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A study of the power consumption of mine scrapers

Stanley Francis Johnsen

A STUDY OF THE POWER CONSUMPTION OF MINE SCRAPERS

BY

STANLEY FRANCIS JOHNSEN

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THESIS

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Several scraper and scraper hoist manufacturing companies were also helpful in sending catalogs and other data pertinent to scraper operations.

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INTRODUCTION

Since scrapers were first employed in underground mining work, numerous changes in scraper design have transpired until now there are several common types of scrapers in use in mines over the world. These proved models of scrapers have been developed over a period of more than fifty years.

Although specific scrapers have been tested to determine the amount of power consumed, no literature could be found concerning the relative power consumption of the different types of scrapers when operated under identical conditions.

Purpose of Problem

The purpose of this study is to determine the relative efficiency of different types of mine scrapers with regard to power consumption. Because rope speed and scraper weights are important factors affecting power consumption, these two factors were considered in conjunction with the different kinds of scrapers in this study; moisture tests were also conducted. Rock of mixed size grades was used in all tests.

Problem Procedure

Four types of scrapers were tested. These were: The straight bail hoe scraper; the slope bail hoe scraper; the box scraper; and the crescent scraper. The four scrapers tested were available in the mining laboratory as they had been used in previous studies of model scrapers.(1 and 2) All the model scrapers were constructed

(1) Forrester, J. D., and Clayton, A. B., A Study of Mine Scraper Buckets and their Efficiency, Missouri School of Mines and

Metallurgy, Technical Bulletin Vol. 17 No. 2, 1946, 48 pages.

(2) Forrester, J. D., and Carmichael, R. C., The Effects of Rope Speed and Moisture on the Use of Scrapers in Mining, Missouri School of Mines and Metallurgy, Technical Bulletin Vol. 18, No. 1, 1947, 31 pages.

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at a scale of 1 to 6.

A small electrically-driven hoist and a table on which to run the tests were also available from previous work. A Westinghouse recording wattmeter was connected with the electric motor to record the power consumed.

For each test a given number of passes was made at the rock in the muck pile on the table. The rock scraped was weighed, and the amount of power consumed was determined from the graph traced by the wattmeter. The results and conclusions of the tests were established from a study of these figures.

REVIEW OF LITERATURE

History of Scraping

The first successful application of power scraping in moving mine muck is believed to have taken place at the Bunker Hill and Sullivan Mining Company mine near Kellogg, Idaho in 1898.[3]

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(3) Van Barneveld, Charles E., Mechanical Underground Loading in Metal Mines, Coop. work of U. S. Bureau of Mines and Missouri School of Mines and Metallurgy, 1924, pp. 210 and 211.

The development and history of mine scrapers since that time has been described by Forrester and Clayton.[4]

(4) Forrester, J. D., and Clayton, A. B., A Study of Mine Scraper Buckets and their Efficiency, Missouri School of Mines and Metallurgy, Technical Bulletin Vol. 17, No. 2, 1946, pp. 1-4.

Scraper Operation Data

Applicability of Scrapers

Scrapers are now used in practically all types of mining work. The choice of mucking equipment depends on many factors and the decision as to use of scrapers or another type of mechanical loader should be arrived at only after a careful and complete study of these factors. Each mucking or transportation problem will present unique features which must be considered when selecting the most efficient type of equipment. These features may include (1) lowering of development costs, (2) increased production from working faces, (3) reducing hazards of mucking, (4) availability of a certain type of machinery, (5) amount of ore or waste to be moved, (6) the type of power available, and (7) the mining method employed.

The extensive field of scraper operations as applied to mining may be outlined as follows:

- Development work
    - Inclined shafts
    - Drifts and cross-cuts
- Production stopes
    - Top slicing stopes
    - Open stopes
    - Room and pillar stopes

Sub-level caving stopes

Cut-and-fill stopes

Glory-hole or mill-hole stopes

Square-set stopes

Shrinkage stopes

Block caving stopes

Waste filling of stopes

Transfer of material in sub-levels

Moving of material in open pits

Reclaiming tailing piles

Placer mining

If scrapers are chosen in preference to mechanical shovels, another choice must be made concerning the type of scraper, its digging angle, scraper weights, and various other factors affecting efficient scraper operation. According to Jackson (5) the principal

(5) Jackson, Chas. F., Underground Scraping Practice in Metal Mines, U. S. Bureau of Mines Manuscript Report No. 1, March 1933, pp. 11-12.

considerations affecting the choice of scraping equipment suited to local conditions are (1) character of the material to be handled, (2) method of digging, whether from the face of the pile or across the pile, (3) tonnage of material and rate of handling desired, (4) length of drag, (5) purpose for which the scraper is to be employed and method of disposal of the material handled, (6) inclination and nature of the floor over which the scraper will operate, and (7) size and shape of area and total tonnage to be handled from a single setup of the hoist.

Table 1, modified from one compiled by Jackson,[6] lists data

(6) Jackson, Chas. F., Ibid, p. 37.

concerning typical scraper installations. This table illustrates the relationship between horsepower of hoists, size and weight of scrapers, rope speed, approximate capacity of scraper, scraping distance, and type of ore to be scraped.

Motive Power

Air Hoists -- In many of the earlier scraper installations air-driven hoists were used, and are still preferred by some mine operators. Matson [7] reports that the first types of air hoists employed

(7) Matson, R. C., Scraping Practice in the Michigan Iron Mines of the Lake Superior District, Michigan College of Mining and Technology, Bulletin 4, Vol. 2, 1929, p. 44.

used 225 C.F.M. of air at 80 lbs. pressure, and were rated at 6 horsepower. These earlier air motors were the piston type; later both piston and turbine type motors came to be employed in air hoists. The turbine motor is usually faster but is more apt to freeze. While this difficulty is overcome in the piston types by use of a larger exhaust, more air is used. Matson [8] reports that the upkeep of both types

(8) Matson, R. C., Ibid, p. 45.

of machines is about $5 per month.

Larger capacity scrapers necessitated the development of larger air hoists, and today 25 horsepower air hoists are available with rope speeds up to 250 feet per minute. Data on typical air hoists

Table 1. Data on typical scraper installations

	Type of ore	Hoist Hp.	Hoist Rope speed f.p.m.	Hoist Type	Size in inches	Approx. load cubic feet	Scraping dist. feet
1.	Soft iron ore	$6\frac{1}{2}$	125	Box	40	12	50, max.
2.	Soft iron ore	15	180	Box	42-48	13-18	75, max.
3.	Soft and hard iron ore	15	180	Hoe	48	13	75, max.
4.	Soft iron ore	15	225	Box	34	10	100, max.
5.	Soft iron ore	15	200	Box	42-48	13-18	75, max.
6.	Soft and hard iron ore	15	200	Hoe	48	13	80, max.
7.	Soft iron ore	15	240-280	Hoe	48	13	75, max.
8.	Soft iron ore	15	240	Semihoe	42	14	75, max.
9.	Soft iron ore	15-25	240-280	Box	48	18	60 to 150
10.	Hard and soft iron ore; some chunks	15	240-280	Hoe	42	9	125, max.
11.	Soft iron ore	15	200	Box	42	13	75, max.
11-a.	Soft iron ore	25	230	Box	48	18	150, max.
12.	Large blocks hard iron ore	25	230	Hoe	48	14	50 to 100
13.	Hard chunky rock or soft iron ore	25	230	Semihoe	54	18	50 to 100
13-a.	Soft iron ore	15	200	Semihoe	30	7	75, max.
13-b.	Soft iron ore	10	200	Semihoe	30	7	75, max.
14.	Large blocks zinc ore, dolomite gangue	25	200 h.s. 144 l.s.	Arc-back hoe	72	2000 lbs.	175, avg. 400, max.
15.	Medium coarse zinc ore in dolomite gangue	10	200	Box	40	12	75 avg. 300 max.
16.	Coarse copper amygdaloid	15	200-400	Patented semihoe	48	13	200 max.
17.	Coarse and fine copper-bearing conglomerate	35 (air)	----	Hoe	48	13	150 max.
18.	Copper amygdaloid; coarse and fine muck	25	230	Hoe	48	13	120 max.
19.	Friable, altered porphyry	25	230	Hoe	48	18	100

Table 1 (cont). Data on typical scraper installations

Type of ore	Hoist Hp.	Hoist Rope speed f.p.m.	Type	Size in inches	Approx. load cubic feet	Scraping dist. feet
20. Very hard ore breaks in large angular blocks sp. g., 4.6	60	------	Arc-back hoe	80	10,000 lbs.	150 max.
21. Hard, siliceous ore; fine, sticky gangue	15	240	Semihoe	40	700 lbs.	200 max.
22. Hard, siliceous ore; flat slabs chunks and fines	15	230	Semihoe	40	700 lbs.	100 max.
22-a. Hard, siliceous ore; flat slabs, chunks and fines	15	230	Semihoe	40	700 lbs.	75 max.
22-b. Sand	15	230	Semihoe	40	400 lbs.	75 max.
23. Iron ore breaking in large slabs.	55	130-150	Box with teeth	48	6,500 lbs.	200 max.
24. Hard, blocky, magnetic iron ore	25	200	Hoe	48	2,240 lbs.	150 avg. 350 max.
25. Large, heavy angular blocks	150	170 pull 190 return	Hoe	84	7,600 lbs. actual ore load	75 avg. 100 max.

showing the relationship between rope speed, weight, rope capacity, and various dimensions are given in table 2.

Although the trend in recent years has been toward electric hoists, particularly in metal mines, there are advantages which accrue to the use of both types. Those advantages credited to air hoists, although relatively minor, are listed below. Probably the best point in favor of them is the fact that an air motor when overloaded will stall without damage. Because of this, however, no momentary excess power is available, which may be needed to dig a large boulder out of a muck pile or to overcome similar obstacles.

An air hoist also has an advantage in poorly ventilated sections of a mine, where the exhaust gases will create some ventilation. According to Matson [9] ventilating costs at one mine were lowered considerably when several electric hoists were replaced by air hoists. In some coal mines which contain large amounts of explosive gas mixture the air hoist is much safer than electric hoists.

