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A comparative analysis of some recent mining practices in the Tri-State Mining District

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A COMPARATIVE ANALYSIS

OF

SOME RECENT MINING PRACTICES

IN THE

TRI-STATE MINING DISTRICT

BY

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A

THESIS

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PREFACE

This thesis is submitted to the Faculty of the School of Mines and Metallurgy of the University of Missouri in partial fulfillment of the work required for the degree of Master of Science in Mining Engineering.

It embodies the results of an investigation, by the time-study method, of underground drilling and transportation mining practices in the Tri-State Zinc and Lead District of Missouri, Oklahoma, and Kansas.

The field work was carried out in the late summer of 1944, and the data and results presented herein apply to the practices in effect at that time.

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INTRODUCTION

The Tri-State District, encompassing contiguous corner portions of Southwest Missouri, Southeast Kansas, and Northeast Oklahoma, has been, for many years, the leading zinc producer of the United States. However, rising labor costs and decreasing grade of ore reserves have meant that many of the mines gradually have become marginal in the economic character of their operations. In an attempt to counteract these adverse effects, steps were taken to attain lower cost mining methods, and mechanization has been introduced over a period of years. Further, the research program of the Eagle-Picher Company, the leading producer of the district, has been accelerated inasmuch as it became expedient to open new mines and to rehabilitate some abandoned properties under the stimulus of war demand.

Clarke[1], recently, has given a concise account of the modified mining methods used and therein came the first hint of a radical change in drilling practice. The old method of drilling using a post (or column) was expensive not only of effort but also of time. In overcoming this disadvantage two main problems immediately were present; first, that of achieving increased production at the time of a man-power shortage because of the war, and second, to accomplish better utilization of the drilling machines, i.e., increased footage per drill shift, and attendant reduction in cost. It was under these conditions that a portable drill carriage mounted on a caterpillar tractor chassis was developed to supersede the old method of mounting the drill

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1. Clarke, S.S., Mining Methods, Eagle-Picher Number, Engineering & Mining Journal, Vol. 144, No. 11, pp. 80-89, (Nov. 1943)

on a post. These machines are called "jumbos".

An examination of the records (Table I) of the Eagle Picher Mining and Smelting Company, and their interpretation (Plate I), indicated that a definite improvement in production has resulted since the introduction of the capterpillar jumbos.

This study of drilling operations was undertaken as a comparative analysis of the old and new methods to determine the reasons for the improvement. In addition, the transportation systems in use were analysed to determine how far they are fitted to cope with the increased unit production from the jumbos.

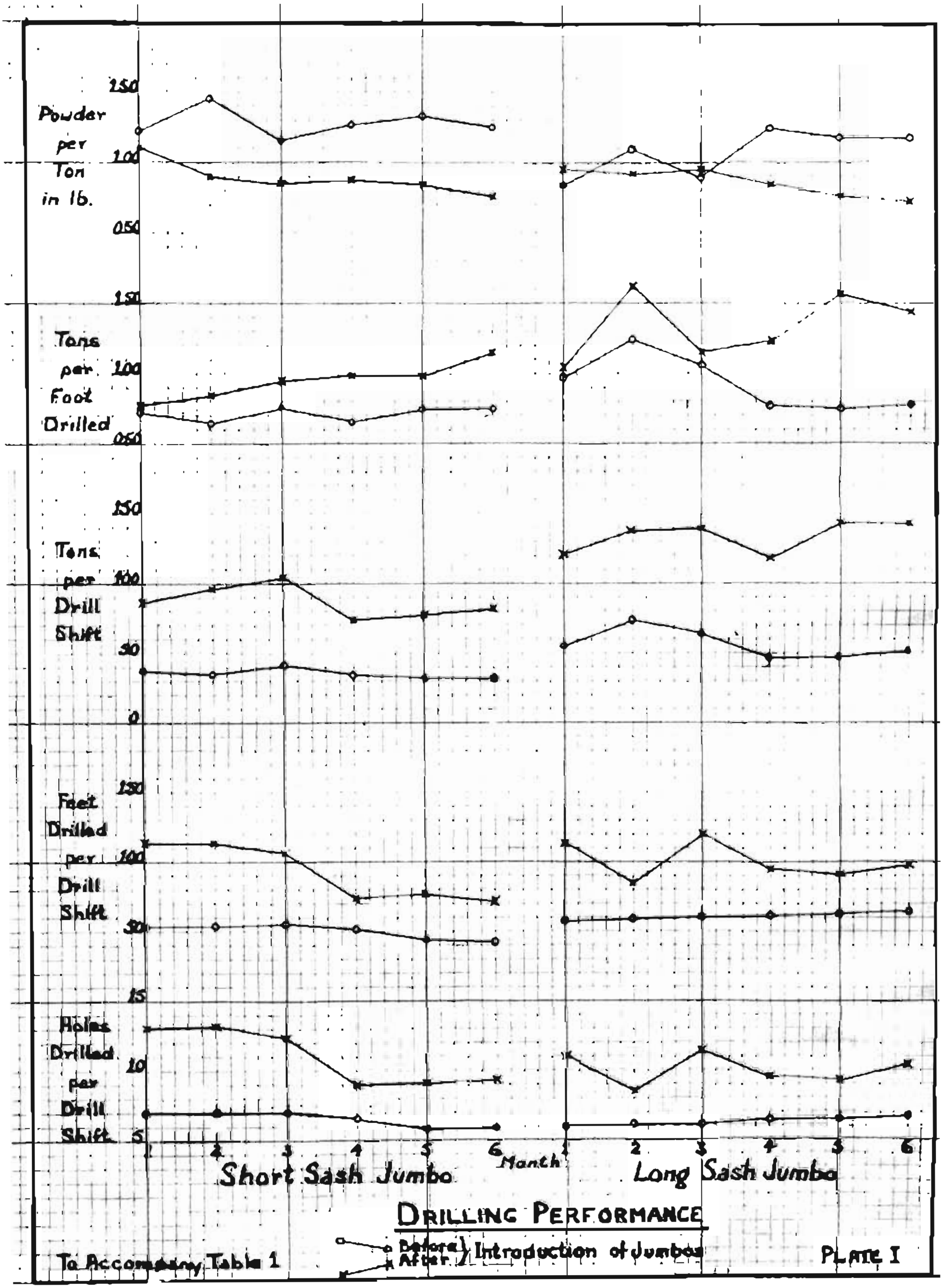
Table I - Monthly Production Data

Before and After Introduction of Jumbos

(Courtesy of Eagle-Picher M. & S. Co.)

Month		1	2	3	4	5	6
MINE NO. I SHORT SASH JUMBO							
Holes Drilled per Drill Shift	B*	7.0	7.0	7.0	6.7	5.8	5.9
	A*	13.1	13.2	12.3	9.0	9.1	9.5
Feet Drilled per Drill Shift	B	53.0	53.2	55.7	51.6	44.0	42.6
	A	114.3	113.4	107.9	73.9	78.7	71.5
Tons per Drill Shift	B	38.1	34.6	41.6	34.1	32.7	32.0
	A	87.6	96.8	103.7	72.8	78.1	82.0
Tons per Foot Drilled	B	0.72	0.65	0.77	0.66	0.74	0.75
	A	0.77	0.85	0.96	0.99	0.99	1.15
Powder per Ton in lb.	B	1.22	1.47	1.17	1.27	1.53	1.26
	A	1.10	0.90	0.86	0.88	0.85	0.77
MINE NO. II LONG SASH JUMBO							
Holes Drilled per Drill Shift	B	6.0	6.2	6.2	6.5	6.6	6.8
	A	11.0	8.6	11.6	9.7	9.3	10.5
Feet Drilled per Drill Shift	B	58.0	59.6	60.4	62.0	62.6	64.3
	A	114.4	85.9	120.7	96.3	91.1	99.4
Tons per Drill Shift	B	55.8	73.3	64.5	47.8	47.0	50.4
	A	120.2	139.3	139.5	118.0	143.4	143.0
Tons per Foot Drilled	B	0.96	1.23	1.07	0.77	0.75	0.78
	A	1.05	1.62	1.16	1.23	1.57	1.44
Powder per Ton in lb.	B	0.83	1.10	0.90	1.26	1.18	1.13
	A	0.96	0.92	0.95	0.85	0.76	0.72

B* Before introduction of jumbo
A* After introduction of jumbo



DRILLING PERFORMANCE

PLATE I

GEOLOGY

The geology of the district has been elucidated by Fowler and associates[2 3] in several publications. Briefly, the Boone formation, of lower Mississippian Age, to which the ore deposits are almost entirely confined, comprises flat lying beds of limestone, dolomite, and massive chert. Sphalerite, the principal ore mineral, is associated with galena, and lesser marcasite, pyrite, and chalcopyrite.

The ore deposits occur in such ways that two terms have been adopted in mining practice to indicate the manner under which the mining operations are pursued, that is, "sheet ground" mining extending laterally over wide areas, and "high ground" mining where greater vertical extents are excavated, and the lateral limits are more closely confined.

Fowler and Lyden[4] have described the O, P, and Q, beds of the Boone formation, in which the most important and extensive sheet ground workings occur, as, "O, 8-9 ft. thick. Important ore bed in a few mines. Round, flat nodules (2 to 4 in. by 3 to 6 ft.) embedded with cherty bands 1 to 4 in. thick. In some mines contains interbedded layers of nearly pure galena or sphalerite, or both, varying in thickness from a fraction of an inch to several inches. These sheets of ore are often persistent over large areas------P. 8-11 ft. thick. Large flat chert nodules embedded in chert. Barren in most instances.----Q. 17-18 ft. thick. Limestone and flint, generally

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2. Fowler, G.M. and Lyden, J.P., The Ore Deposits of the Tri-State District, Amer. Inst. Min. & Met. Engrs. Trans. Vol. 102, pp. 206-251----(1932).
3. Fowler, G.M., Tri-State Geology, Eagle Picher Number, Engineering & Mining Journal, Vol. 144, No. 11, pp. 73-79, (Nov., 1943).
4. Fowler, G.M., and Lyden, J.P. (1932) op. cit., p. 218.

massive." The high ground excavations ordinarily extend vertically through several of the flat lying beds of the Boone formation, but the mine in which observations were made is largely working the M bed, described as "M, 19-22 ft. thick. Where metamorphosed, definite nodules from 4 to 12 in. dia. occur through out entire thickness of bed. Often large nodules (from 6 to 12 in. thick by 2 to 5 ft. dia.) are bound at bottom of bed."

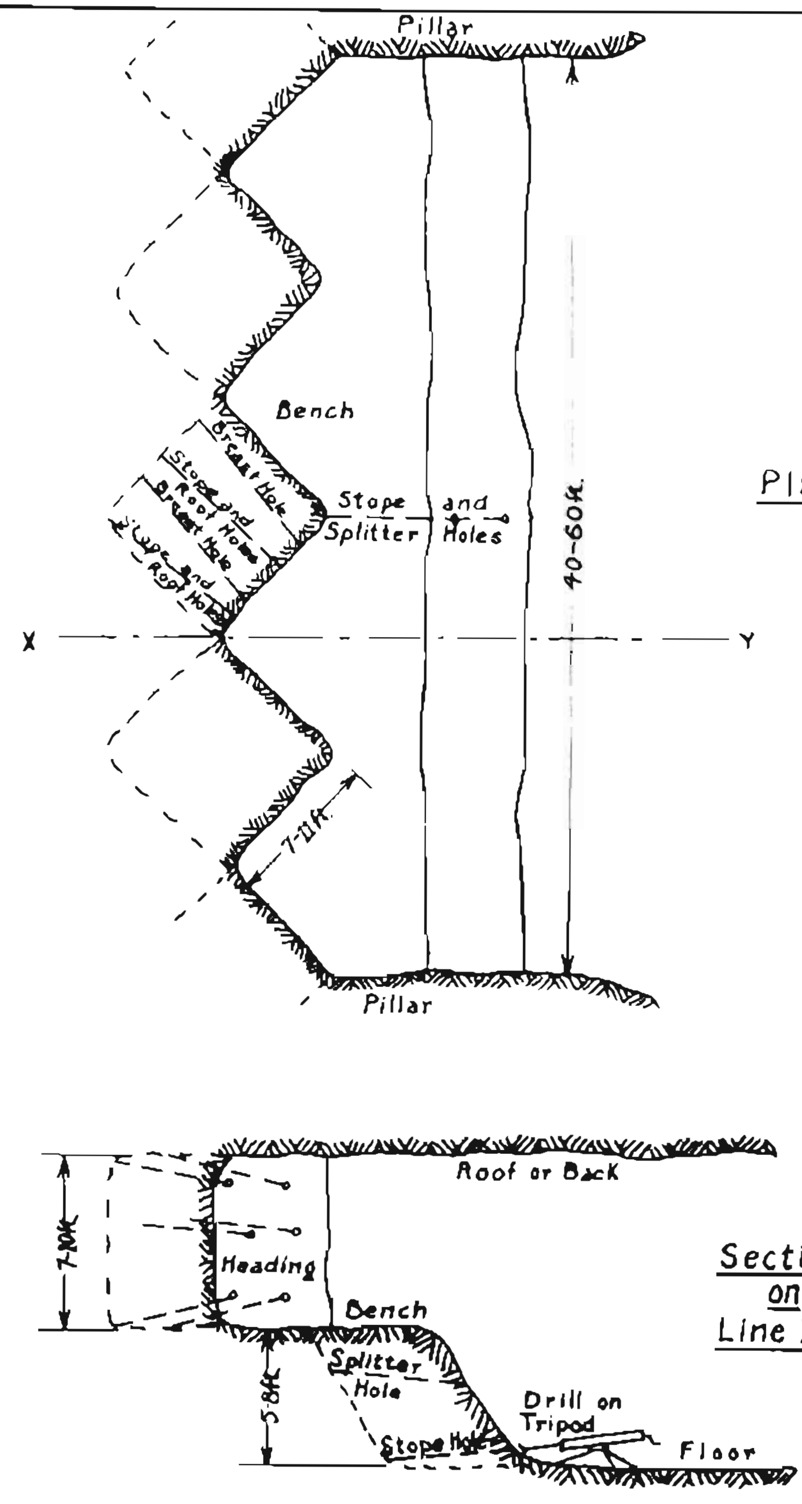
The rock sequence of beds in any mine is variable in physical character and ranges from porous cavernous material to massive hard chert.

MINING METHODS AND DRILLING EQUIPMENT

Netzeband[5] has described the general procedure of underground practice which has been followed for a number of years in the Tri-State District, viz., open stope mining with pillar support irregularly spaced. However, as some changes in methods have resulted from the introduction of the jumbo, and new transportation equipment, it is desirable to give some consideration to these developments. For example, in sheet ground mining, where the stopes range from 8 to 16 feet in height, it was the practice when using post mounted drills to advance any stope higher than 10 feet by a heading and bench method. This required the use of a tripod in drilling the bench holes (Plate II); but now, by using the jumbo it is possible to take out the entire height without a bench. In high ground mining it also has been the practice to drill for advance of the excavation by a heading and bench system after the previously blasted rock has been removed. When the jumbo is used, this practice is not followed, as drilling of a cut starts at the stope floor, and works progressively towards the roof, the jumbo climbing up the muck pile after each blast, (Plate III). It appears that, as yet, no attempt has been made to standardize the "round", or number and placing of drill holes, for the high ground jumbo drilling, but rather to spot the holes to take advantage of the previous break.

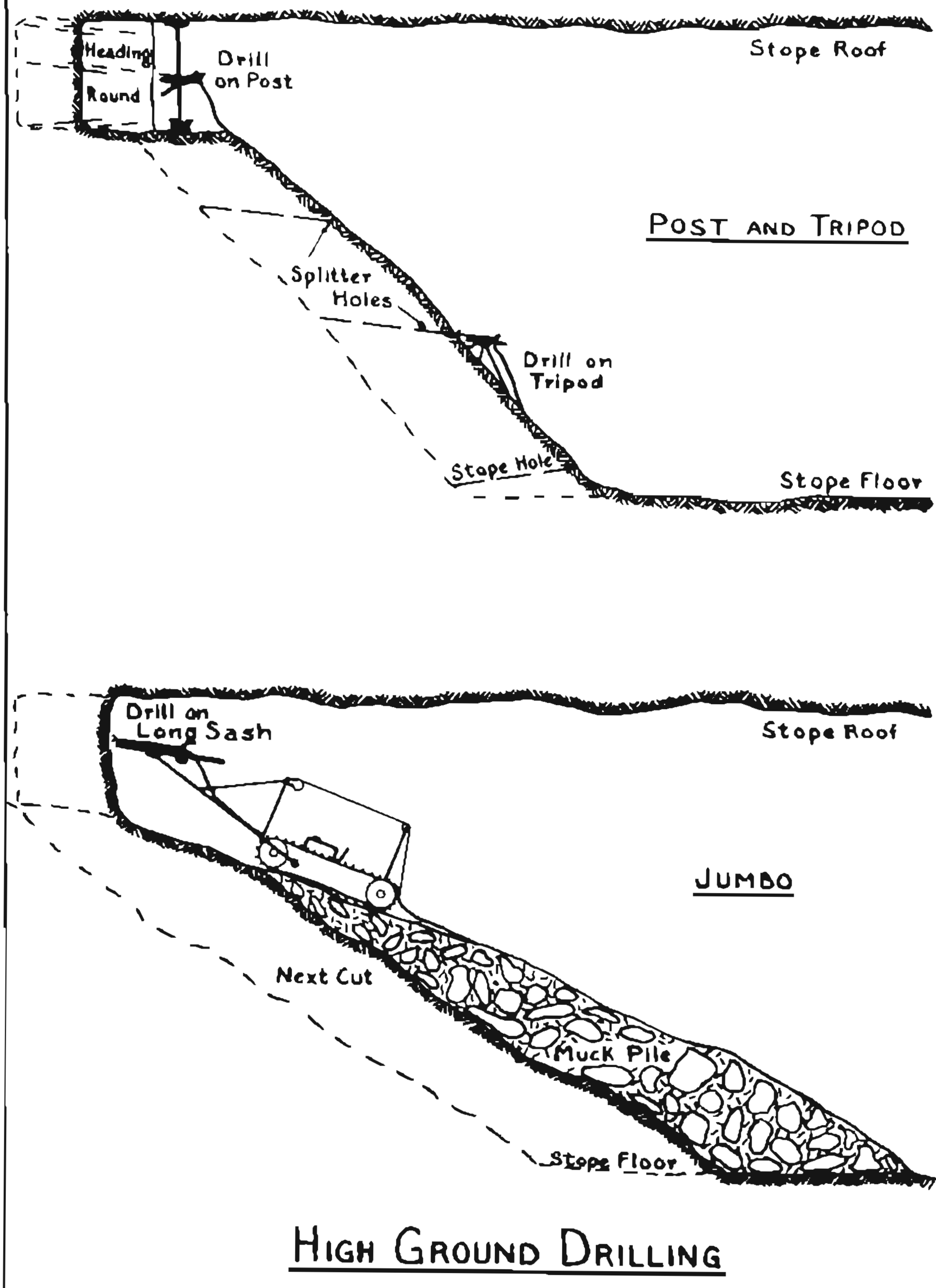
Ideally, the sheet ground round, whether drilled from post or jumbo, consists of six holes, namely two stope (or lifter) holes, two breast holes, and two roof (or back) holes (Plate IV). However,

5. Netzeband, W.F., Method and Cost of Mining Zinc and Lead at No. 1 Mine, Tri-State Zinc and Lead District. U.S. Bureau of Mines, Inf. Cir. 6113, 11 pp. (1929).



