development and operation of the Ashland, Aurora, Tilden, Superior and Comet mines.

About 1895, on account of the health of his wife, he moved to Colorado Springs, Colorado, and lived there until his death on September 15, 1921.

MURRAY MORRIS DUNCAN

Murray Morris Duncan was born in Washington, D. C, May 10, 1858, the son of Maria L, Morris and the Rev. Thomas Duncan, D. D. After attending school in Washington, he entered Lehigh University in 1875 and was graduated in 1880 with the degrees of engineer of mines and analytical chemist.

Mr. Duncan was first employed by the Cambria Iron Company, at Johnstown, Pa., as assistant chemist. He left there for Chattanooga, Tenn., where he entered the employ of the Roan Iron Company, first as chemist then being promoted to superintendent of the open hearth furnaces. He later served this same company at Rockwood, Tenn., being in charge of the blast furnace, ores and fuel. In 1891 he left the Roan Company to become general manager for the Cardiff Iron Company, which was then building furnaces and opening mines at Cardiff, Tenn.

In 1892 Mr. Duncan went to Michigan as general manager of the Antrim Iron Company, which operated a charcoal blast furnace at Mancelona. In 1897 he became agent for the Cleveland-Cliffs Iron Company, with headquarters at Ishpeming. In 1908 he succeeded the late Peter White as a director. In 1916 he was named vice-president and general manager of mines. He resigned the general managership in 1928, but continued as vice-president until the time of his death, December 17, 1928.

An exceptional leader and executive, Mr. Duncan played a large part in developing the Cleveland-Cliffs Iron Company into the strong industrial concern which it is today. His activities outside of the affairs of the company were numerous and varied. For many years he served as a member of the Board of Control of the Michigan College of Mining and Technology, the Carnegie Library Board, Ishpeming; the Ishpeming Board of Public Works and the Marquette County Road Commission. He was over a long period of years the Chairman of the Republican Congressional Committee. He was President of the Miners' National Bank? Ishpeming, and during the World War served on several of the district war boards.

Mr. Duncan held membership in the American Institute of Mining & Metallurgical Engineers for 44 years. He joined the Lake Superior Mining Institute in 1907 and was its President in 1908-09, when he called attention to the "urgent necessity for a change in the laws governing personal injury." He was a

member of the American Iron & Steel Institute and of the American Mining Congress. He also belonged to the Aztec Club, of Washington, D. C, and the University Club, Chicago. He was honored by the Masonic order with the thirty-third degree in recognition of his services. He was a staunch member of the Episcopal church and the President of the Department of Finance of the Diocese of Marquette. His entire life was a most active one.

Mr. Duncan was married in 1881 to Hariette DeWitt Coppee, daughter of Dr. Henry Coppee, the President of Lehigh University. To them were born three children, William Duncan, Pauline Duncan Gervin and Helen Duncan Hyde.

ADELBERT D. EDWARDS

Adelbert D. Edwards, aged 72, an outstanding figure in the political, social and mining life of the Copper Country for forty-six years, died at his home at Atlantic Mine, April 1, 1928.

He was born in Lincklaen, Chenango County, New York, June 15, 1856, of American parentage. He received his early education in the district schools and at the age of sixteen taught school, working on a farm during vacations. He attended the Cincinnatus Academy, Cortland, New York, and graduated from the Michigan State Normal College at Ypsilanti in 1882. After his graduation from Ypsilanti he came to the Copper Country to teach, but soon gave up teaching for book-keeping, and was chief clerk of the Atlantic Mining Company for over twenty years.

During his early residence in Adams Township he held the offices of Township Clerk, Township Treasurer, and Justice of the Peace. In 1897 he was elected Supervisor from Adams Township, a position which he held for seventeen years, from 1905 to 1914 as Chairman of the County Board.

In the fall of 1907 Mr. Edwards was elected Representative in the State Legislature from the third district of Houghton County. He served as legislator four consecutive terms and his record won him recognition from the leaders of all parties. He was closely identified with the public schools, was for a time County Commissioner of Schools, and at the time of his death Secretary of the Adams Township Board of Education. He was also President of the South Range Bank, and a director of the Houghton and Upper Peninsula Building and Loan Association, and the Houghton Masonic Building Association. Mr. Edwards never married.