Another advantage of air power is the control of rope speed which may be accomplished by throttle manipulation; rope speed may be decreased for digging and increased for dragging. Air motors are also less susceptible to damage by moisture than electric motors, and leaks in air lines are usually easily detected and repaired.

Compressed air is normally available in all sections of the mine where an air hoist would be employed. In the case of an electric hoist, special power cables may be required.

(9) Matson, R. C., Ibid, pp. 51-52.

Table 2.® Rope speed, rope pull, drum capacity, weight, and dimensions of compressed air hoists.

DOUBLE-DRUM AIR HOISTS

Rope pull*		Weight	Overall length	Width	Rope capacity	
lbs.	ft. per min.**	in lbs.	in inches	in inches	3/8"	1/2"
1500	175	1360	58	34 7/8	400	225
1650	300	1565	52 1/2	32 7/8	600	330
1760	150	1325	52 1/2	30 1/4	475	275
1800	175	1450	58	34 7/8	400	225
3300	200	2495	57 7/8	32 1/4	500	300
2000	210	1540	59 3/4	34 7/8	400	225
5000	200	4345	73 1/2	42 1/2	---	1000
1975	250	2035	64 3/8	38 1/2	575	325

THREE-DRUM AIR HOISTS

Rope pull*		Weight	Overall length	Width	Rope capacity
lbs.	ft. per min.**	in lbs.	in inches	in inches	
2000	120	1423	64 5/16	29	250'---7/16"
2000	130	1960	68	29	300'---7/16"
2000	165	1500	61 1/8	29	250'---7/16"
2000	210	2065	69 3/4	29	300'---7/16"
3000	220	4250	83	43 3/4	450'---1/2"
2475	200	2560	75 1/2	33 1/8	325'---1/2"

® Compiled after data in catalogs of Sullivan Division of Joy Manufacturing Company and Ingersoll-Rand Company.

* Rope pulls are based on 80 pounds air pressure.

** Tail rope speeds average about 30% faster than pull rope speeds.

Electric Hoists — Although the first scrapers were powered by air-operated hoists, electric hoists were developed soon afterwards, and are more widely used at the present time. This shift to electricity was inevitable because of the much lower cost of electric hoists as compared to air hoists. Theoretically, 4 horsepower is required at the compressor to deliver 1 horsepower of useful work at the air hoist; this does not take into account leakages in the air lines, etc. After considering such losses, probably 5 or 6 horsepower would be required at the compressor for each horsepower delivered at the air motor. However, Matson (10) has presented figures which show the

(10) Matson, R. C., Ibid, 75 p.

ratio of the cost of air power to the cost of electric power to be still higher. In the example given, 91,124 tons were scraped by electric hoists and 604,005 by the air hoists. The power cost per ton of ore scraped was $0.034634 for the air hoists and $0.004165 for the electric hoists, which is a ratio of about 8 to 1.

According to Jackson, (11) other operators have reported that power costs are from 4 to 7 times greater for air hoists than for electric hoists.

(11) Jackson, Chas. F., Op. cit., p. 39.

H. A. Walker (12) lists the electric power costs for scraping

(12) Walker, Harlan A., Mining Methods and Costs at El Potosi Mine, Chihuahua, Mexico. Information Circular 6804, U. S. Dept. of the Interior, Bureau of Mines, Washington D. C., November, 1934, p. 23.

as $0.0056 per short ton at the El Potosi mine in Chihuahua, Mexico.

Table 3 [13] illustrates the cost of electric power in comparison with other scraper operation costs at the El Potosi mine.

(13) Walker, Harlan A., Ibid, p. 23.

Table 3. Underground Scraping Costs: Year 1932

Item	Cost per short ton
Making and repairing scrapers	$ 0.0054
Power lines	.0004
Hoist installations	.0056
Hoist repairs	.0167
New cable and cable repairs	.0038
Electric power	.0056
Lubrication	.0014
	$ 0.0388

Table 4, compiled by Harrison and Mackay, [14] also shows various operating costs in scraper operations.

(14) Harrison, A. R., and Mackay, K. E., Mining Practice at NKana, II; Engineering and Mining Journal, Vol. 137, No. 1, January, 1936, p. 17.

Table 4. Scraping Costs, NKana Mine

Six months period
per ton scraped

	Shillings	
European salary and wages	0.17	$0.04
Native labor	0.18	0.02
Supplies, including explosives ...	0.22	0.05
Workshops	0.03	0.01
Underground mechanics and electricians	0.07	0.02
Power, electric	0.03	0.01
Totals	0.60	$0.15

Figure 1 shows a wattmeter graph which illustrates the power distribution in a scraping cycle. The hoist was powered by a 6½ hp., 260-volt, d.c. motor, and the operations were considered severe at the time.

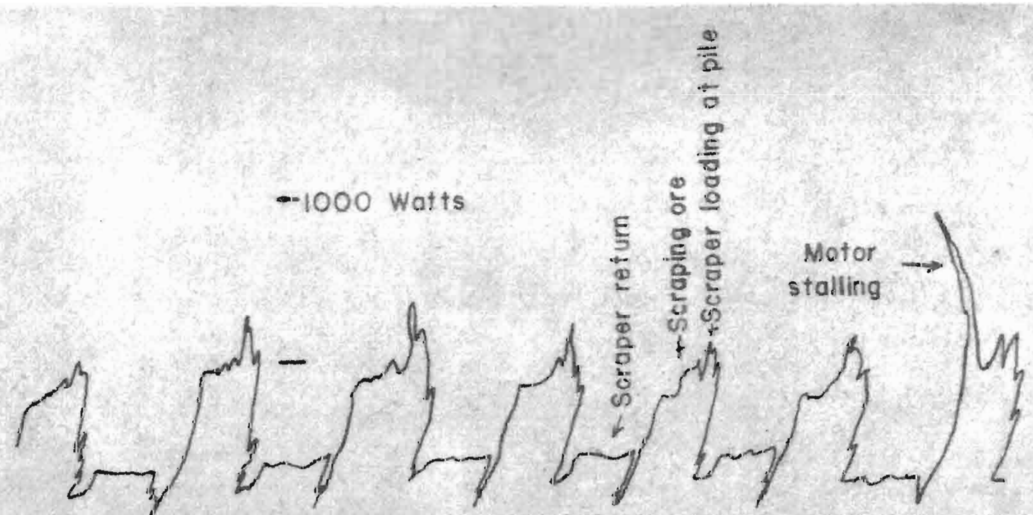

FIGURE 1

Portion of a wattmeter chart (after Matson).

When electric hoists were first used, they were powered by direct current motors, and took their current from the trolley lines. (15) This tended to overload the trolley lines, however, and

(15) Eaton, Lucien, Underground Scraping Equipment, Engineering and Mining Journal, Vol. 134, No. 4, April, 1933, p. 156.

alternating current motors came into use. Sixty-cycle a.c. at 220 or 440 volts is generally used for scraper hoists in this country. Direct current motors are used by many operators, however, and are available from the larger hoist manufacturers. Data in table 5 illustrates the relationship between horsepower, weight, rope capacity and general dimensions of typical alternating current and direct current scraper hoists.

As noted, electric hoists are more popular than air hoists. This is because of the many advantages the electric hoist has over the air hoist.

The largest advantage of electric power is the relatively low cost of this type of power compared to the cost of air power. According to Matson, (16) under the same conditions, electric power

(16) Matson, R. C., Op. cit., p. 52

costs 1/6 as much as air power. Figures showing actual costs of the two types of power have been presented on pages 11 and 12. Electric hoists are about 65 per cent efficient; air hoists are only about 15 per cent efficient.

Electrical equipment can supply any demand of power, no matter how excessive it may be at certain periods of the day. When many air

Table 5.* Horsepower, rope pull, rope capacity, weight, and dimensions of typical A.C. and D.C. scraper hoists.

DOUBLE-DRUM ELECTRIC HOISTS

25 & 50 cycle			Wt. in lbs. with a.c. motor	Wt. in lbs. with d.c. motor	Length in inches with a.c. motor	Width in inches	Rope capacity					
Motor h.p.	Rope pull lbs.	Rope speed f.p.m.					3/8"	7/16"	1/2"	5/8"	3/4"	1"
7 1/2	2150	115	1788	1661	54 3/4	30 1/4	475	---	275	165	---	---
7 1/2	1800	137	1540	1580	64 1/4	28	600	440	340	---	---	---
10	2300	145	1815	1859	54 3/4	30 1/4	475	---	275	165	---	---
10	1980	167	1570	1625	64 1/4	28	600	440	340	---	---	---
15	2500	190	1859	1905	56	32 7/8	600	---	330	210	---	---
15	1980	250	1645	1786	64 7/16	28	600	440	340	---	---	---
20	3750	175	2475	2552	58 3/4	32 1/2	500	---	300	200	---	---
20	3168	208	2030	2220	65 9/16	33 1/8	575	425	325	210	---	---
25	3600	230	2723	2992	59 3/4	34 5/8	800	---	450	280	---	---
25	3960	208	4225	4420	91 3/4	40 1/8	---	---	1275	850	575	325
30	5800	170	4884	4719	74 1/8	42 1/2	---	---	1000	625	450	---
30	4752	208	4620	4725	97 3/4	40 1/8	---	---	1276	850	575	325
35	4800	240	5060	4950	76 5/8	42 1/2	---	---	1000	625	450	---
35	5550	208	4620	4725	97 3/4	40 1/8	---	---	1275	850	575	325
45	6200	240	5148	5060	78 5/8	42 1/2	---	---	1000	625	450	---
50	6800	240	5148	5060	78 5/8	42 1/2	---	---	1000	625	450	---
50	6600	250	4665	4920	97 3/4	40 1/8	---	---	1275	850	575	325
60	6800	240	5148	5236	78 5/8	42 1/2	---	---	1000	625	450	---
60	---	---	4720	4970	97 3/4	40 1/8	---	---	1275	850	575	325
75	10,000	245	5535	5625	92 1/8	54 1/4	---	---	980	630	435	---
100	15,000	200	9250	9550	113	68	---	---	[illegible]	1026	715	405
125	15,000	250	9200	9200	100 11/16	68	---	---	---	1025	715	405

* Compiled after data in catalogs of Sullivan Division of Joy Manufacturing Co. and Ingersoll-Rand Co.