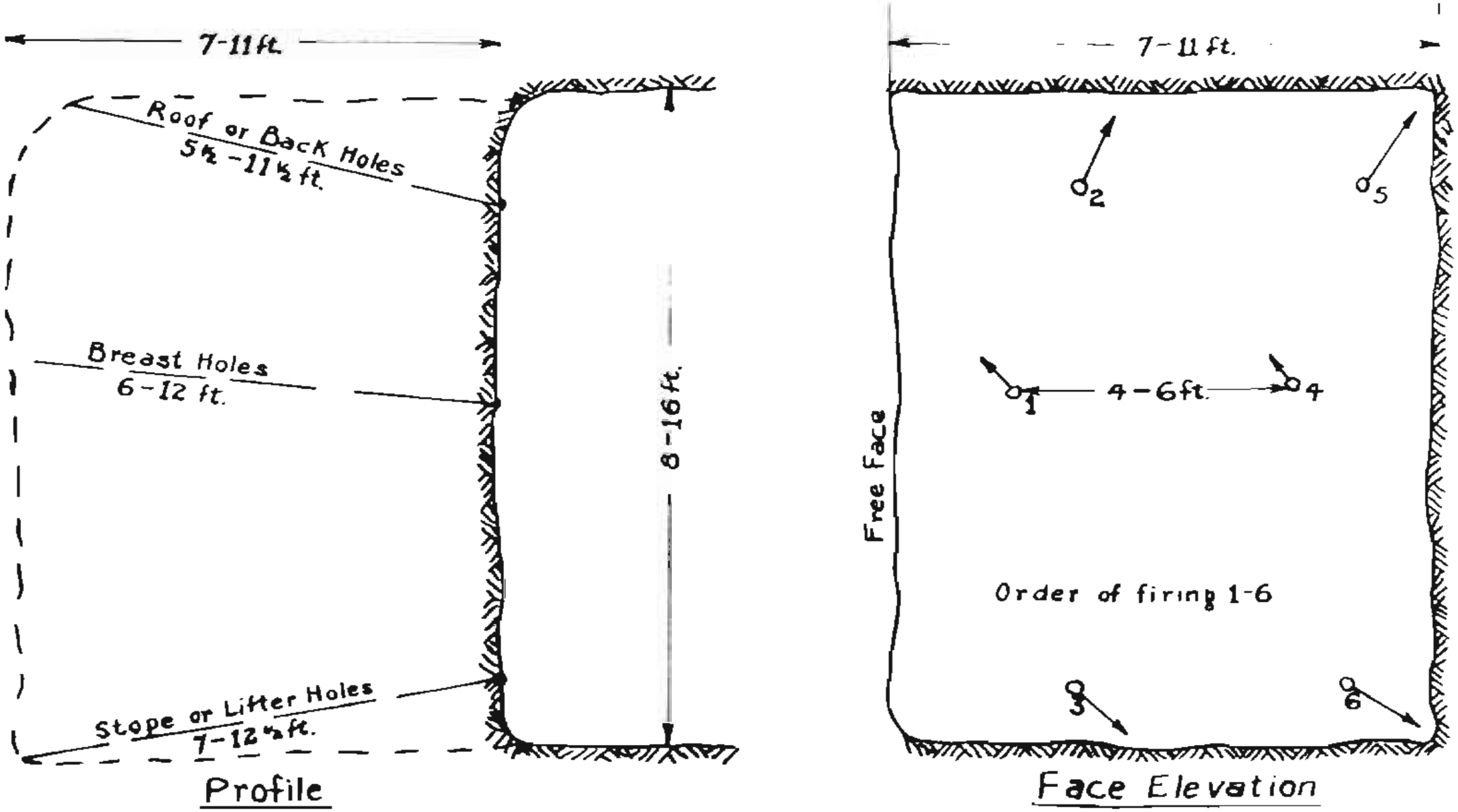
HEADING AND BENCH EIGHT HOLE ROUND
(Post & Tripod)

PLATE II



HIGH GROUND DRILLING

PLATE III



Standard Six-Hole Round

(Jumbo or Post)

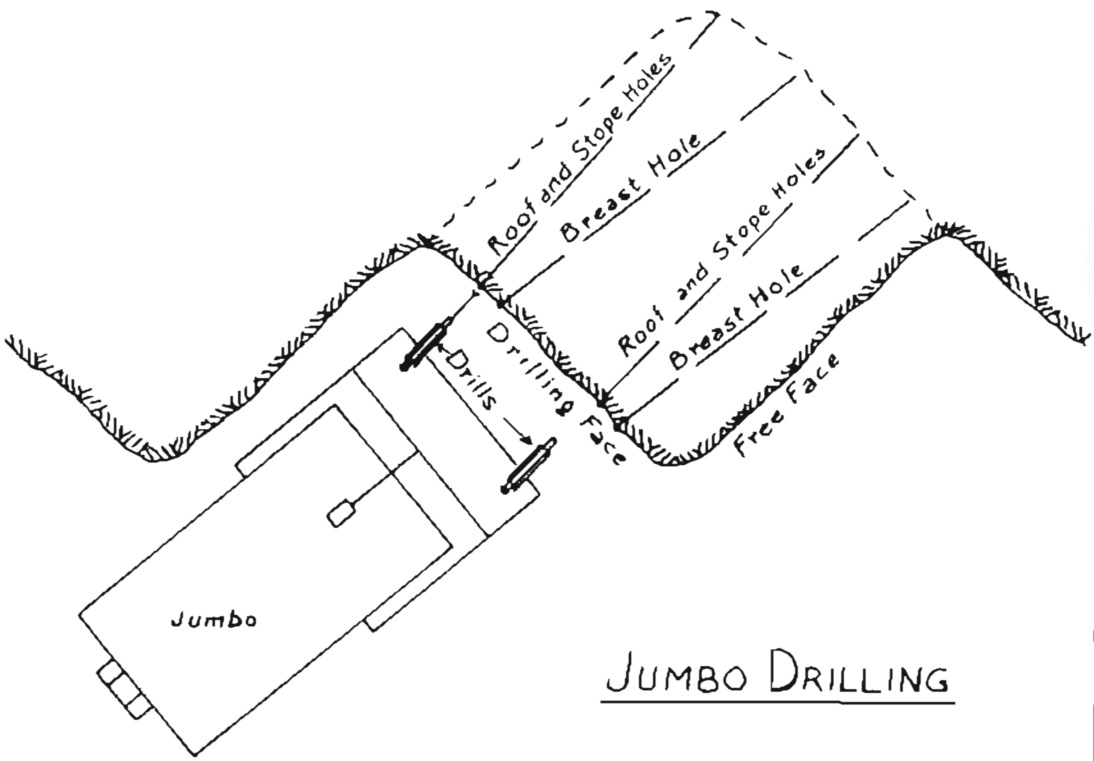
Plate IV

if the previous blast has yielded a markedly imperfect or irregular face to be drilled, one or more extra holes, located anywhere between the floor and roof, may be requred to square and reestablish uniformity of the face for the next round. Although the breast hole, closer to the free face in the standard round is the relief hole, or that first blasted, where extra holes to accomplish breaking are deemed necessary, these are blasted first, and thereby become the relief holes. The face or heading, which is usually from 40 to 60 feet wide between pillars or unbroken rock left for roof support, is advanced in zig-zag fashion as shown in Plates II and V.

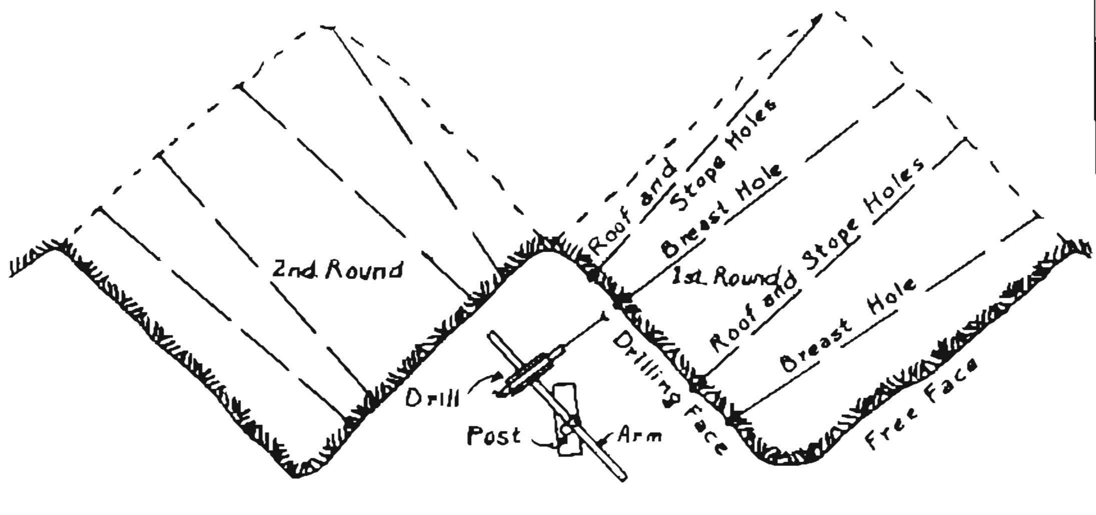
Where a post and arm is used for drilling, it is possible by means of a long arm to drill two rounds from the one erection of the post, whereas with the jumbo, each round requires that the machine as a whole be moved (Pate V). On the other hand, jumbo equipment can be moved to work in three, four, or even five separate headings, while a post mounted machine is limited to one, or at the most two headings.

The blasting practice followed is that outlined by Clarke[6], namely, $1\frac{1}{4}$ x 8 inch semi-gelatin cartridges, which split under the impact of the loading stick, are used for all holes. Stope-holes are double-primed, others single-primed. In the mines visited, stemming was not used, the holes being filled with all the powder they would take. The holes are loaded by the powderman in the afternoon and blasted shortly after the shift has ceased; the order of blasting is as given in Plate IV.

6. Clarke, S.S., op. cit., (1943), page 88.



JUMBO DRILLING



POST DRILLING

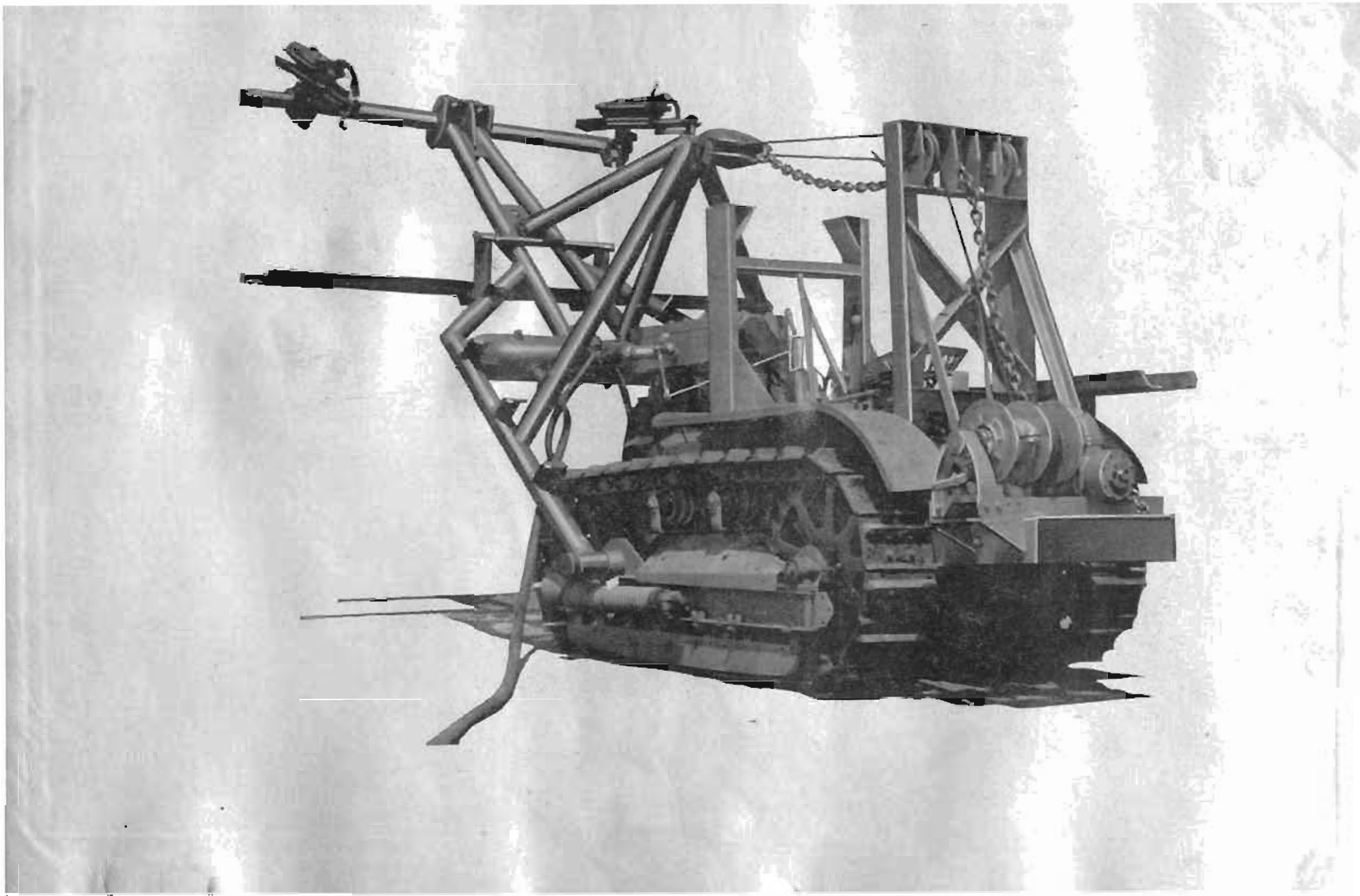
PLATE V

Safety regulations, under which drilling is performed, are few and simple. All holes must be drilled wet and this applies to starting or collaring a hole. Before drilling is begun, the entire working place is hosed down with water. Safety goggles are provided the men when a hole is being collared or when breaking slabs. The barring down of loose slabs at the drilling face, or in the roof, is the job and responsibility of the roof trimmers, but in practise, the machinemen also engage in this work. In the main, the safety regulations are adhered to, but as always, with a contract system, there are some who are willing to sacrifice precaution for the extra time made available for drilling.

All drill machines for both post and jumbo mountings, for which data in this study have been accumulated, are 4-inch drifters. Drilling is done wet with 2 5/8 inch detachable bits on 1 1/4 inch round hollow steel. The bits are of a special three-wing design, developed to meet the extremely abrasive drilling conditions in the Tri-State mines[7]. Compressed air, for both drilling and other air operated machines, is furnished at an average pressure of 80 lb./sq.in. For post drilling, a 24 or 30 inch feed solid guide sash (or drill carriage) with handcranked screw, or in a few cases some form of automatic feed, is standard equipment. As before noted, arms up to 6 ft. in length, clamped to double-screw posts, permit the drilling of two rounds from each erection of the post.

In Plate VI there is illustrated a jumbo fitted with two short sash drills. Although it is convenient to refer to the jumbo machines

7. Clarke, S.S., Development of Three-wing Bits in the Tri-State District, Amer. Inst. Min. & Met. Engrs., Tech. Pub. 1426, 5 pp. (1942)



The SHORT SASH JUMBO.

Fig 2.

~~PLATE VI.~~
Fig. 2

as short or long sash, depending on the drill carriage used, fundamentally both classes are of the same design. The illustration, therefore, other than for the short sash drills, is that of a typical jumbo. The apparatus is composed of a model 30 Caterpillar tractor frame, normally powered by a Ford Model A engine which has been converted by adjustment of valves to function as a compressed air engine. Some of the early models, however, were powered with a 15 horse-power Fairbanks-Morse electric motor, but it has been found generally more satisfactory to use an air engine. An adjustable boom made of double or triple strength 5½ inch pipe, and from 10 to 14 feet long, is pivoted close to the front axle of the tractor. The boom is raised or lowered to the height required for drilling by a small hoist powered either by a separate air tugger device, or by a take-off from the main engine; the hoist is located at the rear of the jumbo and from there the hoist cable passes over a pulley to the boom block. The boom at its front end carries a 6 or 7 foot arm of triple strength 4" pipe, on which the sashes supporting the drills are mounted. After the boom has been set in drilling position it is held by a stout chain and the hoist cable is allowed to slack. A footstand, attached to the boom, provides a convenient working place for the miners when breast and roof holes are being drilled. Thepipe of the boom structure may be fitted to serve as air and water manifolds. No two jumbos are exactly alike in detail as the machines are little more than in the experimental stage, and in addition at present, the materials used in their construction depend largely on what is available from the secondhand market.