GUY B. EDWARDS

Guy Banker Edwards was born at Gloversville, N. Y., on April 6, 1875. He graduated from the civil engineering course at Union College, Schenectady, N. Y., in 1895.

From 1895 to 1906 he was assistant engineer at Gloversville and from 1906 to 1911 he worked for landscape architect firms.

In 1911 he became resident engineer of the Iowa Engineering Company at Clinton, Iowa, in which position he was in charge of asphaltic concrete paving and sewer system and disposal plant construction. Later he accepted a position as resident engineer in charge of water supply developments for Akron, Ohio, remaining there until 1916. From 1921 to 1923 he was employed by A. D. Taylor of Cleveland in charge of general construction work and as resident engineer of several housing developments on the Gogebic Range.

He entered the employ of the Oglebay Norton Company in September 1923 as efficiency engineer and remained with that Company until his death November 4, 1927.

JOHN LUTHER HARRIS

John L. Harris, who occupied a prominent place in the civic and political life of the City of Hancock and in the mining industry of the Copper Country, was born in Eagle Harbor, Keweenaw County, Michigan, June 21, 1868. He was a member of the first class to enter the Michigan Mining School in 1886, and was graduated with a Bachelor of Science Degree in 1888, and in 1916 was granted the Degree of Engineer of Mines as a recognition of his valuable contributions to the mining industry. Mr, Harris was also a graduate of the Massachusetts Institute of Technology. As mining engineer for the Quincy Mining Company he became thoroughly acquainted with this property and in 1900 succeeded his father as superintendent, which position he held for three years. He resigned to become superintendent of the reorganizd Hancock Mining Company, retiring after fifteen years of service with that company.

Mr. Harris was for a number of years President of the Alumni Association of the Michigan College of Mines, a member of the County Board of Supervisors, and at the time of his death he was Chairman of the Hancock Republican Committee. His death on January 1, 1927, removed from the district one of its most useful and highly respected residents.

SAMUEL B. HARRIS

Captain Harris was born near Camborne, Cornwall, England, December 18, 1834. Born in a section noted for its miners, he came from a family of this vocation, both his grandfather and his father, Benjamin Harris, having been miners in the Cornwall mines.

As a boy, Captain Harris attended the national schools until his eleventh year when he became assistant to a mine surveyor and assayer. Four years later he became a miner and remained at that employment until he was nineteen years of age, when he came to America. He obtained his first work in this country at Dodgeville, Wisconsin, in the lead mines, working on speculation and being paid pro-rata for what ore was recovered. Having spent his spare time studying he took an examination and was granted a teacher's certificate. He taught a district school until 1856, when he again returned to mining, this time at the old Minnesota mine in Ontonagon County, Michigan. Two years later, with a party of three, he went to the gold fields of Nova Scotia, which were then being opened and which promised great fortunes to adventurers.

His stay in Nova Scotia lasted only three months and upon his return to the Copper Country he went to work as a miner in the Phoenix mine. Returning to Dodgeville, Wisconsin, shortly afterward, he became principal of the public schools of that city. After two years of teaching he again returned to mining securing a contract at the Isle Royale mine. Later he worked at the Mesnard and Pontiac mines, now a part of the Quincy Mining Company, where in 1864 he was made mining captain. His next position was as mining captain of the Phoenix mine, then as agent for the Eagle Harbor property with several mines under his management. After two years he resigned to become assistant mining captain at the newly organized Calumet & Hecla mine. This position he resigned after a year and a half to become agent of a group of mines in Ontonagon County including the Ridge, afterwards the Mass, the Adventure and others. He was agent of this group for thirteen years resigning in 1882 to accept the superintendency of the Quincy Mining Company. He remained in this position until 1904, when he resigned and retired from active business life, making his home in Hancock until his death. His position at the Quincy was taken by his son, John L. Harris.