Table 5 (continued)

THREE-DRUM ELECTRIC HOISTS

Motor h.p.	25 & 50 cycle Rope pull lbs.	25 & 50 cycle Rope speed f.p.m.	Wt. in lbs. with a.c. motor	Wt. in lbs. with d.c. motor	Length in inches with a.c. motor	Width in inches	Rope capacity 3/8"	Rope capacity 7/16"	Rope capacity 1/2"	Rope capacity 5/8"	Rope capacity 3/4"	Rope capacity 1"
7 1/2	1900	130	2413	2250	71 1/2	34	475	----	275	165	----	----
7 1/2	2400	100	1970	2040	68 1/2	28	400	300	225	----	----	----
10	2000	165	2465	2520	73	34	475	----	275	165	----	----
10	2400	137	2115	2170	73 1/8	28	400	300	225	----	----	----
15	2000	245	3510	3500	80	41 1/4	500	----	300	200	----	----
15	2970	167	2760	2900	79 3/8	33 1/8	575	425	325	210	----	----
20	2700	245	3575	3565	80	41 1/4	500	----	300	200	----	----
20	3960	167	2770	2960	79 3/8	33 1/8	575	425	325	210	----	----
25	3600	230	3720	3870	81	43 3/4	800	----	450	280	----	----
25	4950	167	5695	5890	109	39 1/8	----	----	1000	650	450	250
30	3700	270	3720	3675	81	43 3/4	800	----	450	280	----	----
30	4752	208	5870	5975	109	39 1/8	----	----	1000	650	450	250
35	6800	170	6450	6450	98 3/4	50	----	----	1000	625	450	----
35	5550	208	5870	5975	109	39 1/8	----	----	1000	650	450	250
45	----	----	6600	6550	100	50	----	----	1000	625	450	----
45	6200	240	6600	6550	100	50	----	----	1000	625	450	----
50	6800	240	6600	6550	100	50	----	----	1000	625	450	----
50	6600	250	5915	6170	109	39 1/8	----	----	1000	650	450	250
60	----	----	6700	6600	102	50	----	----	1000	625	450	----
60	----	----	5965	6220	109	39 1/8	----	----	1000	650	450	250
100	11,000	300	13,000	13,500	155	64	----	----	----	----	750	375
125	13,700	300	13,377	14,000	155	64	----	----	----	----	750	375

drills are in use, air operated hoists are difficult to operate and their efficiency is decreased.

Electric hoists operate much more quietly than do air hoists. When the hoist operator is some distance away from the face, the noise of the hoist may prevent him from hearing signals from his assistant. The noise may also prevent the men from hearing sounds which might indicate danger.

A.C. Motors Versus D.C. Motors -- When scrapers were introduced in underground work, certain electrically operated equipment was already in use in most mines. This equipment included haulage locomotives, fans, and lights. Since this equipment was operated with direct current it was natural that the first electric scraper hoists were powered by direct current motors. However, in time the many advantages of alternating current motors caused that type of motor to gradually replace most direct current motors for scraper hoists. It is true that many direct current powered motors are still used, but a comparison of the advantages and disadvantages of each type motor indicates that the alternating current type is best for operating scraper hoists.

The largest advantage of alternating current is the low line losses as compared to the line losses in direct current. Less copper is also required for the conductance of alternating current. With equal voltages, and a power factor of unity, the alternating current lines will require only 75% as much copper as will the direct current line. (17)

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(17) Goodman Mining Handbook, Chicago, 1927, p. 38.

When an alternating current motor is overloaded it will not burn; therefore, there is less handling and repair work than there would be for a direct current motor. Direct current motors require generator sets underground, while alternating current motors simply use "step-up" or "step-down" transformers.

Direct current motors have a better speed control than alternating current motors and a better starting torque. The alternating current motor has a practically constant speed, regardless of the load. Direct current motors give slow speed with nearly maximum torque when operating under a maximum load, and higher speed under a lighter load. Consequently, when the scraper is digging in under maximum load, a slower speed is automatically obtained; this is desirable at this point in the scraping cycle. When a light load is being pulled, or when the empty scraper is being returned the hoist will automatically move the scraper faster. This may be important considering the time saved. However, with an alternating current motor, slower speeds may be effected by slipping the clutch.

Alternating current motors have a lower first cost than direct current motors. They also have no commutator troubles, and there is no danger of the armature burning when overloaded.

Because of the several advantages of alternating current motors, they are generally preferred for scraper hoists. In the case of a new mine being opened, the same advantages would seem to indicate that the alternating current type of power should be used for operating all electrical equipment.

Design of Scrapers

Through the years of the development of scrapers, three standard types have come to be generally accepted. These are (1) the hoe scraper, (2) the box scraper, and (3) the crescent scraper. There are modifications of each of these types. Side plates are oftentimes constructed on hoe scrapers, teeth may be added to cutting edges, and counterweights may be effectively used to produce the desired balance of a scraper or to increase its digging or carrying capacity. The hoe type scraper is best for handling hard, chunky ore and rock. Those of the box and crescent kind are most effective in handling finely broken or granular material.

Scrapers vary greatly in size and weight. For ordinary mining work, almost any size and weight of equipment is available from the manufacturers. The capacity of a scraper for any given installation depends chiefly upon the quantity of the material to be moved and the rate of handling which is desired. The weight of a scraper for a given condition is dependent on the size and weight of the material to be handled.

The digging angle of a scraper is that which the cutting edge of the scraper blade makes with the muck pile when the rope is under maximum tension. According to Van Barneveld [18] the theoretical maximum digging effect of a scraper would occur when the plane of the cutting edge lies in the resultant of the pull and of the force of gravity. The force of the pull is greatest when the scraper is digging in to the muck and least when it is being pulled over a

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(18) Van Barneveld, Charles E., op. cit., p. 225

relatively smooth surface. The weight of the scraper is constant but the direction of its application with respect to the long axis of the scraper varies according to the shape of muck pile and position of the scraper. Both of these factors vary, but theoretically the digging angles are 30 degrees or below. Experience has shown, however, that digging angles of 45 to 50 degrees will give better results when scraping either on the level or on an incline.[19]

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[19] Ingersoll-Rand Company, Modern Methods for Scraper Mucking and Loading, 1939, p. 6.

Forrester and Clayton [20] conclude from results of tests run with

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[20] Forrester and Clayton, Op. cit., p. 24.

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model scrapers that the most effective digging angle for slope and straight bail hoe scrapers is 45 degrees.

If the muck pile is deep, some provision is usually necessary to prevent the scraper from digging after it has gathered its load. A forward curvature at the top of the blade or a baffle plate fastened to the top of the blade will cause the scraper to cease digging after it is loaded.

Balance is an important factor governing the digging and riding characteristics of a scraper. Counterweights may be applied to the upper back-side of the blade to facilitate better digging. Too much weight on the blade, however, may cause the bail to move upward when the scraper is empty, therefore endangering overhead timbers or installations. The bail for hoe and box scrapers should be long and heavy enough so that the bail will rest on the ground when there is no tension on the pull rope.

Scrapers must be of rugged construction in order to withstand the intense shock and abrasion they encounter in underground usage. Factory-made scrapers are constructed of cast steel; all parts are bolted together and are usually replacable. Manganese steel, and alloys of chrome, molybdenum, and nickel commonly are used in the construction of scrapers. The alloys used must be of great hardness and tensile strength but should also possess the fusing properties essential to arc welding; points of excessive wear are oftentimes built up by welds.

Forrester and Clayton [21] have listed the important factors of scraper design as follows:

[21] Forrester and Clayton, Op. cit., p. 16.

1. Selection of proper type for material to be moved.
   a. Hoe type for coarse material.
   b. Box or crescent for fine material.
2. Proper digging angle and shape of blade.
   a. Average angle near 45 degrees.
   b. Top of blade curved forward to provide lifting action.
3. Proper balance so that the bail will not rise in the air but still blade has sufficient weight for digging force.
4. Rugged construction to withstand abrasive action of ore and sudden shock.

APPARATUS FOR SCRAPER TESTS

Equipment Used in Tests

As previously described, the model scrapers tested had been used in earlier studies of model scrapers. The four scrapers were constructed on a scale of 1 to 6. Since the average mine scraper is about 48 inches wide, the models are 8 inches wide. The four scrapers tested are shown in figures 2, 3, 4, and 5.

The motive power for the experimentation was supplied by a quarter horsepower, split phase, electric motor which used 60 cycle A.C., 115-volt current. The motor furnished 1750 RPM. A 2-inch pulley on the motor shaft was belted to a 12-inch pulley on a jack shaft. A three-step cone pulley on the opposite end of the jack shaft was belted to a similar pulley on the hoist shaft.

According to Forrester and Carmichael [22] this combination of pulleys and belts reduces the RPM of the motor to 155, 211, 233, 317, 429, 475, and 646 RPM at the hoist drum. They used the diameters of the pulleys in their calculations of the above RPM. Since the distance (radius) from the center of the drum to the core of the first lap of cable was 1.53 inches (Forrester and Carmichael used 1/8 inch cable), they calculated the theoretical rope speeds available to be 125, 169, 187, 254, 344, 381, and 518 feet per minute. Because belt slippage probably reduced those speeds somewhat, they used a tachometer to measure the RPM of the hoist shaft. Using the RPM obtained from the tachometer, the pulley combinations they used gave rope speeds which they computed to be 105, 220, and 315 feet per minute.

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(22) Forrester, J. D., and Carmichael, R. L., The Effects of Rope Speed and Moisture on the use of Scrapers in Mining, Missouri School of Mines and Metallurgy, Technical Bulletin Vol. 18, No. 1, 1947, p. 19.