SHORT SASH JUMBO.

Fig. 3
Hand-cranked
Short Sash
Jumbo machines

Fig. 1. Drills, Arm, Boom, and Footstand.

Fig. 3. Moving Jumbo.

Fig. 4

Fig. 2. Drilling a Roof Hole.

with Automatic-Feed Short
Sash Jumbo Machines

Fig. 4. Setting Up, Breast Hole.

Fig. 7
Setting up Short
Sash Jumbo Machine
to Drill Breast Holes.

PLATE VII.

A few of the early short sash jumbos were equipped with the handcranked, screw-feed sash (Plate VII, Fig. 1) but now almost all are provided with automatic 24 or 30 inch screw feed sashes (Plate VII, Fig. 2). As attempts to mount three drills on the arm were not successful, the standard practice now is to use two drills spaced 4 to 6 feet apart. The services of two workmen, driller and helper are used on each drill and thus the short sash jumbo, as a whole, employs four men.

In the case of the long sash unit the drill mountings used are of the conventional, wagon-drill, automatic chain-feed type, 11 or 12 feet long (Plate VIII). This sash allows the drilling of an 8 or 9 foot hole with one steel, and deeper holes with two steels, as compared with the three or more required when using the short sash. A helper for each machine is not employed, and the long sash jumbo, mounting two drills, is completely serviced by two drillers.

Methods and equipment of haulage and hoisting practice in the Tri-State District will be discussed later.

Fig. 1. Front View of Sash

Fig. 2. Side View of Sash and Boom.

Fig. 3. Drilling in High Ground

Long Sash Jumbo

Plate VIII

TIME STUDY PROCEDURE AND RESULTS

Although time study methods have been employed widely in various industries, as a means of determining and improving efficiency, their applications to mining have been sporadic, some companies instituting extensive programs, others feeling that the expense involved was not warranted. The publication of the results obtained from studies, which have been conducted, has been even more sporadic and those available are confined largely to analyses of coal mining operations.

Time studies have been used most in those enterprises where a high degree of standardization, or co-ordination of working processes, is possible. The uncertanities of ground conditions, the wide range of possible working procedures, the need for a great deal of planning by the workers themselves, poor lighting, and a host of other factors, combine to make mining a difficult problem for standardization. Thus the reasons for the seeming lack of interest in the application of time study methods to metal mining operations lies, apparently, in the nature of the industry, for, as Linton[8] has said, "....standardization can readily be applied to most manufacturing processes------mining operations on the other hand, are carried on under conditions that vary widely in different mines and even in the same mine."

Carson and Cole[9] recently have given a good account of the uses of time study under machine shop conditions; their observations that, (1), improvements result from a reduction in the number of elements

8. Linton, R., Standardizing by North Butte Mining Co., Amer. Inst. Min. & Met. Engrs., Trans. Vol. 66, p. 183, (1921).
9. Carson, G.B., & Cole, L.G., Predicting Machine Productivity for Future Applications, Mechanical Engr. Vol. 66, No. 6, pp. 384-388, (June, 1944).

required of the operator, and a simplification of those remaining; and (2), an intangible benefit is the elimination of worker thought and analysis, are as true in mining as in manufacturing. Therefore, with the advent of mechanization in any mining venture, and the development of methods which contribute to more cyclic operations, there is an approach to machine shop conditions. Under any circumstances, however, there will always remain the uncertainties inherent in mining, such as the common variable conditions of the ground being worked, poor lighting, etc.

Drilling

Harley[10] has proposed a rock or ground classification so that results obtained by one system of drilling in any district might be compared with those from other areas. In this present work his classification of rock types is not deemed pertinent, inasmuch as the purpose of the study is to compare the several systems of drilling. Further, though the rock materials in this one district range from cavernous substances to hard chert, as before noted, these variations are encountered in any or all drill holes and it may be considered that the tests upon which the data of the paper are based were conducted in sensibly uniform material. The same author[11], in a later paper, gave a detailed account of a time study for a drift round, the basis of analysis being the drill and not the workmen. In the writer's opinion much valuable data is lost if the individual workmen are ignored in the time study as it is then impossible to attain any idea of the co-

10. Harley, G.T., Proposed Ground Classification for Mining Purposes. Engineering and Mining Journal. Vol. 122, pp. 368-372, pp. 413-416, (1926).
11. Harley, G.T., Time Study Methods for Mining Operations. Engineering and Mining Journal, Vol. 123, pp. 722-729, (1927).

ordination achieved.

Methods of Drilling Time Studies

The method of time study used is that proposed in 1929 by the "Colliery Guardian"[12]. The equipment required is simple, comprising an ordinary watch, a pencil, observation sheets mounted on a clip board, and a measuring tape. The time taken in performing a given occupation or activity is regarded as the time elapsing between the nearest minute a job is begun to the nearest minute the next is commenced. Table II is a sample Observation Sheet with some recordings entered. Each man studied is assigned a separate column, and the time at which he completes an occupation is recorded alongside a note of that activity. On completion of a hole the depth drilled, type of hole, and the number of steels used are entered on the sheet. Following the method of Truscott[13], the field observations are posted to a Summary Sheet (Table III) whereon each occupation is allotted a column for times devoted to it by each man--the interval, elapsing between completion of one job and completion of the next, is entered as time devoted to the latter. For example, referring to Table II, the time spent in inspecting the face by the driller of the left side machine was 0750-0742 = 8 mins. When the observations for a particular study are finished, the totals for the activities each man has performed during each day are entered on a Consolidation Sheet (Tables IV, V, VI, VII). From the overall totals of the study, the average time and

12. Time Studies in Mines. Colliery Guardian, Vol. 139, p. 318, (1929)
13. Truscott, S.J., Mine Economics, London, Mining Publications, 1937, Chap. XVII.

Table II - Drilling--Time Study Observation Sheet

Working Place ____X____ Date __________ Mine ____2____

Type of Machine __Jumbo--2.I.R. D.505__ No. of Men 2 drillers

Remarks __Heading clear__

Left Side

Hours Mins.		
0730	On Shift	
42	Travelling time	
50	Inspect face	
0801	Barring down	
07	Move jumbo	
10	Set up	
15	Oiling	
17	Drilling	
19	Helping other drill	
37	Drilling--11 ft. breast	2
45	Wait--other drill	
47	Set up	
0900	Drilling--8 ft. roof	1
03	Wait--other drilling	
08	Set up	
22	Drilling--10 ft. stope	2
26	Wait--other drilling	
29	Blow holes	
31	Drill maintenance	
35	Move jumbo	
37	Set up	
38	Oiling	
39	Helping other drill	
59	Drilling--12 ft. breast	2

Right Side

Hours Mins.		
0730	On Shift	
35	Travelling time	
50	Inspect face	
0801	Collect oil	
07	Move jumbo	
10	Set up	
15	Repairing hose	
17	Helping other drill	
23	Collar hole	
25	New Set up	
45	Drilling--11½ ft. breast	2
47	Set up	
0903	Drilling--10 ft. roof	2
08	Set up	
26	Drilling--11½ ft. stope	2
29	Blow holes	
31	Drill maintenance	
35	Move jumbo	
37	Set up	
38	Oiling	
43	Drilling	
48	Stuck Steel	
58	Drilling--9½ ft. breast	2
59	Wait--other drilling	

and so on, throughout the working shift

Table III - Drilling--Time Study Summary Sheet
All times given in minutes

Wait at End of Shift	80	80
Excessive Rest	26	26
Direct Powder Man		
Straighten Steel		
Oiling	5 1 1	7
Drill Maintenance	2	2
Hose and Light Repairs	1 1	2
Wait on Collect Supplies		
Collect Supplies		
Wait on Stuck Steel		
Stuck Steel		
Wait on Extra Holes	12	12
Wait on other Drill	8 3 4	15
Collar Hole		
Wait on Blow Holes		
Blow Holes	3 4 2	9
Clean Out Hole		
Helping other Drill	2 1 2 1 1 1	8
Drilling & Changing	13 18 10 15 (R) 20 20 19 (B) 14 17 17 14 (S)	175
Setting Up	2 2 3 5 2 (R) 3 2 2 (B B) 5 4 2 4 (S)	36
Moving Jumbo	6 4 4 6	20
Hose down		
Wait on Barring down		
Barring down	11 1	12
Face Inspection	8 5 2 2	16
Travel Time	12 10 7 10	39
No. of Steels	1 2 2 2 2 2 2 2 2 2 2	21
Feet of Hole	8 *12 8½ 11 (R) 9 12 9½ (B) 10 11½ 10½ 9½ (S)	111½

No. of Holes 11 Mine 3 Machine Left Side Date

*The symbols R, B, S, refer to Roof Breast, and Stope holes, respectively.

percentage of shift-time consumed in each occupation may be computed and entered on the consolidation sheet.

Before beginning the detailed time study it is necessary to make a preliminary survey of the complete drilling operation to determine what occupations are involved and the field which each covers. For example, from an inspection of a driller's work which includes both actual drilling and changing of steel it is evident that they are so closely related that little or no purpose would be served by their separate time study treatment. Thus drilling-rate, as here considered, incorporates the two activities, thereby emphasizing the effect of the different methods of drill feed on the total time spent in drilling. On the other hand, the time spent in changing of steel by the helper is recorded.

The operation of drilling is broken down into eleven subdivisions based on their part in promoting work. Each sub-operation is composed of one or more distinct occupations, the various classes of delays time, etc., being regarded as separate activities. Definitions of the sub-operations are as follows:

1. Travel Time - time spent in journeys between the shaft collar and working place when going on and off shift. As it is the practice in the Tri-State District for the men to lunch on the surface, four trips are included.

2. Face Preparation - the time consumed in performing the essential preliminary acts before the jumbo machine or post is moved to drill a round.

"Wait on Muck Out" - in cases where rock or muck prohibit access to the face for drilling, a delay is experienced until this material has been loaded or removed.

"Face Inspection" - the working place is inspected to decide where the jumbo machine is to be placed, or the post erected as the case may be, to obtain the best results from the drilling.

"Barring down" - any loose slabs in the roof or face are removed by the machine men or roof trimmers.

"Wait on Barring down" - this is the time spent waiting for the trimmers to make the working place safe.

"Hose down" - the working place is water sprayed to allay dust.

"Wait on Hose down" - one member of the drilling crew usually can satisfactorily accomplish the hosing down and, unless the others are engaged in another occupation, they are charged as waiting on hose down.

"Moving Boulders" - time spent during jumbo operations in disposing of large blocks or boulders which, by reason of their size, must be reduced before loading. When they occur the jumbo may not be able to move directly to the drilling face.

3. <u>Drill Preparation</u> - the time spent in the placing of the drilling machines in such a position that they may proceed to prod ctive work, that is, the drilling of holes.

"Erecting Post" - dismantling the post (or tripod) after drilling at one face and erecting it at the next face to be drilled.

"Moving Jumbo" - in jumbo drilling the counterpart of post and/or tripod erection is the moving of the machine from one face to the next. On the short sash jumbo one man drives the apperatus, and the other three drag the air and water hoses into place, whereas with the long sash jumbo only one man is available for dragging the hoses and, therefore, it is customary to disconnect the water hose.

"Setting Up" - each type of hole requires a different position of the drilling arm. With post drilling this means that the arm must be moved for every hole; in jumbo drilling the arm carries two drills and one movement of the boom permits the drilling of two holes. Setting up also includes the time devoted to alignment and clamping of the drill machine and placing of steel in the chuck.

4. Drilling-Productive Elements - the time of those cyclic occupations which are essential to the actual drilling of every hole.

"Drilling and Changing" - time spent by the driller in operating his machine, including both that of drilling and changing steel. Freeing stuck steel, collaring hole, etc., are not considered as phases of actual drilling.

"Changing" - where post and tripod or short sash drilling is used, the driller's helper prepares the steel, removes the previous length, and places the new piece in the drill chuck.

"Helping other Drill" - on the long sash jumbo there are no helpers, and it has been found advantageous for both drillers to cooperate in starting each drill. This is accomplished by running one machine until it has penetrated to a depth of 6 inches, more or less, both men then work on the second machine until it too, is underway.

5. Drilling-Non-Productive Elements - this is the time consumed in those occupations which are essential to the drilling procedure but, which within themselves, do not result in a deepening of the drill hole.

"Wait for Changing" - during the bulk of the time that drilling is in progress the helper stands by waiting for the next change of steel.

"Clean out Hole" - after a stuck steel has been removed it usually is necessary to clean out the hole with a raking stick.

"Blow Holes" - at the end of each round, and whenever necessary during the drilling of a round, the holes are cleaned by blowing with a jet of compressed air through a pipe designed for this purpose.

"Wait on Blow Holes" - as the efforts of only one or two men are required to satisfactorily blow the holes, the remainder of the crew wait for the next move of the machines.

"Collar Hole" - it may be difficult to start, or collar, a drill hole, and if such is the case, a new set up of the equipment may even be required. Any time over one minute spent in starting a hole is considered as outside the category of drilling and is entered under collar hole.

6. Productive Delays - in any class of jumbo drilling occasions arise where one drill will be idle while the other is working. This is time during which only half of the drilling capacity is being utilized on productive work.

"Wait on other Drill" - whenever either one of the drilling machines completes a hole before the other machine has finished its hole, a delay occurs.

"Wait on Extra Holes" - where it is necessary to drill holes in addition to those of the standard round, one machine is idle while the other is working.

7. Non-Productive Delays - during the drilling cycle, time may be taken up by delays that are neither productive nor essential.

"Stuck Steel" - when a drill steel becomes wedged or fast in a hole, the progress of drilling is interrupted. Time which is spent in overcoming this condition, so that the drilling may proceed, is entered as stuck steel.

"Wait on Stuck Steel" - when, by reason of stuck steel in a hole being drilled by one machine on a jumbo, the other drill is prevented from starting the next hole, the delay to the latter machine is charged in this category.

8. Supply Delays - this is time which transpires whenever it is necessary for any member of a crew to be absent from the drill operation because of a lack of supplies, such as, oil, bits, drill-steel, etc.

"Collect Supplies" - all supplies are obtained by the drill crews from racks located at the shaft station. Therefore, to secure new materials, a trip to the shaft from the drilling site is necessary.

"Wait on Collect Supplies" - when a drill cannot be operated pending the collection of supplies.

9. Maintenance Delays - the time required to maintain the equipment in working order.

"Hose Repairs" - when an air or water hose breaks, drilling ceases until repair is effected.

"Drill Maintenance and Repairs" - any repair work performed on the drills or sashes during the drill shift.

"Wait on Drill Repairs" - repairs of the drills or sashes usually require only two men and, therefore, with the short sash jumbo, the other men may be idle.

"Repairs to Jumbo" - if repairs of a jumbo are necessary, and can be accomplished by the drilling crew, they are placed under this heading.

"Oiling" - the oiling of drills is a routine maintenance job.

10. Miscellaneous Delays - the time consumed by infrequent and non-predictable delays.

"Machine off Sash" - time involved in replacing the drill.

"Blasting Damage" - if equipment is not suitably protected during blasting, damage by flying rock may result and repairs are then necessary.

"Straighten Steel" - drill steel may be bent when a stuck steel is being freed, or by continued drilling after a machine has moved out of alignment. Subsequently, such pieces may be straightened for use again.

"Direct Powder Man" - if the locations of the holes of a completed, but unblasted, round are not clearly marked the powder man may ask for some guidance in finding them.

"Powderman Loading Holes" - if the roof is high, the powderman may make use of the jumbo in lieu of a ladder to assist him in the loading of holes. In the meantime the drilling crew will not be working.

11. Idle Time - that time during which drilling procedures are not being furthered.

"Excessive Rest" - whenever the entire drilling crew is idle without apparent reason.

"Wait at End of Shift" - the time which elapses between completion of the day's drilling and when the workmen are hoisted at the end of the shift.

Comparison of Drilling Methods

Tables IV, V, VI, and VII are consolidation sheets on which the data obtained in the manner previously described (page 21) are recapituated. For each occupation the symbols $\frac{D}{H}$ denote driller's time and helper's time on a machine, and L or R signifies which drill, whether left or right side. The Plates, IX, X, XI, XII, accompanying the respective tables, give a graphical picture of the time distribution of the different sub-operations and occupations. The sectors platted thereon represent the percentages shown in the consolidation sheets.

Table IV presents the data of one day's complete operation of a post mounted, hand-cranked, screw-feed drilling machine. Some eight holes, aggregating 65 feet, were drilled and the results are sufficiently close to statistics of previous performances of this type of drilling (Table I) to be of value for comparative purposes.*

Complete operations of the short sash, and long sash jumbos, in sheet ground, were each observed for five days and the consolidated data are given in Tables V and VI respectively. The results for two days spent observing the long sash jumbo in high ground are found in Table VII.