Captain Harris was a life-long Republican, and held the office of Supervisor of Quincy Township from 1884 until 1904. He was at one time President of the First National Bank of Hancock, President of the Detroit and Northern Michigan Building & Loan Association and also a Director of the Peninsula Electric Light & Power Company.

His death October 18, 1927, at the age of 93 years, marked the passing of the last of the pioneer mining men who were responsible for the development of early mining projects in the Michigan Copper Country.

JOHN H. HICOK

Mr. Hicok was born in Homer, New York, May 14, 1868. He came to the Michigan Copper Country in 1892 as a newspaper reporter. Later he was clerk at the Wyandotte mine for three years, returning to Hancock to become manager of the Portage Coal & Dock Company office in Hancock and the Pickands Mather branch in Marquette, a position held at the time of his death. He was a director of the First National Bank of Hancock and the First National Bank of Calumet, served for several years as a member and President of the Hancock Board of Education and was Secretary and Treasurer of the Hancock Consolidated Mining Company from the time of organization.

Mr. Hicok was a man of integrity, keen business acumen and strong will-power. These traits contributed to his rapid advancement in business circles and to his success in handling responsibilities. He was of retiring disposition, never seeking the spot light and accepted positions of public trust in response to wishes and activities of friends, rather than of any effort on his part.

His sudden death as a result of a hemorrhage of the brain, August 19, 1927, removed from the community a man who ever had the interest of the city and district as a whole at heart.

THOMAS HOATSON

Thomas Hoatson, of Laurium, Michigan, well known capitalist and mining man died in Phoenix, Arizona, where he had been spending the winter, February 1, 1929. Mr. Hoatson was Vice President and a Director of the Calumet & Arizona Mining Company and the New Cornelia Copper Company; and a Director of the Verde Central Copper Company, the Merchants & Miners' Bank of Calumet, and the Keweenaw Copper Company.

"Captain Tom" as he was familiarly known by his intimate friends, usually spent his winters in Arizona and his summers in the Copper Country. He maintained a cottage at Bete Gris in Keweenaw County, where he spent much of his summers and where he delighted to hunt and fish, roam the woods, and entertain a host of friends by whom he was loved, Iris genial personality endearing him to all.

Mr. Hoatson was born in Canada in October, 1861, and came to Michigan's Copper District with his parents in 1872. His father, Thomas Hoatson, Sr., was superintendent of the Calumet & Hecla Mining Company. Thomas Hoatson, Jr., was for a time a mining captain for the C. & H.

Captain Hoatson was widely known and respected for his ability in the mining profession, his reputation in mining circles being nation wide. Although he maintained his residence in the Michigan Copper Country and kept up a deep interest in local enterprises, he did much in the way of development of copper mining in the Southwest. He, with his brother, James Hoatson, and Charles Briggs of Calumet, organized the Lake Superior & Western Development Company, now the Calumet & Arizona. This was the beginning of a long list of developments, in that section.

His death, in a Phoenix, Arizona, hospital, which was caused by a respiratory ailment, followed a considerable period of ill health. Mrs. Hoatson, three sons and three daughters survive him.

ALFRED OWEN JOPLING

Alfred Owen Jopling was born near London, England, January 12, 1852. Most of his early years were spent in Italy where his father, Charles M. Jopling, a civil engineer, was building railways afterwards known as the Italian Central, in which he was a partner of the firm headed by Mr. Thomas Brassey, the father of Lord Brassey who later bought the Michigan Iron & Land Company's property in the Upper Peninsula.

Alfred's early life in Italy started his taste not only for music but also for his accomplishment in drawing. He was not only a good draughtsman in engineering but at one time was offered a position of illustrator for the press. After schooling in England he emigrated to Canada in 1870 with his brother Harold and they were employed there by old business associates of their father.

First in Montreal and later in Toronto he was engaged in the building of railroads.