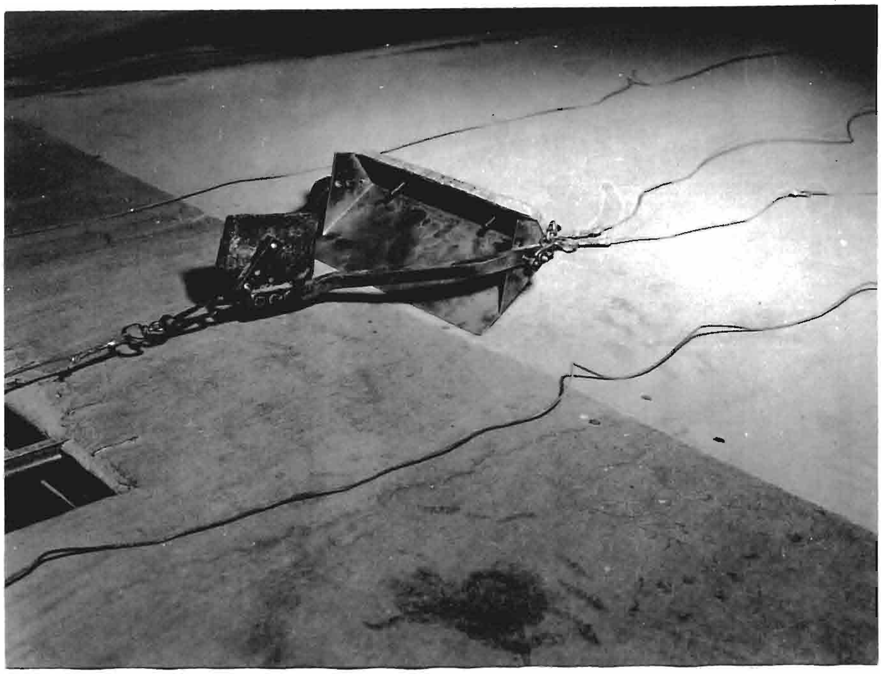

FIGURE 2

Photograph of Slope Bail Hoe Type Scraper. Note counterweights on bail and baffle plate. Blade angle is 45 degrees to line of pull.

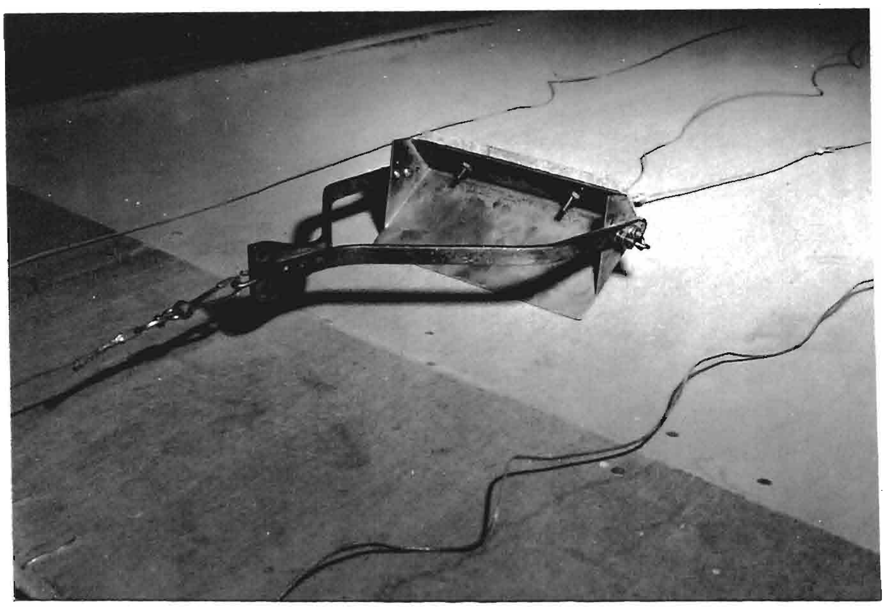

FIGURE 3

Photograph of Straight Bail Hoe Type Scraper. Scraper has a counterweight on baffle plate. Blade angle is 45 degrees to line of pull.

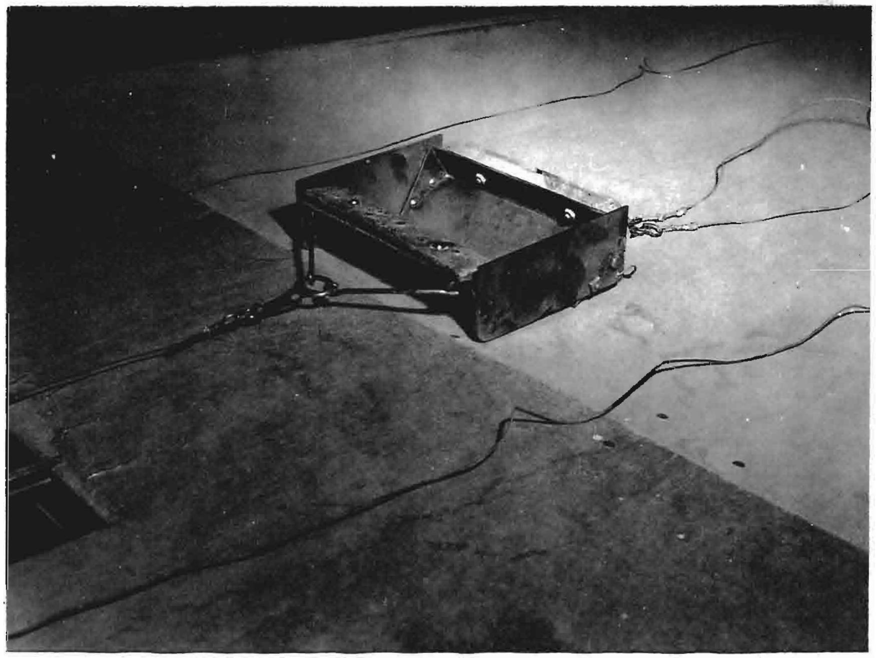

FIGURE 4

Photograph of a Box Type Scraper. The blade is bolted at a 30 degree angle to the line of pull.

FIGURE 5

Photograph of a Crescent Type Scraper. The digging angle on this scraper is 60 degrees.

In checking the RPM of the hoist shaft as determined by Forrester and Carmichael, difficulty was encountered in using a tachometer. Because of the size and arrangement of the hoist shaft, tachometer readings varied greatly; accurate readings were difficult if not impossible to obtain. It is believed, therefore, that the calculated rope speeds used by Forrester and Carmichael in their tests are liable to correction.

It was decided to determine the RPM available at the drums by counting the RPM of the clutch plates. A notch was filed in one of the clutch plates. A small thin piece of wood held against the plate while the hoist was running produced clearly audible clicks. It is obvious that one revolution of the hoist would produce one click. The number of clicks per minute was counted, the time interval being determined by a stop watch. Several RPM checks were made for each combination of pulleys used in the scraper tests. The hoist speeds used in the tests were thus determined to be 160, 242, 319, and 430 RPM.

The radii of the hoists drums were measured with calipers and found to be 1.48 inches. Since the hoist cable was 1/16 inch in diameter, the effective radius of each drum (from the center of the drum to the core of the rope) was 1.51 inches. Using this radius, the rope speeds tests were calculated to be 126, 191, 252, and 340 feet per minute. Clutch slippage probably lowered these speeds slightly, but there was no way to accurately determine its effect.

Wire cable, 1/16 inch in diameter, with six strands of seven wires each and a cotton cord center, was used to pull the scrapers.

The tensile strength of the cable was rated at 150 pounds.

The scraper tests were conducted on a table 15 feet long and 4 feet wide. The table was surfaced with rough Masonite fiber board to provide a uniform coefficient of friction. The end of the table opposite the hoist could be inclined above or below the horizontal, if desired. A grizzly was located two feet from the hoist end of the table. The grizzly is about one foot square and equipped with brass rails set 3 inches, center to center. An inclined chute below the grizzly directed the rock to the receiving pans on the floor. Two sheave wheels were fastened at the end of the table opposite the hoist. The table had side and back boards which prevented rock from spilling off the table.

A Type R Westinghouse recording wattmeter was set up on a table near the hoist end of the scraping table. (See figure 6) The self-

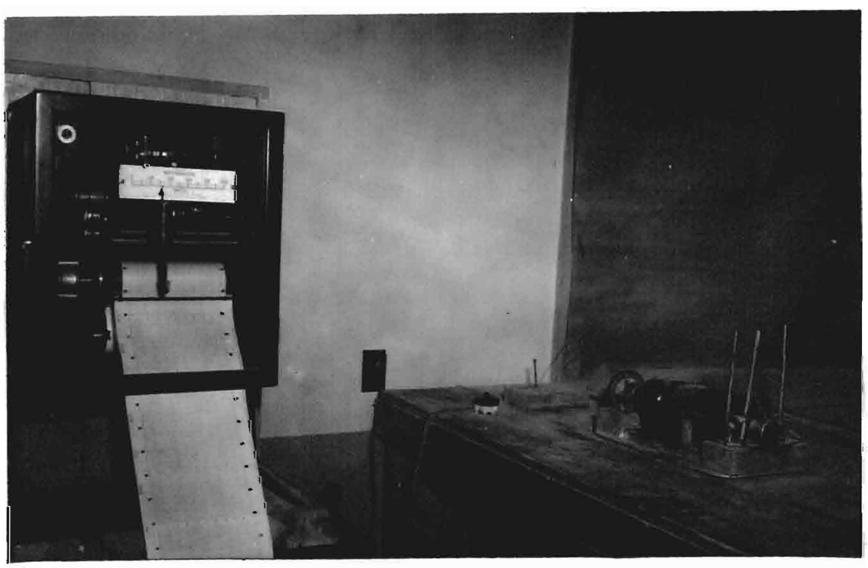

FIGURE 6

Photograph showing set-up of wattmeter and electric hoist.

winding clock motor on the wattmeter turned the recording drum about one revolution every 4 hours. Since this movement was obviously too slow to record scraping cycles, the original motor was replaced with a one RPM syschronous motor. The syschronous motor turned the drum at such a speed that good traces of the scraping cycle were recorded. A wiring diagram of the wattmeter and motor is shown in figure 7.