The drilling elements which are cyclic, or standardized in all cases, and therefore, are the only ones that can be compared respectively for each type of machine, are the sub-operations of drill preparation and productive drilling (drilling and changing). Accordingly, some additional observations of these elements were made for post and tripod drilling to obtain a better basis for their comparison with the more extensive data accumulated for the jumbo machines. These statistics are consolidated in Tables VIII, IX, and X, wherein detailed

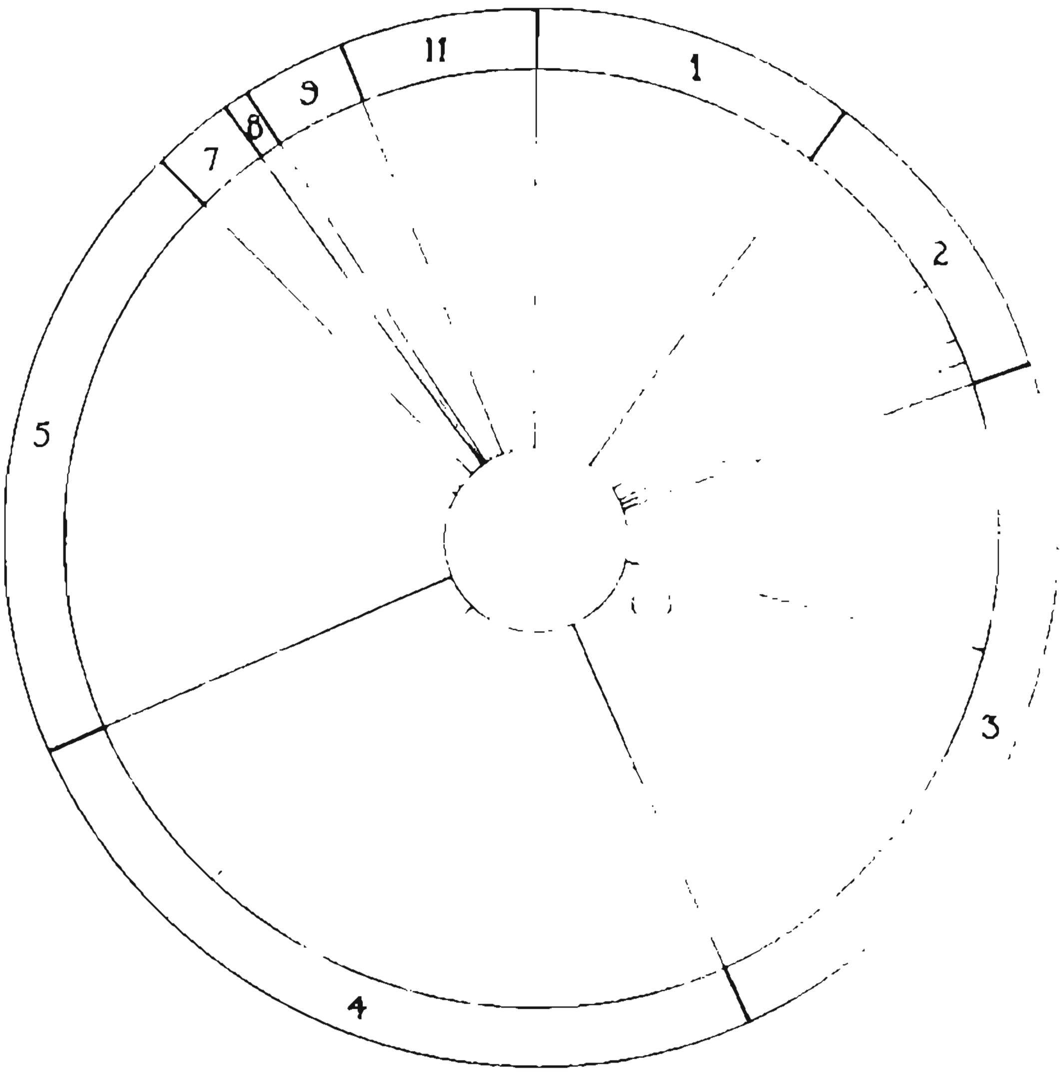
* In drilling studies when observations of number of holes drilled and footage per drill shift check with company operating records accumulated over a long period of time they are deemed sufficient and reliable.

Table IV - Drilling

Post-mounted Drills-Time Study Consolidation Sheet

All times given in minutes

				Percent	
1-TRAVEL TIME		D	48		
		H	48		
		Total	96	10.00	10.00
2-FACE PREPARATION	Wait on Muck Out	D	28		
		H	28		
		Total	56	5.83	
	Face Inspection	D	10		
		H	10		
		Total	20	2.08	
	Barring down	D	0		
		H	0		
		Total	0	0	
	Wait on Barring down	D	0		
		H	0		
		Total	0	0	
	Hose Down	D	8		
		H	0		
		Total	8	0.83	
	Wait on Hose Down	D	0		
		H	8		
		Total	8	0.83	9.57
3-DRILL PREPARATION	Erecting Post	D	44		
		H	44		
		Total	88	9.17	
	Setting Up	D	70		
		H	70		
		Total	140	14.58	23.75
4-DRILLING PRODUCTIVE ELEMENTS	Drilling & Changing	D	179		
		Total	179	18.65	
	Changing	H	61		
		Total	61	6.35	25.00
5-DRILLING NON-PRODUCTIVE ELEMENTS	Wait for Changing	H	118		
		Total	118	12.29	
	Clean Out Hole	D	12		
		H	12		
		Total	24	2.50	
5-DRILLING (continued)	Blow Holes	D	6		
		H	6		
		Total	12	1.25	
	Wait on Blow Holes	D	0		
		H	0		
		Total	0	0	
	Collar Hole	D	15		
		H	15		
		Total	30	3.13	19.17
7-NON-PRODUCTIVE DELAY	Stuck Steel	D	12		
		H	12		
		Total	24	2.50	2.50
8-SUPPLY DELAYS	Collect Supplies	D	0		
		H	4		
		Total	4	0.42	
	Wait on Collect Supplies	D	4		
		H	0		
		Total	4	0.42	0.84
9-MAINTENANCE DELAYS	Hose Repairs	D	5		
		H	5		
		Total	10	1.04	
	Drill Maintenance	D	6		
		H	6		
		Total	12	1.25	
	Oiling	D	4		
		H	4		
		Total	8	0.83	3.12
10-MISCELLANEOUS DELAYS	None occurred				
11-IDLE TIME	Excessive Rest	D	7		
		H	7		
		Total	14	1.46	
	Wait at End of Shift	D	22		
		H	22		
		Total	44	4.58	6.04



TIME DISTRIBUTION CHART
POST DRILLING

To Accompany Table IV

PLATE IX

Table V - Drilling

Short Sash Jumbo-Time Study Consolidation Sheet

All times given in minutes

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
1-TRAVEL TIME		L D	37	36	40	39	48				
		L H	40	39	40	35	43				
		R D	40	36	43	38	45				
		R H	37	39	43	32	43				
		Total	154	150	166	144	179	793	158.6	8.25	8.25
2-FACE PREPARATION	Wait on Muck Out	L D	0	0	0	0	0				
		L H	0	0	0	0	0				
		R D	0	0	0	0	0				
		R H	0	0	0	0	0				
		Total	0	0	0	0	0	0			
	Face Inspection	L D	5	15	20	1	12				
		L H	2	15	6	9	6				
		R D	2	15	17	13	12				
		R H	5	15	6	1	3				
		Total	14	60	49	24	33	180	36.0	1.88	
	Barring down	L D	7	0	0	15	17				
		L H	0	22	0	0	0				
		R D	0	0	0	0	0				
		R H	0	22	11	15	13				
		Total	7	44	11	30	30	122	24.4	1.27	
	Wait on Barring down	L D	0	13	0	0	0				
		L H	7	0	0	0	8				
		R D	7	22	0	0	17				
		R H	7	0	0	0	17				
		Total	21	35	0	0	42	98	19.6	1.02	
	Hose down	L D	0	5	0	0	0				
		L H	0	0	18	0	9				
		R D	0	2	0	0	3				
		R H	0	2	0	0	7				
		Total	0	0	18	0	19	46	9.2	0.48	
	Wait on Hose Down	L D	0	2	4	0	2				
		L H	0	2	0	0	2				
		R D	0	2	0	0	2				
		R H	0	0	0	0	0				
		Total	0	6	4	0	6	16	3.2	0.17	
	Moving Boulders	L D	0	0	0	0	3				
		L H	0	0	0	0	3				
		R D	0	0	0	0	3				
		R H	0	0	0	0	3				
		Total	0	0	0	0	12	12	2.4	0.13	4.94

Table V continued

Group	Element	Day	1	2	3	4	5	Total	Average per Shift	Percent	
3-DRILL PREPARATION	Moving Jumbo	LD	21	31	14	19	27				
		LH	21	27	14	19	29				
		RD	21	26	14	19	27				
		RH	21	27	14	19	22				
		Total	84	111	56	76	105	432	86.4	4.50	
	Setting Up	LD	54	44	27	21	51				
		LH	47	39	27	21	51				
		RD	49	48	30	30	61				
		RH	49	40	30	30	58				
		Total	199	171	114	102	221	807	161.4	8.40	12.90
4-DRILLING PRODUCTIVE ELEMENTS	Drilling & Changing	LD	175	141	126	81	181				
		RD	127	145	129	109	187				
		Total	302	286	255	190	368	1401	280.2	14.59	
	Changing	LH	37	33	32	21	37				
		RH	30	31	39	26	44				
		Total	67	64	71	47	81	330	66.0	3.44	18.03
5-DRILLING. NON-PRODUCTIVE ELEMENTS	Wait for Changing	LH	121	106	94	57	144				
		RH	94	113	87	83	142				
		Total	215	219	181	140	286	1041	208.2	10.84	
	Clean Out Hole	LD	0	2	0	0	0				
		LH	0	2	0	0	0				
		RD	0	0	0	0	0				
		RH	0	0	0	0	0				
		Total	0	4	0	0	0	4	0.8	0.04	
	Blow Holes	LD	11	8	2	0	0				
		LH	11	3	0	0	0				
		RD	0	18	12	9	13				
		RH	0	3	0	2	2				
		Total	22	32	14	11	15	94	18.8	0.98	
	Wait on Blow Holes	LD	0	11	8	6	8				
		LH	0	16	8	6	8				
		RD	7	6	0	0	0				
		RH	7	17	8	7	8				
		Total	14	50	24	19	24	151	26.2	1.37	
	Collar Hole	LD	8	0	0	0	7				
		LH	4	0	0	0	7				
		RD	4	21	0	6	4				
		RH	4	21	0	6	4				
		Total	20	42	0	12	22	96	19.2	1.00	14.23

Table V continued

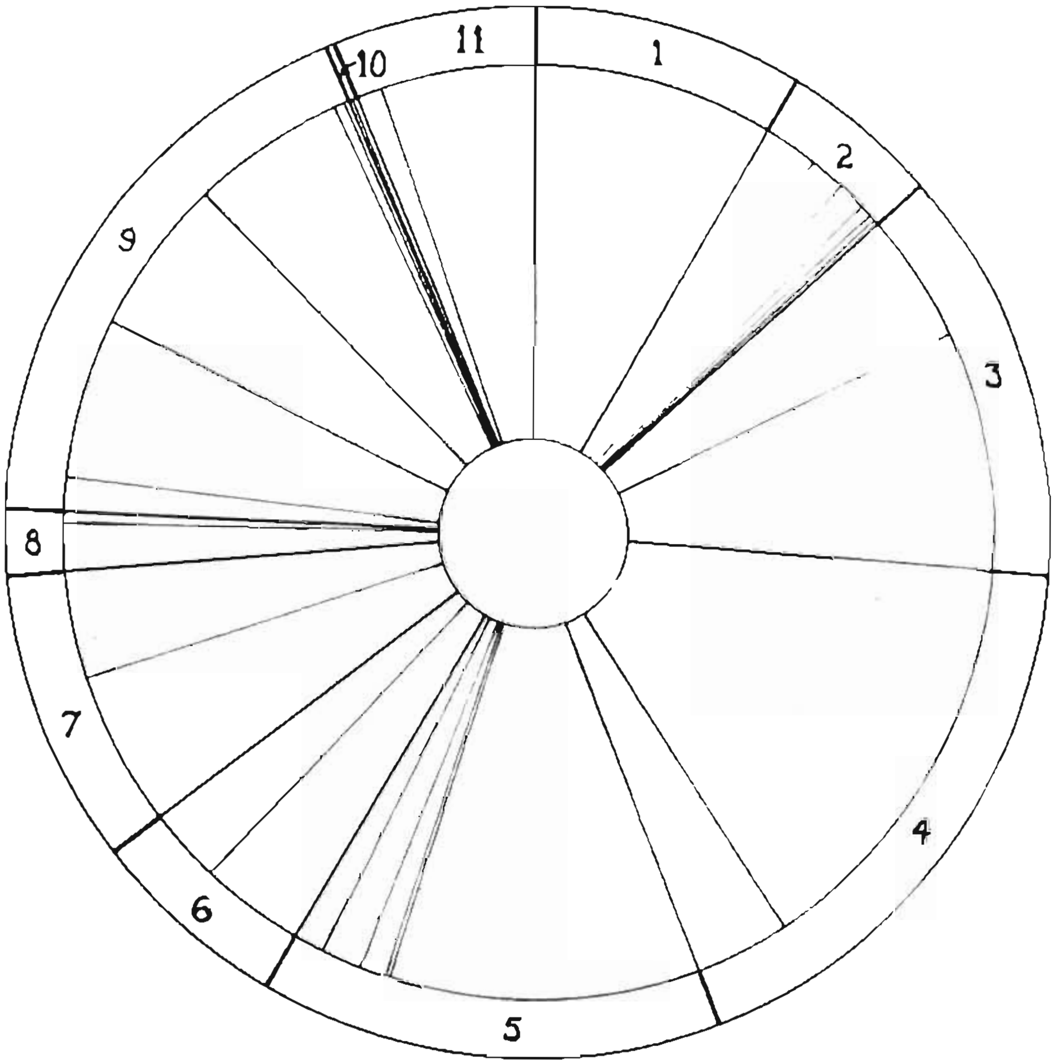
			Day	1	2	3	4	5	Total	Average per Shift	Percent	
6-PRODUCTIVE DELAY	Wait on Other Drill	L	D	9	43	15	28	21				
			H	9	41	17	26	21				
		R	D	23	9	13	0	13				
			H	23	8	13	0	13				
			Total	64	101	58	54	68	345	69.0	3.59	
	Wait on Extra Holes	L	D	0	14	13	12	15				
			H	0	14	13	12	15				
		R	D	53	16	0	0	0				
			H	53	16	0	0	0				
			Total	106	60	26	24	30	246	49.2	2.56	6.15
7-NON-PRODUCTIVE DELAYS	Stuck Steel	L	D	78	27	9	6	9				
			H	74	27	9	6	9				
		R	D	3	19	17	56	31				
			H	3	19	17	56	31				
			Total	158	92	52	124	80	506	101.2	5.27	
	Wait on Stuck Steel	L	D	0	8	5	49	25				
			H	0	8	5	49	23				
		R	D	71	15	4	0	3				
			H	68	9	7	0	5				
			Total	139	40	21	98	56	354	70.8	3.69	8.96
8-SUPPLY DELAYS	Collect Supplies	L	D	5	0	0	0	0				
			H	45	10	0	12	9				
		R	D	0	0	0	0	3				
			H	10	18	13	7	24				
			Total	60	28	13	19	36	156	31.2	1.63	
	Wait on Collect Supplies	L	D	8	7	0	0	0				
			H	0	0	0	0	0				
		R	D	4	9	0	0	6				
			H	0	0	0	0	0				
			Total	12	16	0	0	6	34	6.	0.35	1.98
9-MAINTENANCE DELAYS	Hose Repairs	L	D	21	0	0	4	0				
			H	21	2	0	4	0				
		R	D	23	0	0	4	0				
			H	23	2	0	4	0				
			Total	88	4	0	16	0	108	21.6	1.13	
	Drill Maintenance & Repairs	L	D	27	0	135	49	29				
			H	0	0	139	48	29				
		R	D	0	0	51	0	0				
			H	0	0	34	0	0				
			Total	27	0	359	97	58	541	108.2	5.64	

Table V continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
9-MAINTENANCE DELAYS (continued)	Wait on Drill Repairs	L D	0	0	38	0	0				
		L H	27	0	34	0	0				
		R D	27	0	125	42	20				
		R H	27	0	131	42	5				
		Total	81	0	328	84	25	518	103.6	5.40	
	Repairs to Jumbo	L D	0	0	0	125	0				
		L H	0	0	0	129	0				
		R D	0	0	0	129	0				
		R H	0	0	.0	125	0				
		Total	0	0	0	508	0	508	101.6	5.29	
	Oiling	L D	0	0	0	0	2				
		L H	0	2	0	1	4				
		R D	5	2	1	0	7				
		R H	5	3	3	0	7				
		Total	10	7	4	1	20	42	8.4	0.44	18.72
10-MISCELLANEOUS DELAYS	Machine Off Sash	L D	2	0	0	0	0				
		L H	2	0	0	0	0				
		R D	2	0	0	0	0				
		R H	2	0	0	0	0				
		Total	8	0	0	0	0	8	1.6	0.08	
	Blasting Damage	L D	0	0	2	0	0				
		L H	0	0	2	0	0				
		R D	0	0	2	0	0				
		R H	0	0	2	0	0				
		Total	0	0	8	0	0	8	1.6	0.08	
	Straighten Steel	L D	0	0	0	0	0				
		L H	0	0	0	0	0				
		R D	0	0	0	0	0				
		R H	0	0	0	0	0				
		Total	0	0	0	0	0	0			
	Direct Powder-Man	L D	0	0	0	0	0				
		L H	0	0	0	0	0				
		R D	0	0	0	0	0				
		R H	0	0	0	0	0				
		Total	0	0	0	0	0	0			
	Powderman Loading Holes	L D	0	0	0	0	0				
		L H	0	0	0	0	0				
		R D	0	0	0	0	0				
		R H	0	0	0	0	0				
		Total	0	0	0	0	0	0			0.16

Table V continued

II-IDLE TIME		Day	1	2	3	4	5	Total	Average per Shift	Percent	
	Excessive Rest	L D	0	25	1	0	0				
		L H	0	24	1	0	0				
		R D	0	21	1	0	0				
		R H	0	27	1	0	6				
		Total	0	97	4	0	6	107	21.4	1.11	
	Wait at End of Shift	L D	12	48	21	25	23				
		L H	12	48	21	25	23				
		R D	12	48	21	25	23				
		R H	12	48	21	25	23				
		Total	48	192	84	100	92	516	103.2	5.38	6.49