In 1880 he came to Marquette, Michigan, to work on the survey of the Detroit, Mackinaw & Marquette Railroad, now a part of the Duluth, South Shore & Atlantic system. Later he was engineer in construction of the first 20 miles of railway east of Marquette. He was brought to Michigan by the Hendries, who later took the contract to build the line. Sir John Hendrie was later Lieutenant Governor of Ontario.

In October, 1881, he married Mary Hewitt, the daughter of the late Peter White, the banker of Marquette. In September, 1882, he became a partner in the heavy hardware business of C. H. Call & Co. which bought out the business of Pickands & Co. In 1896 he disposed of his interest in the business. He attended to the landed property of his father-in-law, Peter White. He became associated with the Cleveland-Cliffs Iron Company about 1901, being employed as civil engineer on the surveys for that company's railways. Later he was put in charge of that company's developments on Grand Island, where he built the roads and converted the old Williams house into a hotel. He also built a cottage on Grand Island where he continued to reside for part of the year.

For Alger County he became Chairman of the Road Commission. About 1908 he was appointed by the Governor of Michigan as a member of the Mackinac Island State Park Commission. The present superintendent, Mr. Kenyon, has spoken words of high appreciation of his work. He was a vestryman of St. Paul's Episcopal Cathedral, Marquette. He was a charter member of the Marquette Club and was a Rotarian for several years. He was a Director of the First National Bank. He died January 4, 1929.

FRED W. NICHOLS

Born in Waterdown, Canada, on April 21, 1865, Mr. Nichols came to the Michigan Copper Country with his parents when a child five years of age, residing here until his death. He was prominently identified with civic affairs of Hancock and Houghton. He led in the Liberty Loan campaigns conducted during the World War and was connected with many other activities of a similar nature. He was a generous contributor to charity. Both he and Mrs. Nichols were accomplished musicians and the Nichols' residence in East Houghton was

the headquarters of the St. Cecelia Club, and the musical center of the Copper Country.

Following his graduation from Oberlin College he became identified with the St. Mary's Mineral Land & Canal Company and for twenty years was in charge of the Company's lands and operations.

His death, November 15, 1928, following an illness of only twenty-four hours was due to an acute heart attack, was entirely unexpected, and came as a severe shock to the community where Mr. Nichols had won for hmiself the respect and admiration of a legion of friends.

HORACE BUSHNELL PATTON

Horace Bushnell Patton, Ph.D., Professor Emeritus of the Colorado School of Mines, died at Atascadero on July 15, 1929, after an illness resulting from an operation for appendicitis. He was born in 1857, graduated from Amherst in 1881 and after a couple of years at Howard University, of which his father, Rev. W. W. Patton, was for many years president, he went to Europe. He studied geology (and especially petrography) first at Leipzig under Zirkel, then at Heidelberg in Rosenbusch's laboratory, where I first met him and had the pleasure of field excursions with him, not always geological, I remember.

Returning to America in 1888, after brief teaching appointments at Howard University and Rutgers, 1889, he was again associated with Dr. L. L. Hubbard and myself in more congenial work, combining research and teaching for the Michigan Geological Survey and Mining School at Houghton. His research here was largely petrographic and was to have been correlated with work by Dr. Wadsworth, which the latter's resignation as state geologist upset. However, there are a few pages signed by him in Wadsworth's 1892-93 report. Dr. Patton then accepted a call to the Colorado School of Mines and remained there nearly a quarter century, from 1893 to 1917. For a time he was acting President.—Alfred C. Lane, Tufts College.

FRED M. PRESCOTT

He was born in Denver, Colorado, on September 30, 1863 and was the son of D. Clint Prescott, who for a long time operated the Marinette Iron Works at Marinette, Wisconsin.

Fred M. Prescott graduated from Cornell College in 1885. Returning to Marinette he worked in the machine shop and draughting room of the Marinette plant until June 1886, when he went to Ironwood and opened a General Hardware and Mining Supply Store, acting as selling agent for the Marinette Iron Works and also the A. S. Cameron Steam Pump Works in connection with his general business.