Material Tested

The material used in all scraper tests was fresh unaltered granite. The crushed granite was splintery and blocky in shape and was screened and classified into the following six size ranges: minus 3/16 inch, plus 3/16 inch minus 1/2 inch, plus 1/2 inch minus 1 inch, plus 1 inch minus 1 1/2 inch, plus 1 1/2 inch minus 2 inch, plus 2 inch minus 6 inch. The sizes given are assumed to represent rock 1/6 as large as rock scraped in actual operations.

The specific gravity of the granite was 2.64. This figure was determined by weighing a number of pieces dry and then immersing them in a graduate cylinder to find their combined volume.

Method of Collecting Data

To better facilitate the calculations involved in the tests, the metric system was used for weights and volumes.

In previous testing with the same model scrapers, Forrester and Clayton [23] determined the theoretical volume of material for each

(23) Forrester and Clayton, Ibid, p. 42.

scraper. The volumes of the different type scrapers are shown in

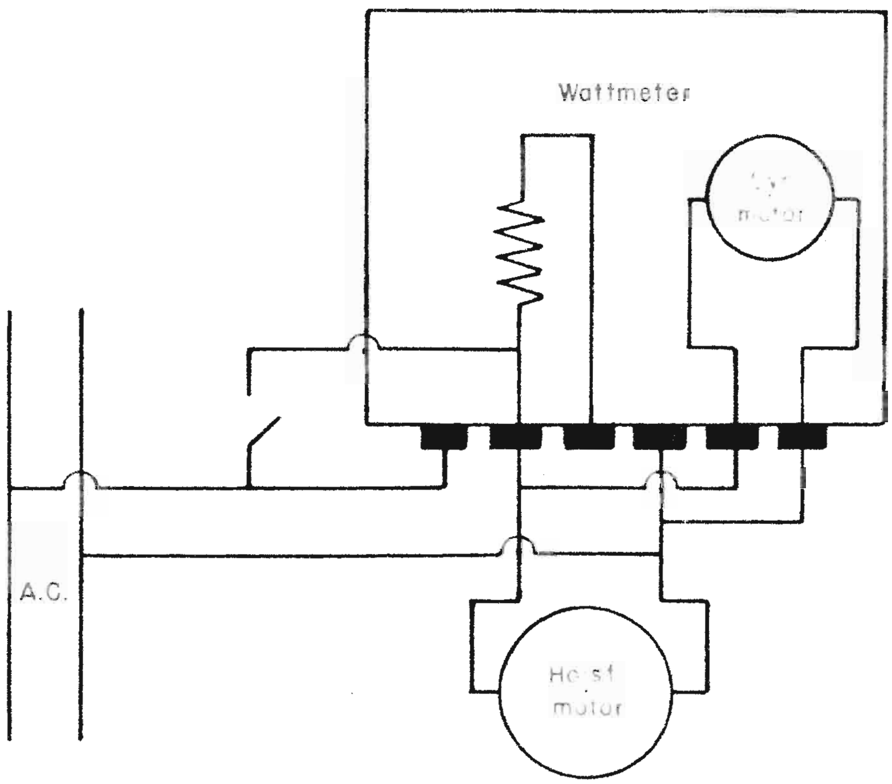

FIGURE 7

Wiring diagram for hoist-wattmeter setup.

appendix F, part 1.

The rock scraped was collected and the volume measured in two galvanized sheet iron pans. The inside dimensions of the pans were 9 by 53 by 53 centimeters. The depth of rock in the pans was determined by taking 8 measurements, the average depth being used to compute the volume of rock moved. The rock was weighed on an Ohaus balance.

The desired moisture content of the rock to be scraped was produced by placing a given weight of dry rock on the table and adding the necessary water. The moisture content of the rock was recorded as per cent moisture by weight.

The amount of power consumed in each test was calculated from the graphs on the wattmeter chart. For these calculations it was necessary to determine the time interval for the drum to wind a given length of chart. Since the clock motor on the wattmeter had been replaced with the one RPM synchronous motor the time intervals on the recording chart were of no value.

In an effort to assign a given time interval to each index on the chart five accurate time tests were run. The lengths the chart had run during each test were to be measured; the time interval was to be determined from the time and distance. However, because of uneven spacing of the indices on the chart, this method for determining the time interval was discarded.

It was decided to use the circumference of the winding drum on the wattmeter as a means for determining the time interval on the chart. The RPM of the drum was clocked five times with a stop watch;

the drum revolved exactly one RPM. The diameter of the drum was then measured with vernier calipers. From an average of five measurements the diameter was found to be 5.416 centimeters. The circumference was computed to be 17.014 centimeters. Using these figures, and reducing them to units applicable to the graphs recorded, the movement of the chart paper was computed to be 2.84 millimeters a second.

Figure 8 shows portions of some of the graphs traced by the wattmeter during various scraper tests. The time differences in scraping cycles will be noted for tests at different rope speeds.

DESCRIPTION OF MODEL SCRAPER TESTS

The testing procedure was similar for both rope speed tests and moisture tests. The heterogeneously sized granite was placed in a pile at one end of the table. The scraper was pulled over the muck pile and forward to the grizzly at the hoist end of the table. After twenty such passes at the rock, the material was measured for weight and volume. The graph of the power consumed during each test was recorded with each test data sheet and the total power consumed was later computed. The weight, volume, and power figures thus obtained were used to establish efficiency relationships between the various scrapers.

Three rope operation was used in all tests. Since the first few scraper loads oftentimes depended upon the shape of the muck pile, the pile was placed in the same shape and position before each test. (See figure 7).

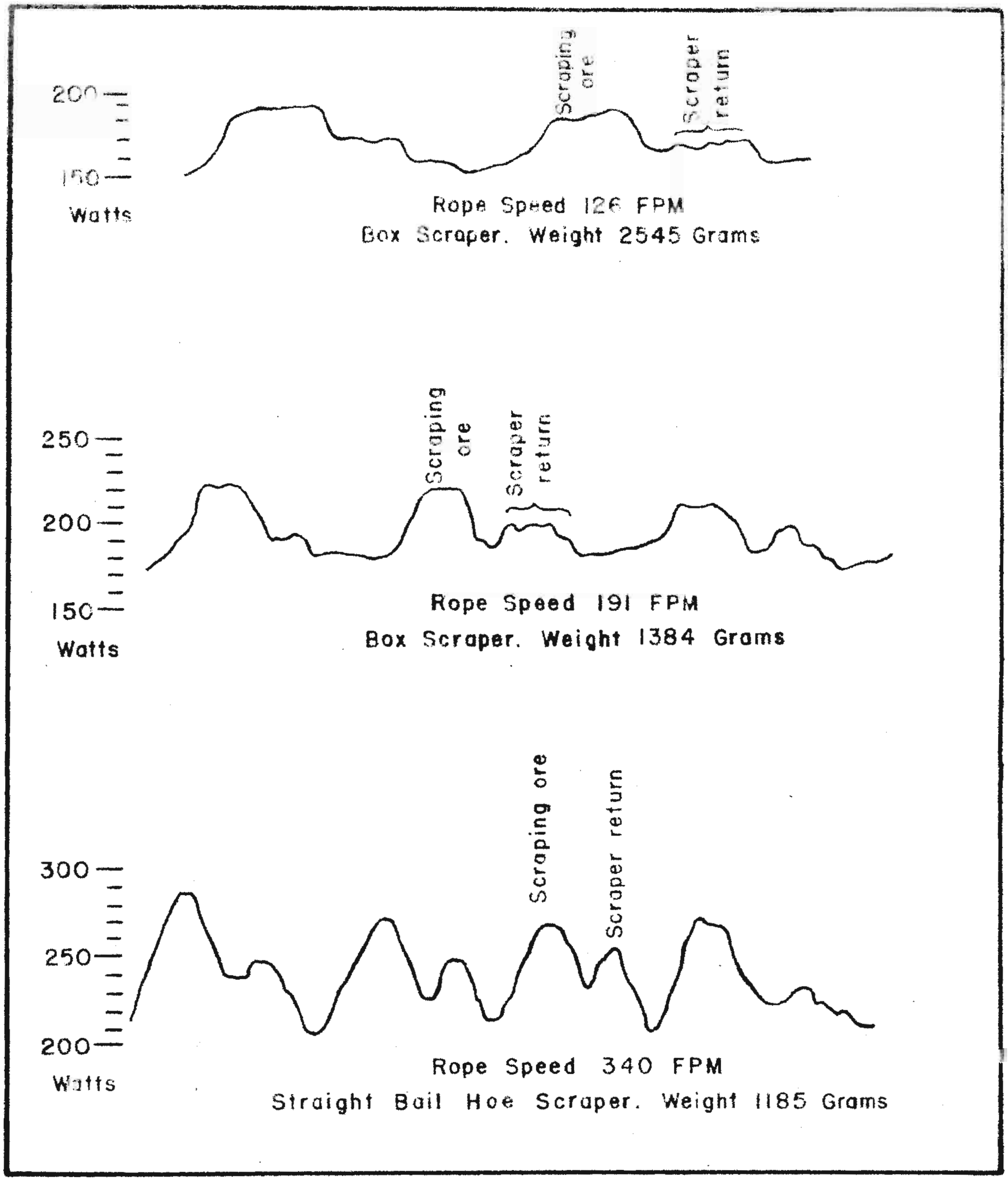

FIGURE 8

Wattmeter graphs of model scraper tests. Note variations in time cycles and rate of power used for different rope speeds.

FIGURE 9

Photograph showing position and shape of muck pile before each scraper test.