Time Distribution Chart
Short Sash Jumbo

To Accompany Table V

Plate X

Table VI - Drilling

Long Sash Jumbo in Sheet Ground--Time Study Consolidation Sheet
All times given in minutes

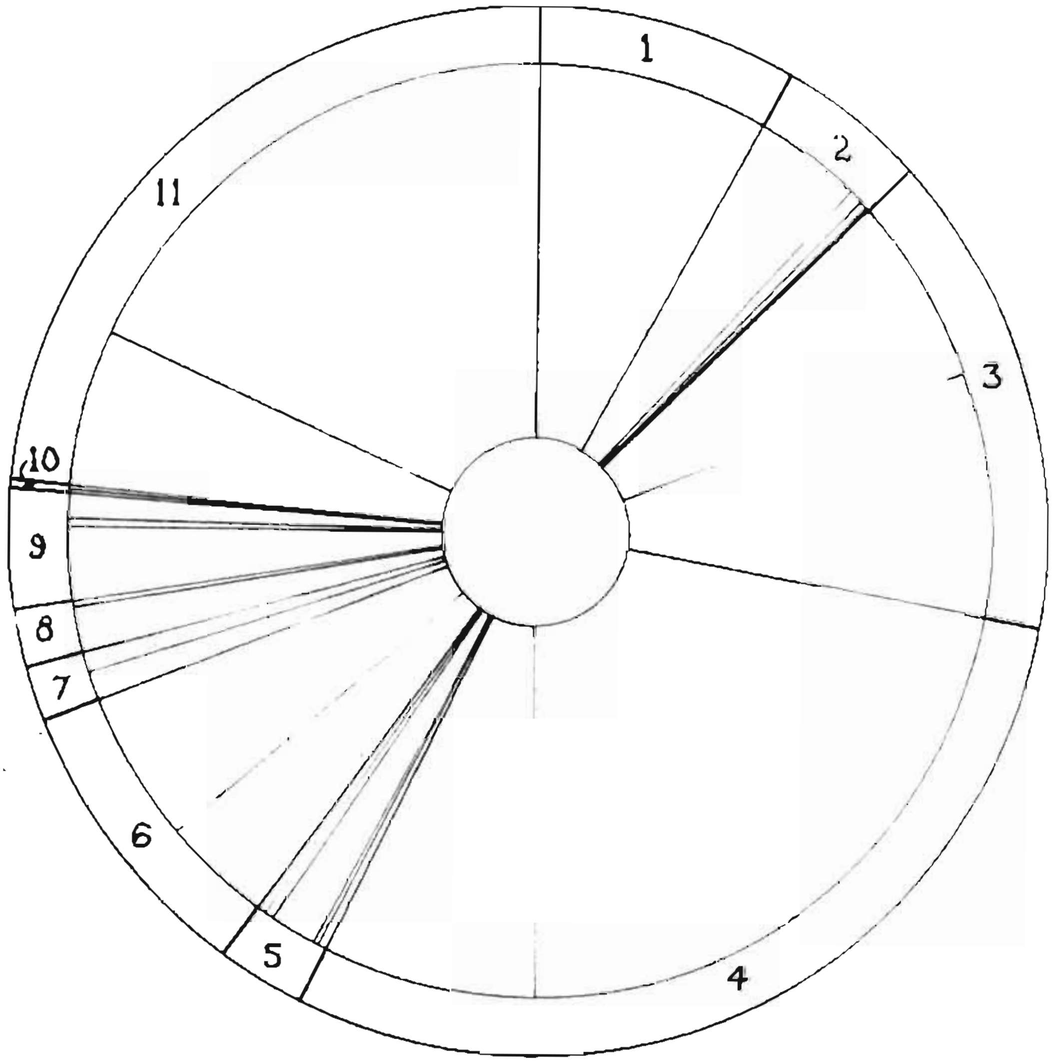
		Day	1	2	3	4	5	Total	Average per Shift	Percent	
1-TRAVEL TIME		L	39	40	38	39	38				
		R	32	40	36	39	43				
		Total	71	80	74	78	81	384	76.8	8.00	8.00
2-FACE PREPARATION	Wait on Muck Out	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0			
	Face Inspection	L	16	24	22	18	12				
		R	22	24	8	18	16				
		Total	38	48	30	36	28	180	36.0	3.75	
	Barring down	L	12	14	0	0	0				
		R	0	0	0	0	0				
		Total	12	14	0	0	0	26	5.2	0.54	
	Wait on Barring down	L	0	0	0	0	0				
		R	4	12	0	0	0				
		Total	4	12	0	0	0	16	3.2	0.33	
	Hose down	L	0	0	0	0	0				
		R	0	3	0	0	0				
		Total	0	3	0	0	0	3	0.6	0.06	
	Wait on Hose Down	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0			
	Moving Boulders	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0			4.68
3-DRILL PREPARATION	Moving Jumbo	L	20	31	30.5	34	37				
		R	20	31	27.5	37	48				
		Total	40	62	58	71	85	316	63.2	6.58	
	Setting Up	L	36	44	46.5	32.5	41.5				
		R	38	43	45.5	32.5	49.5				
		Total	74	87	92	65	91	409	81.8	8.52	15.10
4-DRILLING PRODUCTIVE ELEMENTS	Drilling & Changing	L	169	101	146.5	107.5	136				
		R	152.5	160.5	132	99.5	104				
		Total	321.5	261.5	278.5	207	240	1308.5	261.7	27.26	
	Helping other Drill	L	15	12	15	10.5	2				
		R	7.5	9.5	24.5	9	6				
		Total	22.5	21.5	39.5	19.5	8	111	22.2	2.31	29.57

Table VI continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
5-DRILLING. NON-PRODUCTIVE ELEMENTS	Clean	L	0	6	2	0	3				
	Out	R	0	6	2	0	3				
	Hole	Total	0	12	4	0	6	22	4.4	0.46	
	Blow	L	9	4	22	2	0				
	Holes	R	5	4	17	5	8				
		Total	14	8	39	7	8	76	15.2	1.58	
	Wait on	L	0	0	0	3	8				
	Blow	R	4	0	1	0	0				
	Holes	Total	4	0	1	3	8	16	3.2	0.33	
	Collar	L	0	2	9	0	0				
	Hole	R	5	0	2	0	0				
		Total	5	2	11	0	0	18	3.6	0.38	2.76
6-PRODUCTIVE DELAYS	Wait on	L	13	28	42	0	7.4				
	Other	R	17	23	18	16.5	15				
	Drill	Total	30	51	61	16.5	22.5	180	36.0	3.75	
	Wait on	L	12	53	0	28.5	21				
	Extra	R	27	10	37.5	20.5	39.5				
	Holes	Total	39	63	37.5	49.0	60.5	249	49.8	5.19	8.94
7-NON-PRODUCTIVE DELAYS	Stuck	L0	0	0	0.	13.5	15				
	Steel	R	0	10	7	0	0				
		Total	0	10	7	13.5	15	45.5	9.1	0.95	
	Wait on	L	0	10	6	0	0				
	Stuck	R	0	0	0	11	7				
	Steel	Total	0.	10	6	11	7	34	6.8	0.71	1.66
8-SUPPLY DELAYS	Collect	L	0	6	0	11	17				
	Supplies	R	8	8	15	0	12				
		Total	8	14	15	11	29	77	15.4	1.60	
	Wait on	L	0	6	0	0	0				
	Collect	R	0	4	0	0	0				
	Supplies	Total	0	10	0	0	0	10	2.0	0.21	1.81
9-MAINTENANCE DELAYS	Hose	L	2	0	29	9	22				
	Repairs	R	5	0	29	16	11				
		Total	7	0	58	25	33	123	24.6	2.56	
	Drill	L	2	0	0	0	3				
	Maintenance	R	4	0	0	1.5	3				
	& Repairs	Total	6	0	0	1.5	6	13.5	2.7	0.28	

Table VI continued

		Day	1	2	3	4	5	Total	Average per Shift	Percent	
9-continued	Repairs to Jumbo	L	0	0	0	0	0				
		R	0	0	0	0	m0				
		Total	0	0	0	0	0	0			
	Oiling	L	7	5	1	4	2				
		R	2	2	7	2	9				
		Total	9	7	8	6	11	41	8.2	0.85	3.69
10-MISCELLANEOUS DELAYS	Machine off Sash	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0			
	Blasting Damage	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0			
	Straighten Steel	L	0	4	0	0	0				
		R	0	0	0	0	0				
		Total	0	4	0	0	0	4	0.8	0.08	
	Direct Powder Man	L	0	3	0	0	0				
		R	0	3	0	0	0				
		Total	0	6	0	0	0	6	1.2	0.13	
	Powderman Loading Holes	L	0	0	0	0	0				
		R	0	0	0	0	0				
		Total	0	0	0	0	0	0			0.21
11-IDLE TIME	Excessive Rest	L	26	42	17.5	27.5	20				
		R	25	42	18	32.5	11				
		Total	51	84	35.5	60	31	261.5	52.3	5.45	
	Wait at End of Shift	L	102	45	53	140	95				
		R	102	45	53	140	95				
		Total	204	90	106	280	190	870	174.0	18.14	23.59



TIME DISTRIBUTION CHART
LONG SASH JUMBO
Sheet Ground

To Accompany Table VI

PLATE XI

Table VII - Drilling

Long Sash Jumbo in High Ground--Time Study Consolidation Sheet
All times given in minutes

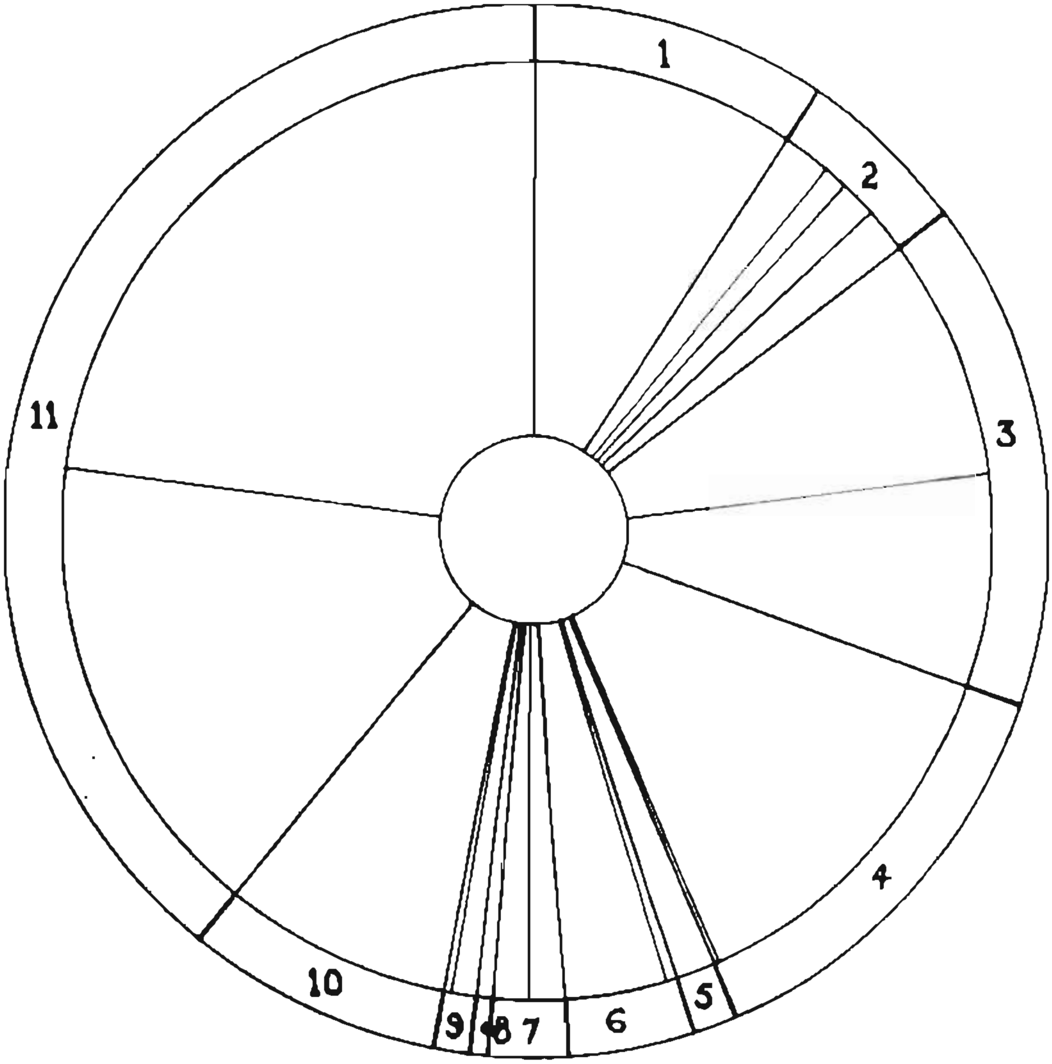
		Day	1	2	Total	Average per Shift	Percent	
1-TRAVEL TIME		L	45	43				
		R	45	43				
		Total	90	86	176	88.0	9.17	9.17
2-FACE PREPARATION	Face Inspection	L	3	9				
		R	3	19				
		Total	6	28	34	17.0	1.77	
	Barring down	L	15	0				
		R	0	0				
		Total	15	0	15	7.5	0.78	
	Wait on Barring down	L	0	10				
		R	15	0				
		Total	15	10	25	12.5	1.30	
	Hose Down	L	10	0				
		R	10	11				
		Total	20	11	31	15.5	1.61	
	Wait on Hose Down	L	0	0				
		R	0	0				
		Total	0	0	0			
	Moving Boulders	L	0	0				
		R	0	0				
		Total	0	0	0			5.46
3-DRILL PREPARATION	Moving Jumbo	L	23	58				
		R	22	58				
		Total	45	116	161	80.5	8.39	
	Setting Up	L	23.5	47				
		R	23.5	43				
		Total	47	90	137	68.5	7.14	15.53
4-DRILLING PRODUCTIVE ELEMENTS	Drilling & Changing	L	14	87				
		R	56.5	98				
		Total	70.5	185	255.5	127.8	13.31	
	Helping other Drill	L	3	0				
		R	0	0				
		Total	3	0	3	1.5	0.16	13.47

Table VII continued

		Day	1	2	Total	Average per Shift	Percent	
5-DRILLING NON-PRODUCTIVE ELEMENTS	Clean Out Hole	L	0	18				
		R	0	7				
		Total	0	25	25	12.5	1.30	
	Blow Holes	L	0	0				
		R	0	0				
		Total	0	0	0			
	Wait on Blow Holes	L	0	0				
		R	0	0				
		Total	0	0	0			
	Collar Hole	L	0	0				
		R	0	0				
		Total	0	0	0			1.30
6-PRODUCTIVE DELAYS	Wait on Other Drill	L	0	2				
		R	0	6				
		Total	0	8	8	4.0	0.42	
	Wait on Extra Holes	L	39.5	7				
		R	14	7				
		Total	53.5	14	67.5	33.8	3.51	3.93
7-NON PRODUCTIVE DELAYS	Stuck Steel	L	0	0				
		R	24	0				
		Total	24	0	24	12.0	1.25	
	Wait on Stuck Steel	L	24	0				
		R	0	0				
		Total	24	0	24	12.0	1.25	2.50
8-SUPPLY DELAYS	Collect Supplies	L	4	6				
		R	0	0				
		Total	4	6	10	5.0	0.52	
	Wait on Collect Supplies	L	0	0				
		R	0	0				
		Total	0	0	0			0.52
9-MAINTENANCE DELAYS	Drill Maintenance & Repairs	L	0	0				
		R	0	0				
		Total	0	0	0			
	Repairs to Jumbo	L	0	0				
		R	0	0				
		Total	0	0	0			

Table VII continued

		Day	1	2	Total	Average	Percent	
9-MAINTENANCE DELAYS (con't)	Oiling	L	1	3				
		R	1	0				
		Total	2	3	5	2.5	0.26	1.09
10-MISCELLANEOUS DELAYS	Machine Off Sash	L	0	0				
		R	0	0				
		Total	0	0	0			
	Blasting Damage	L	0	0				
		R	0	0				
		Total	0	0	0			
	Straighten Steel	L	0	0				
		R	0	0				
		Total	0	0	0			
	Direct Powder Man	L	0	0				
		R	0	0				
		Total	0	0	0			
	Powder man Loading Holes	L	56	19				
		R	56	19				
		Total	112	38	150	75.0	7.81	7.81
11-IDLE TIME	Excessive Rest	L	43	115				
		R	44	107				
		Total	87	222	309	154.5	16.09	
	Wait at End of Shift	L	166	56				
		R	166	56				
		Total	332	112	444	222.0	23.13	39.22



TIME DISTRIBUTION CHART
LONG SASH JUMBO
High Ground

To Accompany Table VII

PLATE XII

Table VIII

Move, Set Up, and Drilling Data for
Hand feed, Post-or Tripod-mounted Drills

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time-mins.	65.5	138	98.5	302
	Feet drilled	30	53.5	40	123.5
	No. of holes	3	7	5	15
	Drilling Speed-ft./min.	0.46	0.39	0.41	0.41
	Ave. depth-ft.	10	7.6	8.0	8.2
	Ave. time per hole-mins.	21.8	19.7	19.7	20.1
	No. of steels	15	26	20	61
	Ave. steels/hole	5.0	3.7	4.0	4.1
	Feet drilled/steel	2.00	2.06	2.00	2.02
SETTING UP	Total Time Setting Up-mins.	48	102	88	238
	No. of holes	3	7	5	15
	Ave. time per hole	16.0	14.6	17.6	15.9
	Ave. time of hole per man	8.0	7.3	8.8	8.0
MOVE--A	Total Time Erecting Post-mins.				198
	No. of times Post erected				3
	Ave. time				66.0
	Ave.time per man				33.0
MOVE--B	Total Time Erecting Tripod-mins.				116
	No. of times Tripod erected				3
	Ave.time				38.7
	Ave. time per man				19.4

Table IX

Move, Set Up, and Drilling Data for Short Sash Automatic-feed Jumbo-mounted Drills

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time-mins.	455	389	557	1401
	Feet drilled	241	223	240.5	704.5
	No. of holes	31	29	36	95
	Drilling Speed-ft./min.	0.53	0.57	0.43	0.50
	Ave. depth-ft.	7.8	7.7	6.7	7.3
	Ave. time per hole-mins.	14.7	13.4	15.8	14.5
	No. of Steels	111	103	116	330
	Ave. steels/hole	3.6	3.6	3.2	3.4
	Feet drilled/steel	2.17	2.16	2.08	2.14
SETTING UP	Total Time Setting Up-mins.	317	223	267	807
	No. of holes	31	29	36	96
	Ave. time per hole	10.2	7.7	7.4	8.4
	Ave. time of hole per man	5.1	3.9	3.7	4.2
MOVE JUMBO	Total Time Moving Jumbo-mins.				432
	No. of Moves				21
	Ave. time per move				20.6
	Ave. time of move per man				5.2

Table X

Move, Set Up, and Drilling Data for Long Sash Automatic-feed Jumbo-mounted Drills

	Type of Hole	Stope	Breast	Roof	Total
DRILLING	Driller's Time-mins.	423.5	422	463	1308.5
	Feet drilled	296.5	241.5	308.5	846.5
	No. of holes	29	25	35	89
	Drilling Speed-ft./min.	0.70	0.57	0.67	0.65
	Ave. depth-ft.	10.2	9.6	8.8	9.5
	Ave. time per hole-min.	14.6	16.9	13.2	14.7
	No. of steels	52	45	62	159
	Ave. steels/hole	1.79	1.80	1.77	1.79
	Feet drilled/steel	5.7	5.4	5.0	5.3
SETTING UP	Total Time Setting Up-mins.	186.5	86.5	136	409
	No. of holes	29	25	35	89
	Ave. time per hole	6.4	3.5	3.9	4.6
MOVE JUMBO	Total Time Moving Jumbo-mins.				316
	No. of moves				19
	Ave. time per move				16.6
	Ave. time of move per man				8.5

breakdowns of the various occupations for the three classes of drilling are given.