In 1892 he started the manufacture of steam pumps at his father's plant, the Marinette Iron Works, at Duluth, Minnesota. Sometime later he changed his point of manufacturing to Buffalo and in 1895 he embarked in the manufacture of steam pumps and pumping engines in Milwaukee, forming the Fred M. Prescott Steam Pump Company. This business became so successful and its products of such widespread importance that in 1910, that Company became part of the International Steam Pump Company of New York. Mr. Prescott withdrew from the Company in 1912. In 1914 he resumed the manufacture of pumps in Menominee, Michigan, and continued until the time of his death. During the World War he was engaged in manufacturing engines for some of the small naval vessels.

In 1887 he married Miss Luella Stimson and to them were born three sons, Curry S., Fred H., and James C. His unusually kind disposition attracted all who met him in a business or social way. He represented a high type of business integrity. His fund of humor always made his companionship greatly enjoyed and his loyalty and kindliness to his friends made him greatly beloved. Although not directly connected with the mining industry, on account of his business he had a very wide acquaintance among the mining profession both in the vicinity of Lake Superior and through the West and Southwest.

His death occurred on October 18th, 1928.

W. A. RANKIN

Born in Ohio in 1857, Mr. Rankin spent his early life in that state, graduated from a medical college and for a number of years was a practicing physician. This work was not to his liking and he again went to college and studied electrical engineering. In 1902 he came to the Michigan Copper Country as electrician for the Michigan Smelting Company. Four years later he joined the staff of the Copper Range Company as Chief Electrical Engineer a position which he held for twenty years.

He was accidentally killed on the night of May 15, 1926, while working at the Copper Range substation. Although there were no witnesses to the accident, it is believed that he came in contact with a live line carrying 30,000 volts.

FREDERICK WILLIAM RIDLEY

Mr. F. W. Ridley was born at New Castle on the Tyne, England, in 1874. His father, James Cartwell Ridley, was a steel manufacturer in New Castle. His early education was received in a private school, Giggtiswick, Yorkshire, England, and Durham College of Science, New Castle, England. In 1891 he came to America and entered the Michigan Mining School from which he graduated with a Degree of Engineer of Mines in 1894.

Following his graduation from college he was employed by the Calumet & Hecla Mining Company as Assistant Mining Engineer; as Superintendent in turn of the Gratiot Mining Company, the Allouez Mining Company, and the Centennial Copper Mining Company.

His death at the Presbyterian Hospital in Chicago, May 20, 1927, ended a faithful service of thirty-three years, all of which was spent with the Calumet & Hecla Company and its subsidiaries.

FRANK SCADDEN

Frank Scadden was born in Cornwall, England, on November 27th, 1858, and died in Crystal Falls, Michigan, on September 6th, 1929. He came to America in 1875 at the age of 17 years, going first to Virginia City, Nevada, then to San Francisco, California, and from there to Negaunee, Michigan, where his sister resided. While in Negaunee he became acquainted with Captain C. T. Roberts, who shortly afterwards moved to Crystal Falls to take charge of the Paint River mine, which was one of the mines being opened up in that new mining district. One of the first schools to be established in that district was located near the Paint River mine, and in 1882 Captain Roberts engaged Mr. Scadden to become the teacher of that school. He soon worked away from school teaching and went to work at the Mastodon mine as Office Clerk. Later he became interested in the stock of the Paint River Mining Company and was made Superintendent of its mine and the adjoining Monitor mine. In 1893 the Company with which he was associated acquired the lease of the Shafer mine and

renamed it the Columbia mine and operated it for some years, and in 1897 the same Company acquired the lease on the Mansfield mine property, which property had been idle for some time, due to the caving of the mine, which was directly under the Michigamme River. This Company dug a new channel, diverting the river to a safe distance on the footwall, and Mr. Scadden was in charge of the property when this work was being done. Later he was Superintendent of the Hollister Mining Company, which operated the Hollister mine, and also had charge of various explorations in the Crystal Falls district.

Mr. Scadden has held various Township, City and County Offices and was always active in all efforts to promote the welfare of the community in which the larger portion of his life was spent. He was greatly interested in the Masonic Order, and has filled many prominent offices of that order.

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