Much of the scraper load was lost during the first few passes at the pile due to the rock running from the sides of the scraper. This was especially true of the hoe type scrapers. However, after a few passes, ridges were built up, (see figure 8) and if the scraper was kept between the ridges, very little rock was lost. After several passes, these ridges were of great value in increasing the capacity of each scraper load by allowing the scraper to push rock before it in addition to the normal scraper load. Because of this pushing effect, many average scraper loads were more than 100 per cent of the theoretical capacity of the scraper.

By use of the two tail ropes, the scraper could be maneuvered into any spot on the table in the vicinity of the muck pile. An effort was made to scrape a maximum amount of rock on each trip. However, because of the additional power used during manipulation of the scraper, the maneuvering was kept within reasonable limits.

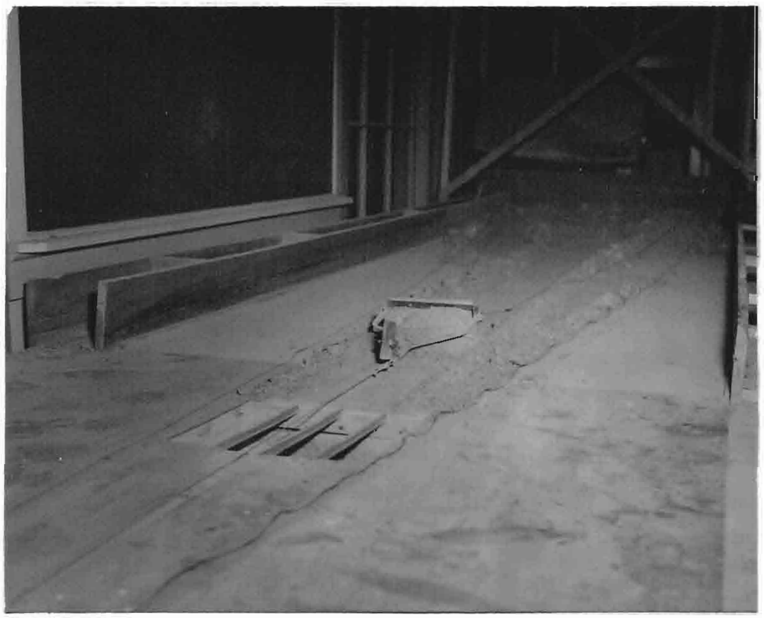

FIGURE 10

Photograph of straight bail hoe scraper moving between ridges of muck.

All rope speed tests were run with the table in a level position. During the moisture tests the table was inclined two degrees toward the muck-pile end to prevent the water from running off the table.

As noted, previous model scraper tests have been conducted by Forrester and Clayton, and Forrester and Carmichael. Efficiencies of the various type scrapers were established with respect to digging angle, scraper weights, rope speeds, and moisture content of the rock. Some of those tests were run with single size grades of rock and some with mixed size grades. Since most material scraped in actual mining operations is of mixed size grades, this type was used in all tests, both for rope speed and moisture determinations. The granite was weighed in proportions as follows: Minus 3/16 inch, 55%; plus 3/16 inch minus 1/2 inch, 25%; plus 1/2 inch minus 1 inch, 10%; plus 1 inch minus 1 1/2 inch, 5%; plus 1 1/2 inch minus 2 inch, 3%; plus 2 inch minus 6 inch, 2%.

Seventy-nine rope speed tests were run. Weights of the various type scrapers were varied during these tests so comparisons with previous similar tests could be made. Forrester and Clayton [24] report

(24) Forrester, J. D., and Clayton, A. B., Ibid, p. 22.

that according to results of their tests, there is an optimum weight for any scraper for maximum efficiency. They go on to say that the addition of more weight to the scraper causes a decline in efficiency of the scraper. Their results were corroborated during the power consumption tests.

The results of the rope speed tests were compared with results of rope speed tests conducted by Forrester and Carmichael. They reported [25] that the efficiency of a scraper gradually declines when

(25) Forrester, J. D., and Carmichael, R. C., Op. cit., p. 13.

worked beyond the optimum operating speed, but that up to a certain point the saving in time with higher speeds would overbalance the small drop in scraper capacity. The power consumption tests showed this to be true when the lighter weight scrapers were tested. However, when more weights were added to the scrapers the majority of the tests showed a progressive increase in efficiency as the rope speeds were increased. The capacity of each scraper load decreased gradually during these tests, but the time saving was enough to affect lower power consumption per given weight of rock scraped. Table 6 shows the maximum efficiencies obtained for any combination of rope speed and scraper type.

Twenty moisture tests were run. These tests were similar to those moisture tests made by Forrester and Carmichael with regard to rope speed, size of rock scraped, scraper weight, and moisture content. They reported [26] that as far as rock scraped per given

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[26] Forrester, J. D., and Carmichael, R. L., Ibid, p. 13.

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weight of scraper was concerned, the scrapers ranked in the following order: Box, slope-bail hoe, crescent, and straight-bail hoe.

However, when results of moisture tests run during this study were compared on the same basis, different efficiency ratings were established. Tests showed the scrapers to rank in the following order: Crescent, Box, slope-bail hoe, and straight-bail hoe. Table 7, a recapitulation of moisture tests, illustrates the efficiency ratios of the various type scrapers.

The comparison on the basis of power consumed per given weight of rock scraped resulted in the following order of efficiency: Box, crescent, straight-bail hoe, and slope-bail hoe.

Table 6. Recapitulation of Rope Speed Tests

Figures given represent watt-sec per gram of rock scraped

Rope Speed	Hoe Straight bail	Hoe Slope bail	Box	Crescent
126 fpm	0.98	0.98	0.48	0.53
191 fpm	0.74	0.88	0.45	0.43
252 fpm	0.60	0.80	0.40	0.40
340 fpm	0.73	0.65	—	—

Table 7. Recapitulation of Moisture Tests

Figures given represent per cent of theoretical capacity
and watt-sec per gram of dry rock scraped,
averaged from 20 trips.

	Scraper Types							
	St. bail		Sl. bail		Box		Crescent	
Per cent Moisture	% Cap.	Watt-sec per Gr. Rock	% Cap.	Watt-sec per Gr. Rock	% Cap.	Watt-sec per Gr. Rock	% Cap.	Watt-sec per Gr. Rock
0	49.5	0.94	93.2	1.21	114.	0.58	65.3	0.69
4.76	53.6	1.25	107.0	1.24	133.4	0.68	68.5	0.87
9.09	52.4	1.07	107.0	1.35	123.7	0.77	68.5	0.87
15.00	43.4	1.27	76.6	1.74	120.5	0.87	68.5	0.89
20.00	49.5	1.05	89.1	1.55	104.0	0.85	71.8	0.83

Hoe Type Scraper Tests

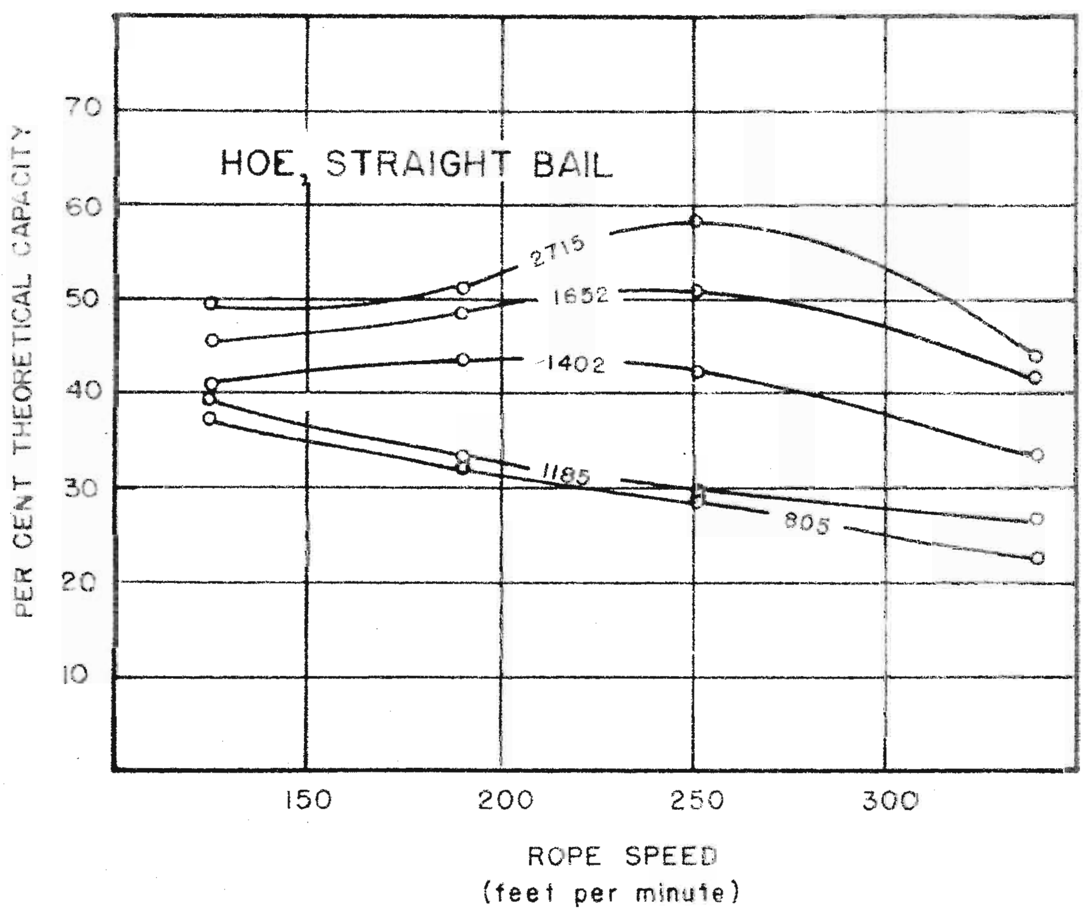
Since hoe type scrapers are most effective with a digging angle of 45 degrees all hoe scraper tests were run with the blade set at that angle. Forrester and Clayton (27) reported that when counter-

(27) Forrester, J. D., and Clayton, A. B., Op. cit., p. 24.