It must be emphasized that, while post or tripod mounted drills, and the short sash jumbo, employ two men per drill, only one man is necessary to run each long sash jumbo drill. From this it arises that in the consolidation sheets (Tables IV-VII) and time distribution charts (Plates IX-XII), the percentages for short sash jumbos are based on a shift of 1920 man-minutes (8 hour shift = 480 minutes), and in the other types of drilling on 960 man-minutes.

The interpretation of the effects on the different sub-operations by the use of jumbos and the new occupations involved in their introduction will now be considered.

1. Travel time. Travel time is always dependent on the distance of the working place from the shaft and, therefore, has not been effected by modifications of drilling methods.

2. Face preparation. With the exception of "Wait on Muck Out" and "Moving Boulders", the occupations of face preparation are comparable elements in all methods of drilling. In the case of "wait on muck out" the jumbo has a distinct advantage over the post and tripod drilling in that three, four, or five working places are available. This is in contrast to the latter form of drilling where, as before noted, only one, or at most two faces can be worked by one crew. Thus the likehood of a curtailment in drilling because of a disruption of the loading cycle is far less likely with the jumbo than with the older method of drilling. "Moving boulders" is a rather infrequent element in jumbo operation and, when it does occur, causes but slight delay.

3. Drill preparation. With the advent of jumbo equipment, the time consumed in drill preparation has been reduced markedly.

Erecting the post is made up of many components, the principle ones being; remove machine from arm, remove arm, remove post, level off floor, move equipment, place foot blocks, place post and head blocks, place arm and clamp, and place machine. Likewise, whenever the tripod is used it also involves many similar components. The times necessary to erect a post and tripod average 33 minutes and 19 minutes respectively. The time thus taken to place a post is within the limits of from 30 to 40 minutes as proposed by Young[14].

On the other hand, moving the jumbo to the face is relatively simple and consumes only 5 minutes in the case of the short sash jumbo and 8 minutes by the long sash equipment. The longer time used in moving the long sash jumbo is because of the smaller crew available for shifting the hoses. Moving the jumbo in high ground is a more complicated operation because the machine must climb up and down the muck piles which, in places, may be very steep (Plate VIII, Fig. 3). This requires considerable time in stabilizing the pile so that the jumbo may be moved safely into position. In two days, five moves took 80 minutes, or an average of 16 minutes.

With the use of the jumbo, the time spent setting up the drills has decreased for all types of holes (stope, breast, and roof). The time has been reduced from an average of 8 minutes for the post and tripod to 4.2 minutes and 4.6 minutes for the short and long sash respectively. This is because, in drilling from a post, the clamps must be released, and then tightened after the arm has been adjusted for each new hole. In contract, setting up to drill two holes from

14. Young, J.J., Elements of Mining, New York McGraw Hill, 3rd ed. (1932) p. 110.

the jumbo is accomplished by simply raising or lowering the boom and slightly shifting the jumbo.

4. Drilling--Productive Elements. Though automatic-feed machines are faster than hand-feed drills, the average drilling rates being 0.50 and 0.41 feet a minute respectively, each will drill at that rate regardless of whether they are mounted on a post or on a short sash jumbo. The average drilling rate for the machines of a long sash jumbo is 0.65 feet a minute, and is a marked improvement over that of either of the other two types. This is because the number of steels required to drill a hole is reduced, and hence the total time spent drilling and changing is minimized.

The average speeds at which the different types of holes are drilled vary widely, and it is apparent that stope holes have, in general, a higher average than others. This is not in agreement with the statmenet by Young[15] that up holes are drilled faster than down holes.

Where changing by helpers is involved as an occupation, the study indicates that time spent in changing with machines equipped with automatic feed is less than for those which are hand fed. This result, together with those determined for respective drilling rates, confirms the claims advanced by drill manufacturers that the automatic machinery is more efficient than that which is manually operated.

As the drillers must help each other in starting the long sash machines efficiently, time consumed in such cooperative efforts has been, as before noted, allocated under the item "helping other drill." This is an occupation peculiar to the manipulation of long sash jumbos and averages approximately 1.25 minutes a hole.

15. Young, G.J., op. cit., p. 108

5. Drilling--Non Productive Elements. As wait for changing is an occupation which applies only to those drilling machine operations where helpers are present as members of the drill crew, it is not an element of long sash jumbo drilling. All other occupations, however, listed under this heading, and defined on page 27, are common to the operation of all types of machines. A portion of the helper's time, which would otherwise be spent as wait for changing, may be usefully employed, such as in collecting supplies. This explains why the times spent in concurrent occupations carried on by the driller and helper of a machine during actual drilling are not equal.

6. Productive Delays. Because two drill machines are mounted on a jumbo, and so may be considered to form an interdependent operating unit, "wait on other drills" and "wait on extra holes" as delay elements are important items.

Wait on other drill results from the fact that the two drill machines do not operate at absolutely equal rates, and also, because the depths of holes drilled may be different. If it were possible to maintain uniformity of these conditions there would, of course, be no delay of this nature. These qualifying conditions, however, can not be completely standardized or controlled, nor can the need to wait on extra holes be overcome, and hence, all such delays are inherent in jumbo drilling. Post and Tripod drilling are not subject to these delays as only one drill is involved in the procedure.

7. Non-Productve Delays. "Stuck Steel" and "Wait on Stuck Steel" are delays that may assume serious proportions if care is not excerized in maintaining the drills in stable position. Although the element of stuck steel is found in all classes of drilling, somewhat more

care is required with the jumbo to minimize delay from this cause on account of the less stable set up as compared with the post. Wait on stuck steel occurs only with the jumbos, and then only when one drill of the unit is prevented from proceeding to work on the next hole.

8. Supply Delays. Supply delays transpire only when actual drilling is retarded because of lack of materials necessary to continue the work. Therefore, in the cases of post and short sash jumbo operations, where it is possible for a helper to collect supplies while the driller continues to run the machine, a delay is seldom experienced, and hence they are not important elements of the drilling cycle. On the other hand, with the long sash jumbo, where the driller must obtain his own supplies, occasions arise when his absence may disrupt the cycle and thus prevent the other drill runner from starting work on the next hole; a total delay of 10 minutes was experienced from this cause over a period of five days.

9. Maintenance Delays. All elements under this heading, apart from oiling which is a daily activity, are sporadic in their occurrence. The item repairs to jumbo is, of course, pertinent only to jumbo equipment and, therefore, is a new delay element which has been introduced by the use of this apparatus. On Table V the comparatively large delay shown for the third day's work for the short sash jumbo is the result of a broken feed screw in an automatic sash. According to Clarke[16], the chain feeds used on the long sash jumbo machines require far less replacement and repairs than either form of screw feed.

10. Miscellaneous Delays. Except for the delay caused by the powder-

16. Clarke, S.S., Oral Communication.

man's use of the jumbo when loading holes, all miscellaneous delays, which appear to be caused largely by carelessness, or bad practice, are unpredictable and non-cyclic.

11. Idle Time. The delay, which transpires during the shift as idle time, is not peculiar to any of the forms of drilling procedures. Reference to the consolidation tables, however, indicates that idle time has increased since the introduction of the jumbo machines because their cyclic operations are accomplished so much more rapidly than with former methods.

Cost of Drilling

In computing costs of operation for drilling, it is customary for mining companies to weigh the total expenses of actual drilling, blasting, repairs, etc., termed "breaking cost", against the tonnage of rock yielded as a result of these expenditures. The overall cost of drilling must, of course, include in addition to breaking cost a prorated allowance for capital cost of equipment. In this analysis, however, the only capital outlay for equipment that need be considered is that which accures in the purchase and installation of jumbos.

Breaking costs in dollars a ton as obtained from the company records for the drilling procedures before and after adoption of the jumbos are summarized below.

	Average for 1943 before jumbos	Average for first 8 months of Jumbos	
Mine No. I	0.95	0.71	(short sash)
Mine No. II	0.80	0.56	(long sash)

It is evident that the breaking cost in both mines has been reduced by $0.24 a ton.

The capital cost of a secondhand tractor frame or chassis suitable for conversion to a jumbo is $1000. An additional $350 is required to purchase and convert a Ford model A engine. The labor and added materials employed in rigging the jumbo brings the total cost of the machine to $2700. In the case of the long sash jumbo machine another $1000 is required for the purchase of two long sashes.

From the statistics of Table I it may be noted that the tonnage produced through the operation of each short sash jumbo drill is approximately 90 tons a shift; or, in other words, 180 tons a jumbo; corresponding figures for the long sash jumbos are 130 and 260 tons. As the breaking cost per ton has been reduced by $0.24, by the adoption of jumbo equipment, it is apparent that the saving per shift that has been realized is $43.2 for operations using the short sash jumbos, and $62.4 for those working the long sash. Now, therefore, as the capital costs of the short sash and long sash machines are $2700, and $3700 respectively, it is evident that, in those mines to which the figures apply, the operation of the short sash units will result in a saving equal to the cost of the jumbo in 63 shifts; the long sash operation in 60 shifts.

Summary of Drilling Methods

The occupations which are most comparable from one drilling method to the next are, as previously stated, those found under drill preparation and productive drilling. Tables XI A and B, and Plate XIII, have been prepared, from the data of Tables VIII, IX, & X, to offer a comparative analysis of the time which is consumed by these cyclic occupations in the different drilling methods. Though depths of holes and rate of drilling ordinarily vary through narrow limits in an actual drilling operation it is necessary, in order to make a logical comparison, that they be set as constants. Table XIA shows these assumed constants as based on the data compiled in the foregoing tables and the prorated time to drill calculated therefrom.

Table XI A--Prorated Drilling Times for Constant Depths of Holes

Type of Hole	Assumed Depth of hole-ft.	Drilling Rate-ft./mins.			Time to drill-mins.		
		Long Sash Jumbo	Short Sash Jumbo	Post and/or Tripod	Long sash Jumbo	Short Sash Jumbo	Post and/or Tripod
Stope	9	0.70	0.53	0.46	12.9	17.0	19.6
Breast	8.5	0.57	0.57	0.39	14.9	14.9	21.8
Roof	8	0.67	0.43	0.41	11.9	18.6	19.5

These prorated data, together with those upon which no assumption is necessary, are assembled in Table XI B and Plate XIII. All times are there entered in the form of total man-minutes devoted to each occupation; e.g., for short sash machines a stope hole is drilled in 17.0 mins., but, as there are 2 stope holes in the round, and 2 men working on each hole, the time taken is 17.0 x 2 x 2 = 68 man minutes which is the figure entered in the table. In drilling from a post, each erection of the post allows the drilling of a round in two separate adjoining faces; therefore, the total man-minutes involved in this operation for any single round is 50% of the combined time used by the driller and his helper to accomplish a given erection and move of the machine.

Allowances for the additional elements of help other drill and collect supplies, which increase the accumulated time, only in the

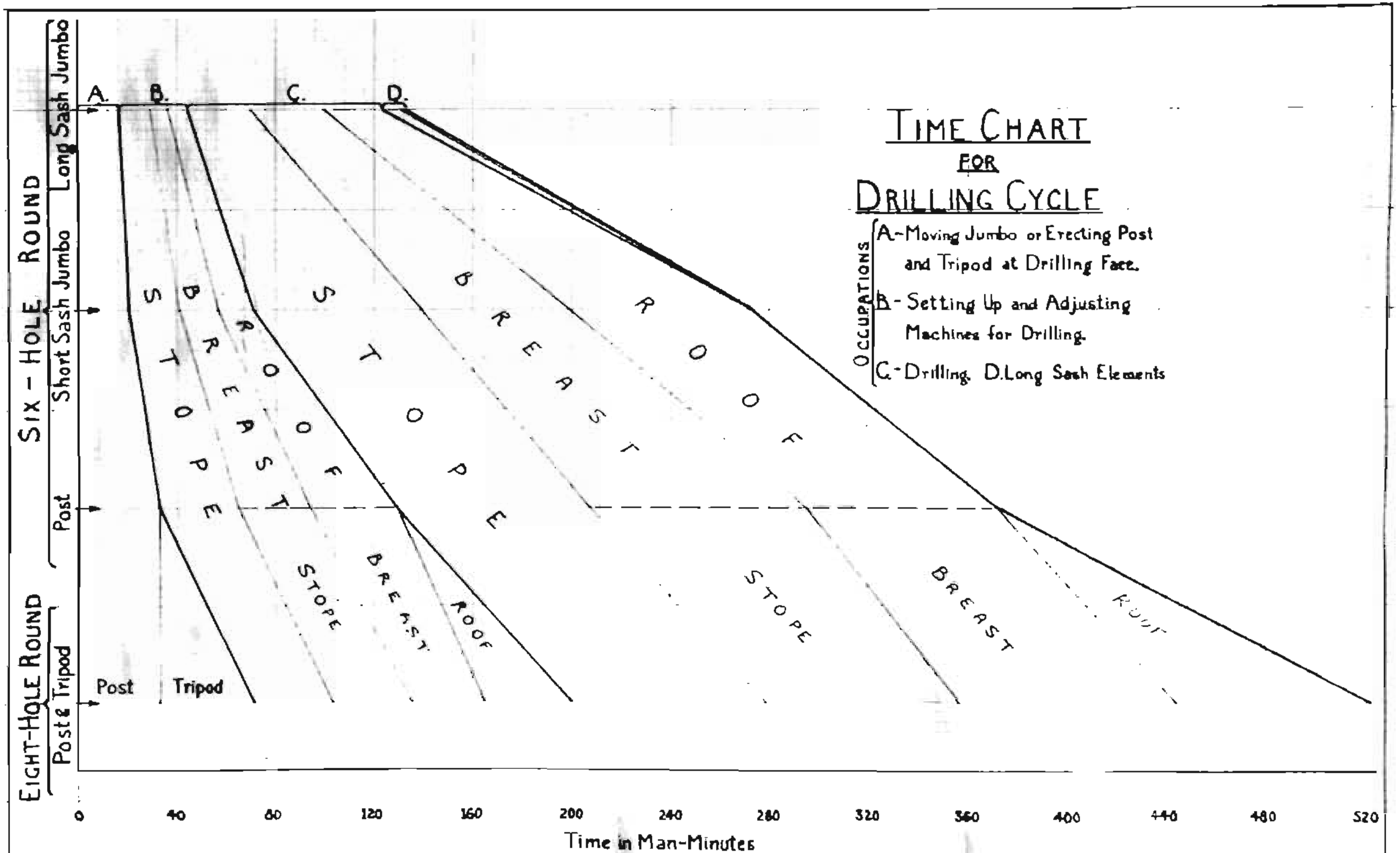
Table XI B - Operational Time Sheet of Drilling

I. Jumbo Long Sash, II. Jumbo Short Sash, III. Post (Six-hole Round)

IV. Post and Tripod (Eight Hole Round)

All times given in man-minutes required to perform occupations

			I		II		III		IV	
	No. of men per hole		1		2		2		2	
		Times Performed	Time	Accum. Time	Time	Accum. Time	Time	Accum. Time	Time	Accum. Time
A-MOVE	Move Jumbo	1	16.6	16.6	20.6	20.6				
	Erect Post	0.5					33.0	33.0	33.0	33.0
	Erect Tripod	1							38.7	71.7
B-SETTING UP	Stope	2	12.8	29.4	20.4	41.0	32.0	65.0	32.0	103.7
	Stope	2							32.0	135.7
	Breast	2	7.0	36.4	15.4	56.4	29.2	94.2	29.2	164.9
	Roof	2	7.8	44.2	14.8	71.2	35.2	129.4	35.2	200.1
C-DRILLING	Stope	2	25.8	70.0	68.0	139.2	78.4	207.8	78.4	278.5
	Stope	2							78.4	356.9
	Breast	2	29.8	99.8	59.6	198.8	87.2	295.0	87.2	444.1
	Roof	2	23.8	123.6	74.4	273.2	78.0	373.0	78.0	522.1
D LONG SASH	Help other drill		7.4	131.0						
	Collect Supplies		1.4	132.4						



To Accompany Table XI

PLATE XIII

case of the long sash jumbo procedure in this analysis, have been entered on Table XI B, because a driller on the long sash machine operation must engage, when necessary, in these occupations. As they are those of a holter in the other types of drilling and for which time, in the latter case, has already been incorporated in drilling man-minutes, it is appropriate that suitable allowances be integrated. These allowances are determined as follows: helping other drill as given on page 82 is approximately 1.25 man-minutes a hole, or 7.4 man-minutes for the round of six holes. A driller, in collecting supplies during the drilling of 89 holes, caused the other driller the delay wait of 10 minutes; therefore, the total supply delay to the long sash jumbo was 80 man-minutes, thus the delay allowance for a round of six holes is 1.4 man-minutes.

The statistics for total accumulated man-minutes for each type of drilling have been plotted on the Time Chart for Drilling Cycle, Plate XIII. The marked decrease, in total man-minutes involved in the cyclic occupations, which has resulted through the adoption of the short sash and long sash jumbos is demonstrated. This decrease, of course, contributes to a more efficient operation inasmuch as, 1, each man-minute regardless of the method employed is paid on the same basic rate, and 2, a correspondingly better utilization of the drilling machines is possible.

This presentation of the data represents the ideal drilling cycle where complete standardization of the round in number of holes, rate of drilling, and depth of holes is possible. If this were the case in actual practice, such occupations as wait on extra holes, and wait on other drill, would not enter the picture. The other occupations, e.g., blow holes, stuck steel, etc., of which no account has been taken in this summary discussion, are assumed in the aggregate to enter each drilling method with equal effect as far as time is concerned. From the fact that there has been a considerable increase in production (Table I) since the introduction of the jumbos, it is evident that the time involved in any new elements is nowhere near sufficient to offset the benefits accruing from a reduction of time devoted to the cyclic elements considered.

The first jumbos that were installed have operated continually for eight months, which is the equivalent of 196 shifts. As they will save their cost, by reducing expenses, in less than a third of this time, their installation has been a financial success, apart from the other benefits above mentioned. At present their working life is an unknown quantity, but it is certainly considerably in excess of eight months. The only parts of the jumbo subject to pronounced wear are the tracks, and pivots of the boom.

TRANSPORTATION

The trend towards mechanization in the activities of breaking and transportation in the Tri-State District mines has introduced conditions which make it desirable that phases of both be considered in their relationship to each other. That is, the maximum benefits obtainable from the jumbo do not accrue unless it is used in conjunction with the transportation system best fitted to handle the production from the jumbos; conversely, changes in transportation do not yield a maximum benefit unless the tonnages to be handled are sufficient to justify any change.

The process of transportation is considered in two parts, haulage and hoisting. The method of time study differs somewhat from that followed for drilling analyses.

Operating costs quoted for the different systems are for the mines at which the studies were made, and are those experienced the first eight months of 1944.

HAULAGE

There are four systems of haulage and the operations of each are divisible into four elements, namely; 1. going into the face empty, 2. loading or switching (turning around), 3. going out to the shaft loaded, and 4. at shaft dumping, or switching. Previous descriptions of efficiency studies of haulage procedures have been aimed largely at describing one system with particular reference to interruptions and, thereby, indicating the effectiveness in utilization of the means provided. In this study no account is taken of interruptions as these are considered to be primarily functions of related activities, such as small shaft capacity, and are not inherent in the haulage system itself.

Readings of the start and stop of the four elements are recorded to the nearest second on an observation and summary sheet (Table XII). They are obtained by the use of a stopwatch. The difference between the two readings (start and stop) gives the time that is taken to perform the element and is entered alongside these data. The average for each element is transferred to other sheets, (Tables XIII-XVII) on which are also recorded details of size of each unit trip, or load in tons, number of trips, haulage distance, length of scraper drag where scrapers are used for loading, and maximum and minimum readings for the set of observations. On these sheets the times which are taken to go a unit distance (100 feet) and to load or dump one ton

Table XIII - Haulage--Time Study Observation and Summary Sheet

Working Place______________________________Date____________________Mine_______________

Remarks e.g. length of haulageway__________________________Type of Haulage_____________

	1. In Trip		2. Load or Switch		3. Out Trip		4. Switch or Dump	
Start	17.20	105	19.45	550	28.55	80	30.15	54
Stop	19.05		28.55		30.15		31.09	
Start	31.09	99	32.48	528	42.10	79	43.29	52
Stop	32.48		41.36		43.29		44.21	
Totals	204		1078		159		106	
Averages	102		539		79.5		53	

are recorded to permit a comparison of the different tracks on which studies were conducted.

<u>Mule Haulage with Cans</u>

Mule haulage with cans though still used in some of the smaller mines is a system of haulage that was much more widely applied in the past. One of the reasons for the decline in use is that it has become the practice to follow the slight dips of the ore body during mining, rather than to maintain haulageway grades of $1\frac{1}{2}$ per cent or less which can not be exceeded if mules are used.

Unlike all other systems in which the carrying media, or receptacles, are loaded by drag scrapers in the mule system mechanical shovel loaders are used to load the empty cans during the time that mules are engaged in pulling a loaded train (or trip) to the shaft and returning with the next empty trip. A mule is capable of hauling seven or eight loaded cans, each can of 0.6 tons capacity, from the face to the shaft in one trip. A time study of the operation of a loader indicated that, with reasonably good conditions, one of these cans is loaded every 60 seconds. If it is assumed that loading and haulage are carried on for at least 7 hours during any given 8-hour shift, the maximum tonnage which can be loaded is 252 tons.

As it may be seen from a study of Table XIII that the haulage distance makes little or no difference in the speed at which mules work, the average time for in and out trips being about 20.4 seconds per 100 feet, it is possible to calculate the haulage distance best suited to match loading time as follows:

$$S + \frac{h \times 2D}{100} = L$$

where, S = total switching time (switch at loader and switch at shaft),

D = haulage distance (one way in feet),

Table XIII - <u>Mule Haulage with Cans--Time Study</u>

		Track A	Track B
Size of Trip--tons		4.2 (7 cans)	4.2 (7 cans)
No. of Trips		8	6
Haulage Distance one way-ft.		900	375
Average and Maxima & Minima Time in Secs.	In (empty)	165 (150-184)	73 (70-75)
	Switch at Loader	31 (15-40)	18 (14-20)
	Out (loaded)	203 (178-227)	80 (76-83)
	Switch at Shaft	17 (12-23)	16 (14-18)
Comparative time In Secs.	In 100 ft. (empty)	18.3	19.6
	Out 100 ft. (loaded)	22.6	21.2

h = haulage rate in seconds per 100 feet,

L = loading time in seconds.

Thus, substituting the values of 41 seconds average switching time, 20.4 seconds haulage time per 100 feet, and 420 seconds loading time for a 7-can trip, and solving for D, the haulage distance at which best co-ordination would be achieved is 930 feet. Therefore, in any case where the distance is greater than 930 feet the loader will be idle part of the time waiting for empty cars; conversely, with distances less than 930 feet the haulage system will be idle because the loader is limited in capacity. It is realized that mules are subject to fatigue but, as an allowance has been made for rest periods by computing the daily tonnages moved on a 7-hour basis rather than an 8-hour shift, it is felt that delays for resting the animals have been sufficiently accounted for.

A brief analysis of the estimated capital cost for a unit of the mule haulage system includes the items of track, mule, and can entities*, comprised of the actual cans, and the flat bed cars on which they sit.

1000 feet 18 inch gauge track =	$1800	
25 cans at $52.5 each	1312.5	
1 mule at $200	200	
TOTAL	$3012.5	i.e. approximately $3000.

It has been found that daily operating costs range between $0.30-0.40 a ton.

* As the cans, but not the flat-bed cars, are used for hoisting as well as haulage, their cost should be prorated between these two. Cost of a can is $25 and half of this is charged to haulage which, with $40 for a flat bed car, makes the total cost of a can unit, $52.50.

Battery Locomotive Haulage With Cars

The system of battery locomotive haulage with cars, which have a capacity of 1.5 tons each, has been used for several years in the Tri-State District and seems to have been applied most extensively where the grade of the tracks is steep. In fact, battery locomotives were observed to be operating on haulageways which even approach 6% in grade for short distances. Therefore, because of the practice of using this system for uphill pulls when going out with a load, the times consumed in moving loaded trips (see Table XIV) are slightly higher than ordinarily they would be under haulage conditions comparable to the other systems. Like mule haulage, the locomotive does not wait at the loading site or shaft while the cars are being loaded or dumped, and thus, no time other than switching is spent at either of these terminals. The discrepancies which exist between the in and out distances in the table are accounted for by the fact that the locomotives must, because of the arrangement of the trackage at the shaft, switch a distance of 120 feet in picking up the empty trip.

A train of 8 cars is pulled by each locomotive and the time consumed in loading this number of cars as a unit is about 530 seconds; or converting to daily tonnages, a maximum of 570 tons is loaded in seven hours. The data obtained from the time studies of the two haulage operations (Tracks A and B of Table XIV) have been combined as mean estimates, and these values have been substituted in the formula*, $S + \frac{h \times 2D}{100} = L$, to determine the optimum haulage distance for battery locomotives. By solution, this distance is calculated to

* formula as proposed on p. 64.

Table XIV - Battery Locomotive Haulage with Cars--Time Study

		Track A	Track B
Size of Trip--tons		12 (8 cars)	12 (8 cars)
No. of Trips		6	4
Haulage Distance-ft.	In	1140	850
	Out	1050	760
Average and Maxima & Minima Time in Secs.	In (empty)	119 (116-122)	92 (85-95)
	Switch at Layby	30 (26-35)	29 (21-33)
	Out (loaded)	166 (157-172)	142 (135-149)
	Switch at Shaft	101 (69-130)	91 (70-117)
Comparative Time In Secs.	In 100 ft. (empty)	10.4	10.9
	Out 100 ft. (loaded)	15.8	18.7

be 1460 feet. It is, in other words, one half the round trip distance where full co-ordination can be achieved between loading and hauling the material to the shaft.

At the mine in which battery locomotives and cars are used, it is the practice for a locomotive to be worked on main line service, that is, it hauls cars over the main track between the shaft and two turnout terminals whence the empty trips are secondarily distributed by the rope haulage method (discussed later) to several scraper loaders. With this arrangement it may be seen (from Table XIV) that 24 tons is moved every 770 seconds over a mean distance of 930 feet, or in a 7-hour period 785 tons may be handled.

Inasmuch as the size of a train is governed chiefly by the track grades to be negotiated and as the round trip is retarded appreciably by the long period for switching at the shaft, it would seem that the equipment could be worked at a higher capacity with respect to both tonnage and speed if these factors were more favorable.

To obtain a measure of locomotive haulage for comparison later with the rope and truck haulage systems, it is necessary to assemble the data in such a way that the same elements are incorporated. There are two cases to be considered:

1. Truck haulage involves the four elements of; in, loading, out, and dumping. Rope haulage also may be used on such a cycle. In computing the round trip time for a locomotive on this cycle times spent switching at shaft and loader have been replaced by estimates for dumping time in a two car rotary dump, and loading time, respectively.

By use of the formula, $T = L + \frac{2Dh}{100} + Wd$, where

T = round trip time in seconds,

L = loading time in seconds --- 530 secs. for an 8 car trip,

D = haulage distance, one way in feet -- here assumed to be 700 feet,

W = load per trip --- in this case, 12 tons,

h = haulage rate in seconds per 100 feet -- average for in and out trips (Table XIV) 13.9 secs.,

d = dumping rate in seconds per ton -- from Table XV dumping rate for a two car rotary dump is 1 ton every 6.4 secs.,

the round trip time is found to be 801 seconds, and the capacity of a battery locomotive on this comparative basis is 378 tons in a 7-hour period.

2. For comparison with the usual type of rope haulage system in which loading is an element, but dumping into a pocket at the shaft does not take place, the four elements of in, load, out, and switch, are taken into account. By solution of the formula,

$$T = L + \frac{2Dh}{100} + S,$$

where S = average switching time at shaft----96 seconds. The other symbols are the same as given under case 1 above.

The round trip time for this cycle of the locomotive is found to be 821 seconds for an 8 car load on a round trip of 1400 feet. In seven hours 368 tons may be transported.

Capital costs for battery locomotive haulage with cars is as follows:

1000 feet of 24 inch gauge track	$1800
locomotive with batteries	4000
battery charging panel	1100
Total	$6900

In addition the cost of each car used is $150, though it should be borne in mind that if the cars are hoisted 50% of this cost should be prorated to hoisting.

Direct operating costs for locomotive haulage are not available but they are of the order $0.25 - $0.30 a ton.

Main and Tail Rope Haulage

Main and tail rope haulage is a system in which cars or cans are connected in a closed circuit by two ropes or cables with a double-drum hoist, and whereby, they are pulled intermittently to and from the loading site and hoist. The main rope passes from its drum direct to the forward end of the train while the tail rope is connected to the rear after passing round a sheave placed beyond the loader. In hauling loaded trips the main rope drum is in gear, the tail rope drum free, the converse is the case when empties are being returned to the loader. Most of the two drum hoists are driven by 15 horse-power induction motors; the main or pull rope used is 5/8 inch cable and the tail rope 1/2 inch. The capacity of a car and a can is 1.5 and 0.6 tons, respectively.

The empties are taken into the scraper loader and each can or car spotted in turn under the loader spout by the hoistman on signal from the train tender at the scraper site. After loading has been completed, the trip is brought out to the hoist and an empty train picked up from the layby switch track, or, in the case of cars, the trip may be unloaded by pulling it through the rotary dump located above the shaft pocket. Thus, if cars are used in the unit they may be placed on a cage and hoisted direct, or they may be dumped into a pocket. If cans are used, they are hoisted.

Table XV gives the data obtained from a time study of main and tail rope haulage where cars were used and Table XVI presents similar data for operations with cans. From these two sets of data; (1), a comparison of the relative efficiency of main and tail rope units which use cans as receptacles and those which use cars can be made and, (2), the statistics can be so treated that comparative analyses of main and tail rope haulage with respect to other systems of haulage are possible. The data of Table XV represent time studies made of procedures wherein the main and tail rope haulage is used as a secondary or feeding unit (Tracks A and B), and as a main line system (Track C); that is, the systems of Tracks A and B pull from loading sites to switch laybys, from which point the loads are moved on the main line system to the shaft station. The data of Tracks A and B may be used; (1) to draw comparisons of the two classes of rope haulage which involve the same elements, namely, in, load, out, switch; while (2), by a combination of certain of this data with that for track C, a comparison may be made with locomotive, and truck haulage.

(1) from the statistics for tracks A & B, the average times obtained are,

in 100 feet	22.2	seconds,
loading 1 ton	41.2	" ,
out 100 feet	18.2	" ,
switch at layby	50.5	" .

Then by use of the formula $T = L + \frac{2Dh}{100} + S$, on the basis of an 8 car or 12 ton load the time for a round trip over a one way haulage distance of 700 feet is 828 seconds; that is, the system is capable of moving 365 tons in seven hours.

Table IV - Main and Tail Rope Haulage with Cars--Time Study

		Track A	Track B	Track C
Size of Trip--tons		12 (8 cars)	9 (6 cars)	18 (12 cars)
No. of Trips		7	6	4
Haulage Distance one way-ft.		450	690	600
Length of Scraper drag-ft.		30	30	—
Average and Maxima & Minima Time in Seconds	In (empty)	102 (96-105)	151 (145-160)	152 (130-160)
	Loading* or Dumping+	331* (305-356)	343* (310-390)	114+ (111-117)
	Out (loaded)	81 (79-85)	127 (120-130)	131 (127-133)
	Switch at Layby	54 (52-56)	47 (43-55)	45 (43-46)
Comparative Time In Secs.	In 100 ft. (empty)	22.6	21.8	25.4
	Loading* or dumping+ 1 ton	44.3*	38.1*	6.4+
	Out 100 ft. (loaded)	13..	18.4	21.8

*Dumping is not an element of the haulage cycle on Tracks A and B.
+Loading is not an element of the haulage cycle on Track C as the system does not extend to the loader

Table XVI - Main and Tail Rope Haulage with Cans--Time Study

		Track A	Track B	Track C	Track D
Size of Trip--tons		4.8 (8 cans)	4.8 (8 cans)	4.8 (8 cans)	8.4 (14 cans)
No. of Trips		10	4	6	8
Haulage Distance one way-ft.		195	205	295	280
Length of Scraper drag-ft.		40	*40	+80	40
Average and Maxima & Minima Time in Seconds	In (empty)	87 (66-113)	82 (80-85)	100 (95-110)	92 (84-102)
	Load	219 (171-259)	259 (235-290)	365 (340-402)	371 (341-407)
	Out (loaded)	60 (58-62)	56 (54-58)	76 (74-78)	73 (65-80)
	Switch at Shaft	40 (38-44)	44 (39-48)	42 (35-46)	54 (49-58)
Comparative Time In Secs.	In 100 ft. (empty)	44.5	39.8	33.8	33.0
	Loading 1 ton	45.6	54.0	76.0	44.2
	Out 100 ft. (loaded)	30.6	27.4	25.7	26.1

*Cleaning up drift
+Loading from sump

In computing the time for a round trip with a can unit, from the data of Table XVI, the unit times for Tracks A and D only have been used in calculating average figures for the four elements. This has been done because the times for loading cans on Tracks B and C are influenced plainly by the facts that, cleaning up operations were in progress in the first instance, and in the other case, the long length of scraper drag is abnormal and, therefore, not considered to be representative. For a loader to shaft distance of 700 feet and a train of 14 cars the round trip time is calculated to be 895 seconds, or a capacity in seven hours of 235 tons.