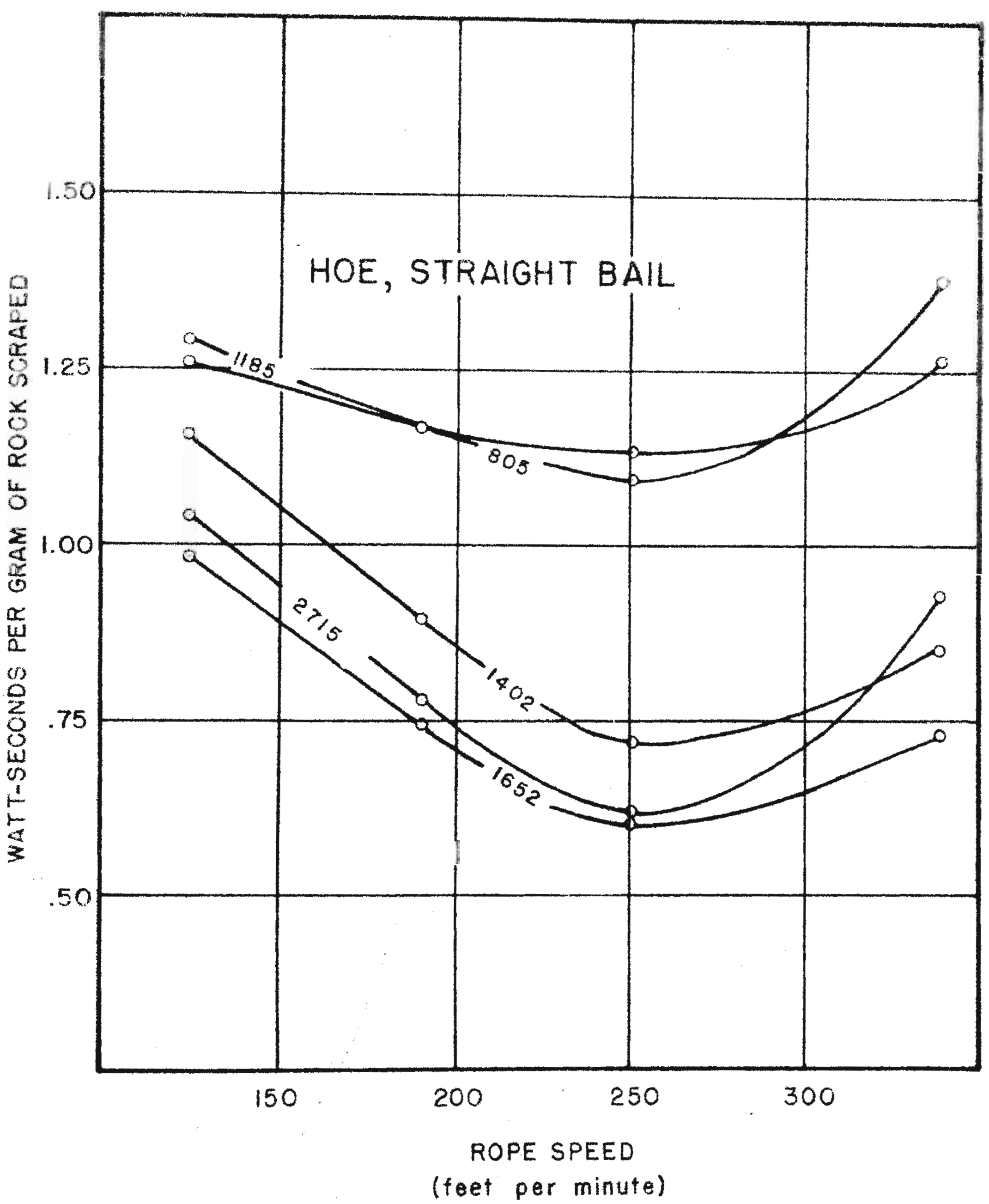
weights are attached to both type hoe scrapers, tests showed that the bail weight should slightly overbalance the weight at the blade, or the heel weight. All counterweights used were applied in such a manner as to conform to the above principle.

Graphs 1 and 3 show the volume of rock scraped for different rope speeds and different weight scrapers. Graphs 2 and 4 indicate the power consumed per given weight of rock scraped as the scraper weight and rope speed are varied. As far as the volume of rock scraped is concerned, the slope bail hoe scraper is much more efficient than the straight bail hoe scraper for any weight or any rope speed.

The addition of weight to the straight bail hoe scraper increases the capacity of the scraper. When the heavier weight scrapers are used the capacity also increases with an increase in rope speed up to a certain point. Much of the digging effect is absent in the lighter weight scrapers and the scraper tends to bounce over medium and large size rocks; observations of the tests clearly indicated that the efficiency of the heavier scrapers was due to the increased digging effect produced by the extra weight. The optimum rope speed appears to be about 250 feet per minute. The power consumption



Graph 1. Relationship between per cent theoretical capacity and rope speed. Scraper weights in grams noted on curves.



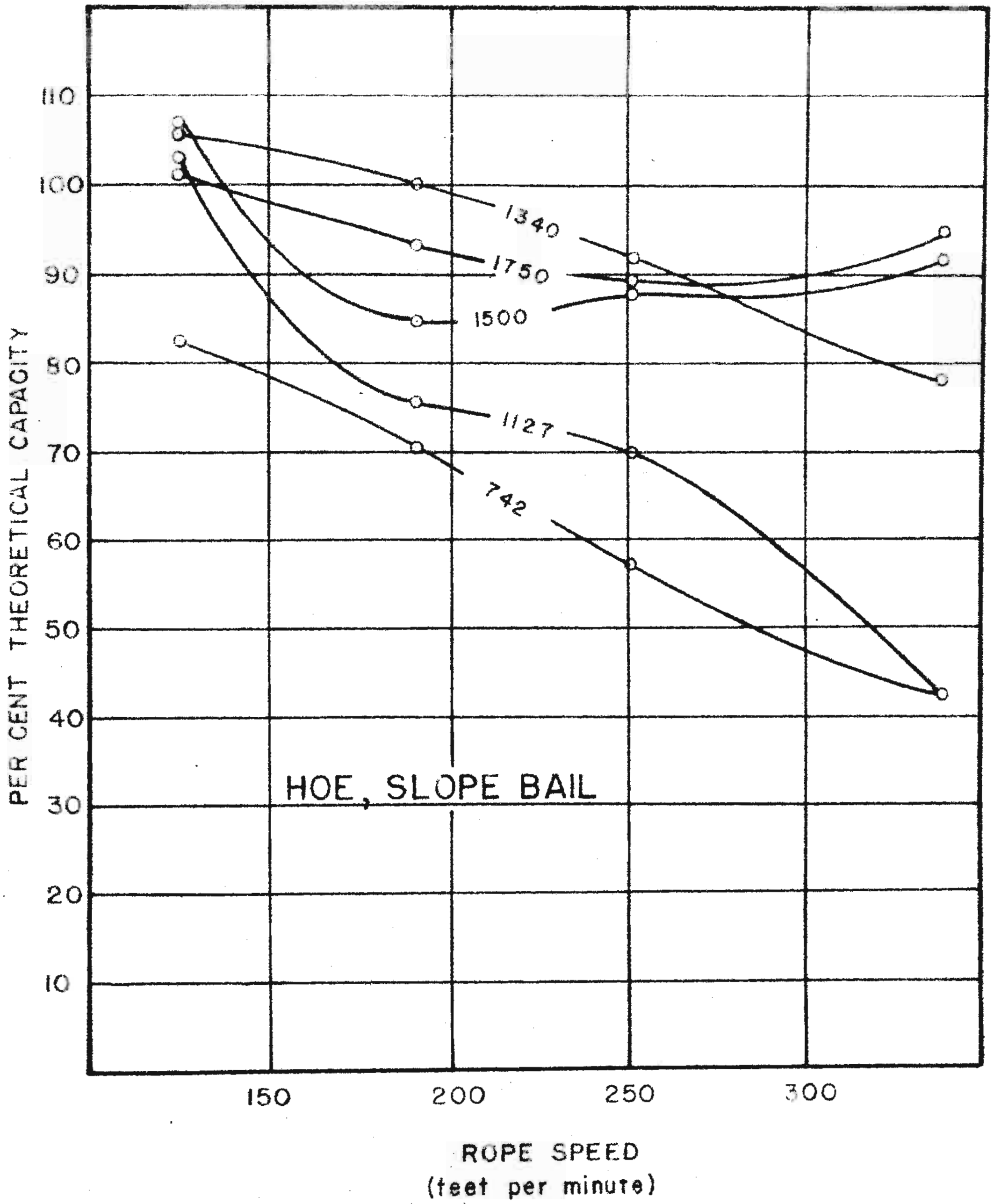
Graph 2. Relationship between rope speed and power consumption. Scraper weights in grams noted on curves.

curves for the straight bail hoe scraper also indicate that the heavier scrapers are more efficient than the lighter ones. The amount of power consumed per given weight of rock scraped decreases with an increase in rope speed up to a certain point, and then increases. The optimum rope speed with respect to power is about 250 feet per minute. Thus the best operating speed for the straight bail hoe scraper, judging from both scraper capacity and power consumption, is about 250 feet per minute.