2. If it is assumed that the cars go 700 feet from the loading site direct to the shaft and are there dumped before the in-trip is begun the round trip time for a 12-car train is found by formula from the following:

in 100 feet	25.4 seconds	
out 100 feet	21.8 "	Track C--Table XV
dumping 1 ton	6.4 "	
loading 1 ton	41.2 "	Average Tracks A and B, Table XV.

This is computed to be 1187 seconds, or converting to shift capacity, 382 tons in seven hours. This estimate can be compared with locomotive and truck haulage.

Capital costs of cars and cans are the same as for the other systems, namely $150 and $65 each, respectively; it will be remembered that a portion of these costs may have to be prorated against hoisting if the receptacle is used in that operation. Other capital costs are,

1000 feet of 24 inch gauge track	$3000 - $3500
1 double drum hoist	1500
Total	$4500 - $5000

Operating costs for rope haulage in the mine using cars average \$0.25 per ton; for cans these costs range from \$0.15 - \$0.38 per ton.

Rubber-Tired, Battery Truck Haulage

This method of haulage is new to the Tri-State District and recently has been discussed in detail in two papers by Clarke[17]. The haulage units described in his first paper are bottom dump trailers of 5 tons capacity. However, where road conditions are not ideal, considerable difficulty is experienced in spotting the trailers under the spout of the scraper ramp. In an attempt to overcome this condition a $3\frac{1}{2}$ ton end-dump, box-hopper body was built direct on the truck chassis and this arrangement has proved very satisfactory. Truck haulage is extremely flexible in its application; the trucks make their own roads after any large slabs have been moved aside, no trackage is required, and grades up to 10% may be negotiated.

Table XVII presents data for four routes, one of them Route D, being for a 5 ton trailer type truck; the other three covering the operations of the $3\frac{1}{2}$ ton trucks. Considering the trailer type truck, it has been calculated from the data of Route D, that for a haulage distance of 700 feet the round trip time is 378 seconds which indicates a capacity of 333 tons in seven hours. Using the average values of the data for routes A, B, and C, there results a time of 228 seconds for a round trip over the same haulage distance by a $3\frac{1}{2}$ ton truck; or in seven hours 386 tons may be moved by this type. The advantage thus lies clearly with the $3\frac{1}{2}$ ton model. This is due

17. Clarke, S.S., Rubber-tired Mine Haulage in the Tri-State District. Amer. Inst. Mining & Met. Engrs., Trans. Vol. 153, pp. 153-157, (1943).
Clarke, S.S., Rubber-tired Blitz Buggies Haul Ore Underground. Engineering & Min. Journal, Vol. 145, No. 12, pp. 88-90, (Dec., 1944).

Table XVII - Rubber-tired Truck Haulage---Time Study

		Route A	Route B	Route C	Route D
Size of Truck--tons		3.5	3.5	3.5	5
No. of Trips		30	5	8	8
Haulage Distance ft.	In	570	660	990	945
	Out	615	630	630	900
Length of scraper drag--ft.		50	40	60	30
Average and Maxima and Minima Time in Seconds	In (empty)	60 (57-63)	70 (67-71)	93 (82-100)	90 (86-98)
	Load	70 (48-99)	67 (64-74)	81 (75-91)	226 (175-274)
	Out (loaded)	67 (63-71)	62 (58-65)	67 (64-71)	88 (85-89)
	Dump	29 (22-39)	21 (20-23)	26 (18-36)	17 (12-26)
Comparative Time In Secs.	In 100 ft. (empty)	10.5	10.6	9.4	9.5
	Load 1 ton	20.2	19.3	23.1	45.3
	Out 100 ft. (loaded)	10.9	9.8	10.7	9.7
	Dump 1 ton	8.2	6.1	7.4	3.4

largely to the difference in unit loading times, a matter which will be discussed under Comparison of Haulage Methods.

The capital cost of a truck is $800, plus $2200 for the batteries, making a total of $3000. In addition, a charging panel valued at $1100 must be installed. However, if more than one truck is used, as is usually the case, this latter cost should be prorated as several vehicles can be served by the same panel. The operating cost for 3½ ton trucks is $0.12 per ton and that for 5 ton units is $0.16 a ton.

Comparison of Haulage Systems

In the foregoing analyses of haulage systems an attempt not only has been made to present the conditions peculiar to each system, but also to assemble statistics in such a way that the several systems can be compared with each other. The tonnage capacities which have been calculated for actual or proposed cycles, are collated in Table XVIII.

It must be realized that each haulage system has a definite field of application; for example, mule haulage is practicable only on nearly level haulageways, or again, truck haulage, because it requires no trackage, has most advantages over other systems where a large area is mined rapidly, as in sheet ground. Consequently the system to be installed in a mine to achieve best results should be determined on the basis of local mine conditions, such as, daily tonnages to be handled rate of advance, gradients, etc., and, in fact, it is often desirable to combine two systems. For example, battery locomotive haulage may be used for gathering or main line service in conjunction with several tail rope systems serving a number of working places. Accordingly, any comparisons drawn between the different haulage systems must be in general terms only based on the assumption that there is an ideal

Table XVIII - Haulage - Time Study Comparison Sheet

Tonnage capacities, as distributed on the basis of the elements commonly involved in the various haulage systems, in a seven hour period over the haulage distances indicated.

Cycle of Elements		Mules with Cans	Battery Locomotive with Cars	Main and Tail Rope with Cars	Main Tail Rope with Cars	Battery Truck
1	In Switch Out Switch	252 tons 930 feet	570 tons 1450 feet	————	————	————
2	In Load Out Switch	————	368 tons 700 feet	365 tons 700 feet	236 tons 700 feet	————
3	In Load Out Dump	————	378 tons 700 feet	382 tons 700 feet	————	386 tons* 333 tons+ 700 feet

* $5\frac{1}{2}$ ton units
\+ 5 ton units

haulageway where all systems are capable of working with maximum efficiency.

Truck, mule, and rope with can haulage systems are relatively fixed in their cycles. The locomotive and rope with car types permit considerable flexibility as the ore may be dumped into a skip pocket at the shaft, or the cars hoisted; a main line system may be used in combination with some other which would serve as a feeding unit or, as an alternative the cars may be taken the whole distance from shaft to loader in one operation. This accounts for the three cycles listed for battery locomotive, and the two for rope haulage with cars.

Mules are in a class by themselves, as they deliver empty cans to, and haul loaded cans from shovel loaders, in contrast to the other systems which are used to serve drag scraper loaders. In this connection shovel loaders are employed most frequently where the working place is so limited in size that it is impossible to operate a scraper loader. The results indicate that where either class of loader may be used, mules have a slightly better capacity than rope haulage with cans, but either system should be adopted only where small tonnages are to be hauled, such as from isolated workings or in the development stages of a mine. Although capital cost is definitely in favor of mules, operation cost a ton for rope with cans haulage is lower. Battery locomotives may be used for main line haulage work (cycle 1 in Table XVIII) when distances, tonnages, and grades are greater than can be operated with mules.

Truck haulage is limited in the size of load per trip but the speed is higher than for any system other than that of the battery locomotive, so that the capacity per shift is relatively high. It has been noted that the 3½ ton trucks have a greater shift capacity than the 5 ton models. All haulage systems which have a trip-load greater than 3½ tons, and which are loaded by scrapers, suffer from the disadvantage of a longer unit loading time than that which is taken in filling the smaller trucks. The only explanation for this appears to be that, no matter what the haulage system or the length of time the trip is absent from the loader, the scraper operator while the trip is away from the loader is engaged in scraping about 3½ tons of ore close to the ramp for the next load.

The operating cost of trucks is lower than for any other system whereas capital cost is little more than that for mule haulage which is the cheapest of all systems in this regard. Rope haulage with cars, and battery locomotive haulage with cars, when operated on the same cycle as trucks (cycle 3) are capable of moving tonnages comparable to that of truck performance. However, higher costs, both operating and capital, rule them out when a new installation is being planned.

Where a dump cage has been installed as a component of the hoisting system there is little to choose so far as capacity is concerned between battery locomotive and rope haulage with cars (cycle 2). The capital cost of the battery locomotive system is considerably greater than that for rope haulage and for this reason the locomotives are usually confined to a main line track so that the maximum use may be made of their services as on cycle 1.

HOISTING

There are three systems of hoisting used in the mines of the Tri-State District; namely, skip, can, and dump-cage types. The time study method employed in analyzing their operations is similar to that followed in the haulage studies.

Where cans are used, there are four elements to be observed and summarized; in or down trip, loading or hooking, out or up trip, and dumping. The time study observations of these elements are made to the nearest second and recorded on a form such as Table XIX, as follows: at the start of an in trip the time is taken and entered under the "In" column and the time at stop of the trip is recorded beneath. A similar sequence is followed for the measurement of the out trips. By this means it is possible to assemble the statistics in such a way that the elapsed times, which transpire during the several elements of the cycle, readily may be summarized. For example, referring to Table XIX, the in trip started at 1445* and as the can reached the bottom of the shaft at 1455, an elapsed time of 10 seconds was noted to have transpired for the in trip. The out trip with loaded can extended through the period 1501-1513, or an elapsed time of 12 seconds; the difference between 1455 and 1501 gives the hooking time as 06 seconds, and that between 1513 and the start of the next in trip, at 1519, is 06 seconds and represents dumping time.

For those operations where the skip or the dump-cage is used, the cyclic elements of a time study are only the two of "load skip", or place car on cage, and "out trip". This is because there are two shaft compartments, and balanced hoisting is in effect, so that when

* The time thus recorded is the equivalent watch time reading of 14 Minutes and 45 seconds.

Table XIX - Hoisting--Time Study Observation and Summary Sheet

Mine________________________Date________________Type of Hoisting_______________

Remarks e.g. length of hoist____

	Stopwatch Times			Elapsed Time in Seconds			
	In	Out		In Trip	Hooking	Out Trip	Dumping
Start	1445	1501		10	06		
Stop	1455	1513				12	06
				11	06		
Start	1519	1536				12	06
Stop	1530	1548					
				11	05		
Start	1554	1610				12	07
Stop	1605	1622					
Start	1629						
			Total	32	17	36	19
			Average	10.7	5.7	12.0	6.3

one cage or skip is being loaded, the other is being dumped simultaneously, and also, during the out trip in one compartment an in trip is taking place in the second.

The respective times, as classified for each system of hoisting are totalled after a set of observations. The averages, therefrom, may be entered on a comparison sheet together with averages of studies of other hoisting systems (Table XX). By totalling the averages of the different elements the average round trip time is determined, and by using this figure, the time which will be required to hoist one ton of ore may be obtained for each system. On this basis the capacities in a seven hour period are calculated to be:

1.	Can hoisting	436 tons,
2.	Dump type cage hoisting	894 tons,
3.	Skip hoisting	1383 tons.

The depths of the three shafts are all sufficiently close to 400 feet to allow these tonnage figures to be used to indicate quantities hoisted from that depth and thus they may be compared one with the other to demonstrate relative efficiencies.

Whenever the walls need support a shaft must be timbered regardless of the type of hoisting in effect. However, as two compartments fitted with guides are not required in a can hoisting procedure, the cost of such a system is always considerably less than that for skip or cage units. Capital costs of the systems are approximately as follows: can $8000 (includes a prorated allowance for cans), dump-cage, $30,000, and skip, $36,000 - 40,000.

The average operating costs per ton are, cans $0.14, dump cage, $0.11, and skip, $0.13. The relatively low operating cost for can hoisting is accounted for by the fact that the can hoists are working

Table IX - Hoisting--Time Study Comparison Sheet

Type of Hoist		Skip	Dump-cage	Can
Capacity—tons		3.5	1.5	0.6
No. of Trips		8	20	30
Depth of Shaft--ft.		420	385	366
Average and Maxima & Minima Time in Secs.	Load or Hook	11.7 (11-13)	7.6 (6-9)	5.3 (4-6)
	Out	52.6 (51-55)	34.7 (32-36)	12.2 (11-13)
	Dump	----	----	6.5 (5-9)
	In	----	----	10.6 (10-12)
Comparative Time In Secs.	Total	64.3	42.3	34.6
	Per ton	18.4	28.2	57.7

almost at maximum capacity whereas the cage and skip hoists, under present conditions, have a large excess capacity, and consequently, a poor utilization factor.

The data presented indicate that the can hoist is limited to small capacities and in this field gives an operating cost comparable with the other systems. The installation of a can hoist for capacities close to the limit of 436 tons, from a depth of 400 feet, could only be justified on the score of low capital cost, for should subsequent developments require an increase in shaft capacity it is not possible to increase the size of can much beyond 0.8 tons. On the other hand, although capital cost of equipment is four or five times that for a can hoist, cage and particularly skip hoists have considerably larger capacities than 436 tons, and therefore, the installation of one other of these methods, depending on the haulage system used and tonnage to be handled, is necessary where mine production is to be on a scale greater than 400 tons a shift.

CONCLUSIONS

In the foregoing discussions an attempt has been made to demonstrate the features of the various systems of drilling and transportation in force in the Tri-State District. It is evident that with the advent of mechanization, considerable economies have accrued.

The use of jumbos for drill mountings, in place of the old post and tripod systems, has permitted a better application of the drilling machines and manpower to the process of rock breaking. This result has been achieved largely for the following reasons:

1. There has been a simplification of the element of "erection" to one of simple "moving", with attendant reduction in time consumed during the occupation.

2. A simplification and standardization of the element "setting up" has further reduced the time for the drilling cycle.

3. The introduction of new delay elements with jumbo drilling has not been sufficient, in the aggregate, to offset the material reductions in time mentioned under 1 and 2, and hence, more time is available for drilling. Certain of the new delay elements, such as "wait on other drill", and "wait on extra holes", are dependent on the lack of standardization of the round, and with an approach to better co-ordination, delays may be further reduced. Other delays, such as "repairs to jumbo", will remain whatever the degree of standardization achieved, but they may be reduced by improved jumbo construction. Still others, for example, "powderman loading holes", represent it would seem, somewhat of a misuse of the jumbo, and are capable of marked reduction.

4. As a consequence of the greater time available for drilling,

there have been increases in the number of holes, and footage drilled per drill shift.

5. With the elimination of the bench system of mining, better spotting of holes is possible and, therefore, there is an increase in tonnage per foot drilled.

6. A consideration of factors 4 and 5 reveals the reason for the improvement in tonnage per drill shift.

7. The increase in production per drill shift also carries with it the implication of increased production per man employed; that is the available manpower is used to better advantage. No special training is required for jumbo drilling, as any man who has worked with post and tripod mounted drills is equally capable of operating from a jumbo. With the simplification of certain of the essential elements, the drilling operation apparently has become less fatiguing.

8. Because jumbo machines can be moved to work in more than two headings, the possibility of drilling being interrupted, due to a disruption of the loading cycle, is minimized.

In addition to the factors above, which are common to both classes of jumbo, the long mash has two further features:

9. The use of the chain-feed, wagon drill mounting has resulted in an increased drilling rate and this permits the drilling of still more footage during a shift.

10. Each drilling machine requires the services of but one man, and so, the manpower requirements are halved. The small amount of time involved in the long mash element "helping other drill", and in "supply delays", and in the longer moving time is not sufficient to justify the presence of a third man to help overcome these delays.

Idle time is a considerable delay item, particularly in the case of the long sash jumbos, and until a sufficient spur is offered the men to continue oper tions throughout the day, the full production possible from the jumbos will not be realized. In fairness to the men, it must be mentioned that in the high ground mine where the data were gathered, a large proportion of the delay from idle time is attributed to the fact that the present transportation system in use, namely, rope haulage with cans, is not adapted to moving large tonnages.

More success has been achieved with the long sash jumbo in sheet ground than in high ground because in the latter case, a greater time must be spent in moving, and there is little or no standardization of the round.

The short sash jumbo, as compared with the long sash, suffers from the disadvantages of a lesser rate of drilling and the present requirement of four men in the jumbo operating crew. The relatively small period during which the helpers are engaged in "changing" and the large amount of time spent waiting for that event, together with other extraneous activities, raises the question that the short sash machines and post-mounted drills might possibly be worked, without helpers, more efficiently with respect to manpowder requirements. Though it is possible to make, from the data gathered, an approximate estimate of the effects of this suggested modification,, it is felt that such an estimate would be based on untenable assumptions and that it would be qualitative rather than quantitative. Accordingly, the matter is left open at this time but is hoped that at some future date, a time study and comparative analysis may be made of the operations of drilling machines in such a cycle.

The best transportation system for a sheet ground mine, in which jumbos are used, appears to be battery truck haulage in combination with skip hoisting. One truck can handle readily the rock obtained from the operation of a jumbo drill unit, and the skip has capacity for the tonnage produced by four or five jumbos. With any other system of haulage, because of the rapid advance of the working face in this type of mining, the track must be shifted and considerable expense is thereby incurred.

High ground mining, with jumbos, allows a somewhat wider choice of haulage system, as the mine face is not advanced with the rapidity which occurs in driving the sheet ground workings. Hence the alternative installation of some combination of rope or battery locomotive haulage with cars, and skip or cage hoisting, may be considered. However, the use of truck haulage, here again, from the stand point of both operating and capital cost appears to be that most logically applied.

Because of the comparatively low hoist capacity, any transportation system in which cans are used does not warrant consideration where the maximum tonnage produced in a shift is greatly in excess of 400 tons. Though the hoist capacity is dependent to some degree on the depth of the shaft it rarely exceeds a production of 500 tons a shift from shallower workings and for delivery from deeper shafts would be much less.

It may be stated in summary, that although the introduction of the jumbo drilling equipment created certain minor operating problems, the general result is that by their development a marked improvement in the application of both man-power and machines to the drilling procedures has become possible.

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