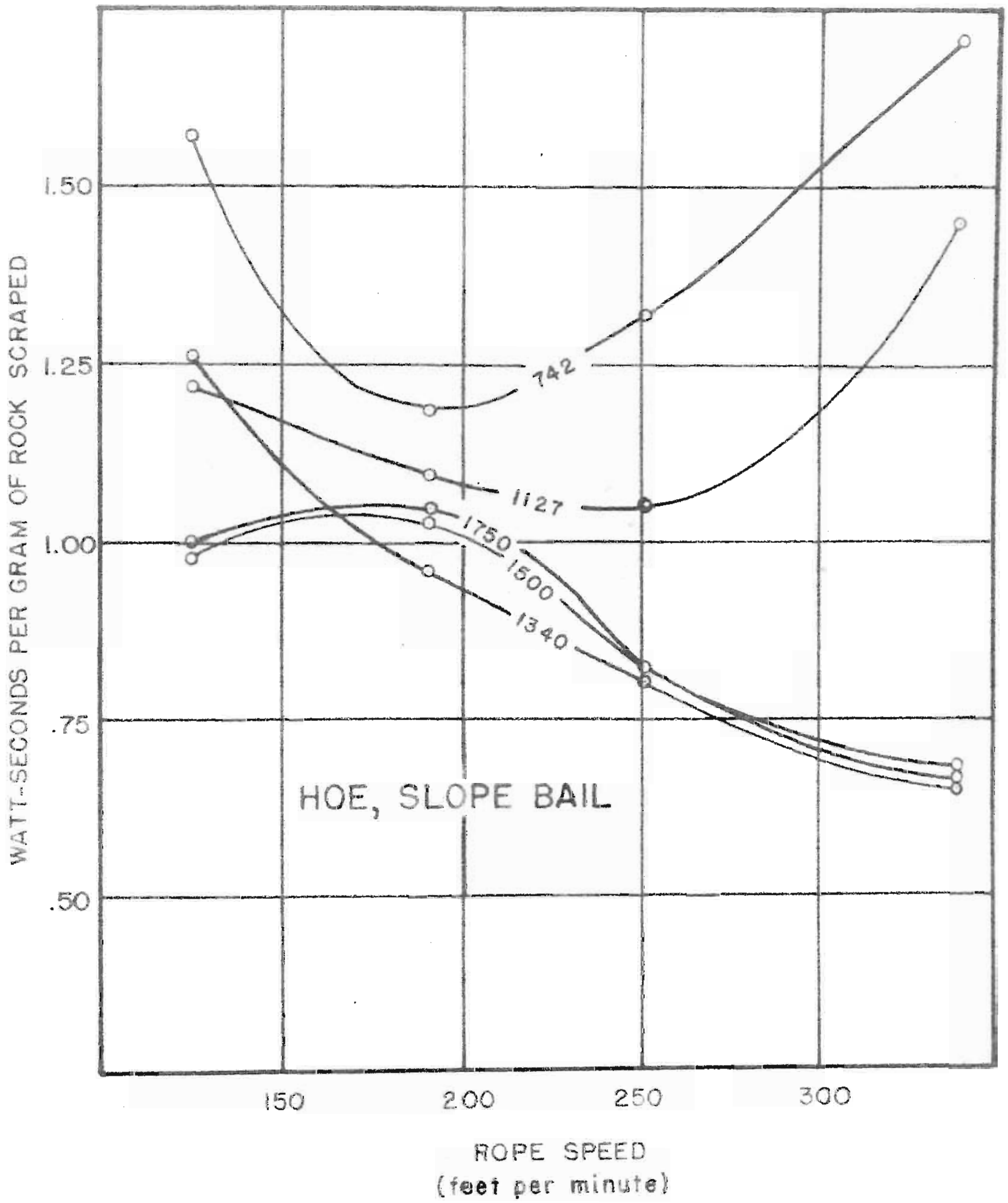
Graphs 9 and 10, plotted from results of moisture tests, illustrate the relative efficiencies of the different type scrapers as the moisture content of the rock is increased up to 20 per cent. As noted, the straight bail hoe scraper is the least efficient type scraper tested for moving wet rock. The weight of rock moved decreases as water up to 15 per cent is added; a moisture content of 20 per cent results in an increase in efficiency. The power consumption curve for this scraper also shows a decrease in efficiency up to 15 per cent moisture with an increase at 20 per cent.

The moisture tests were run with the scraper at a constant weight at a constant rope speed. Further tests with different weight scrapers and variable rope speeds should reveal more of the effects of moisture on the action of the scraper.

The efficiency curves of the slope bail hoe scraper (graphs 3 and 4) are somewhat similar to the curves of the straight bail hoe scraper. Graph 3 shows the efficiency of the lighter weight scrapers to drop with an increase in rope speed. The heavier weight scrapers lose little of their effectiveness when operated at higher speeds.



Graph 3. Relationship between per cent theoretical capacity and rope speed. Scraper weights in grams noted on curves.



Graph 4. Relationship between rope speed and power consumption. Scraper weights in grams noted on curves.

Considering the volume of rock scraped per pass, the slope bail scraper operates best at the slowest rope speed. However, graph 4 reveals that with respect to power consumption, the scraper is most efficient when operated at 340 feet per minute; the scraper seems to be about 45 per cent more efficient when operated at 340 feet per minute as compared with operation at 126 feet per minute. This fact is important because it shows that the efficiency of a scraper should not be arrived at from only the standpoint of volume scraped, but from an integrated study of both the volume scraped and the amount of power consumed per weight of rock scraped.

The optimum efficiency of the slope bail scraper at this high speed as compared with the optimum efficiency of the straight bail hoe scraper at a lower speed is probably due to the sloped bail holding the larger rocks in the scraper. The larger rocks tend to slide out the side of the straight bail hoe scraper.

Results of the slope bail hoe moisture tests paralleled results of the straight bail hoe moisture tests with the slope bail hoe scraper being more efficient with regard to weight of rock scraped. It will be noted in graph 9 that the slope bail scraper is about 25 per cent more efficient than the straight bail type.

However, graph 10 shows the scraper to be less efficient than the straight bail type as far as power is concerned. This decreased efficiency may be due to the lower angle of pull in the slope bail scraper. It is true that a lower angle of pull effects better digging and, therefore, larger loads, but when scraping in wet muck the digging may require more power because the muck is more compact.

Box Type Scraper Tests

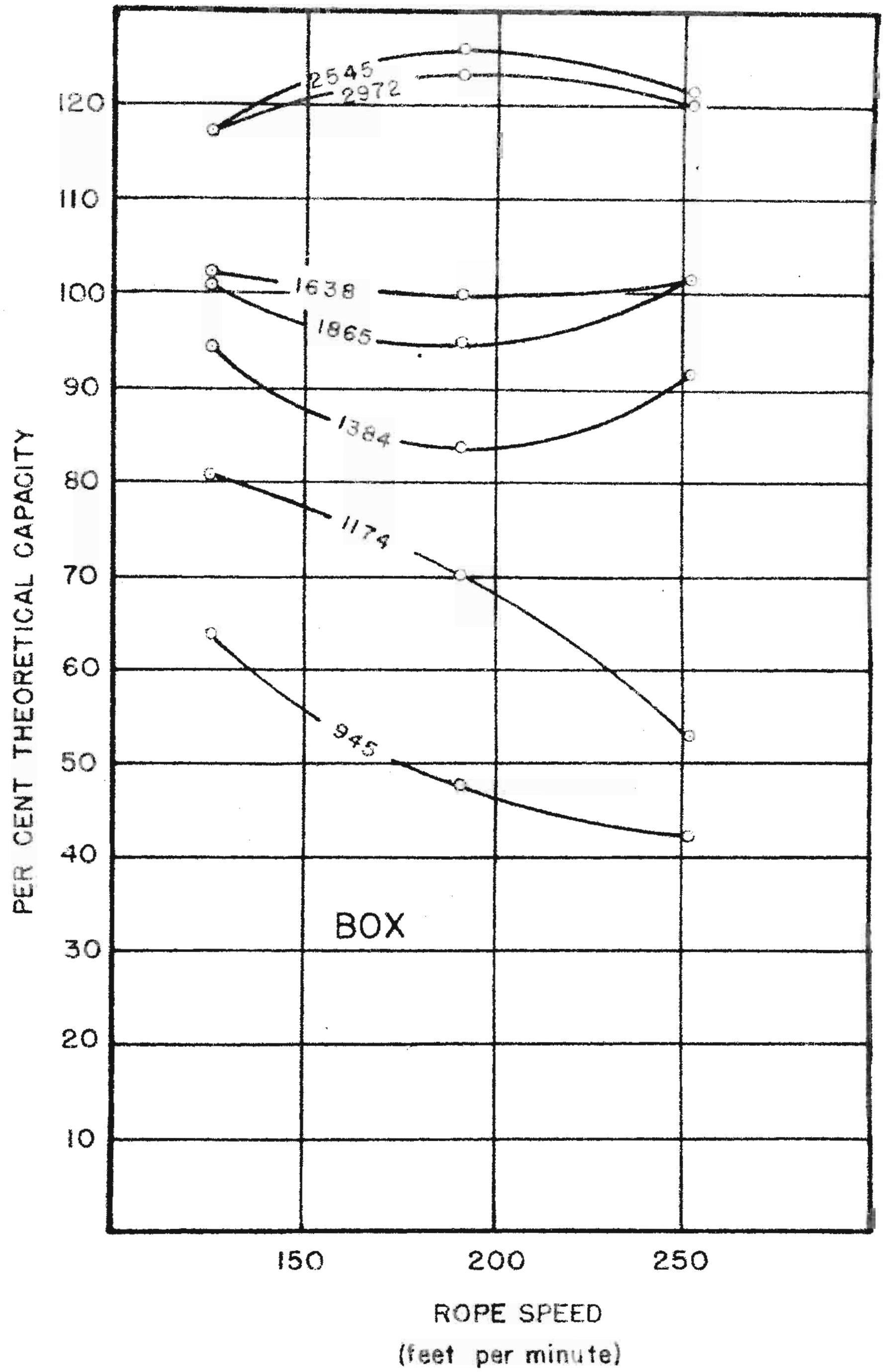
The box scraper was tested at three rope speeds and at seven different scraper weights. It was not tested at speeds higher than 250 feet per minute because above this speed the scraper, especially at lighter weights, bounced around so much that testing would have been impracticable.

Graph 5 shows the lighter weight scrapers to be most efficient when operated at 126 feet a minute. The power consumption curve (graph 6) also shows that rope speed to be the most efficient for the lighter scrapers. The optimum speed is 126 feet per minute because much of the digging effect is lost at higher speeds.

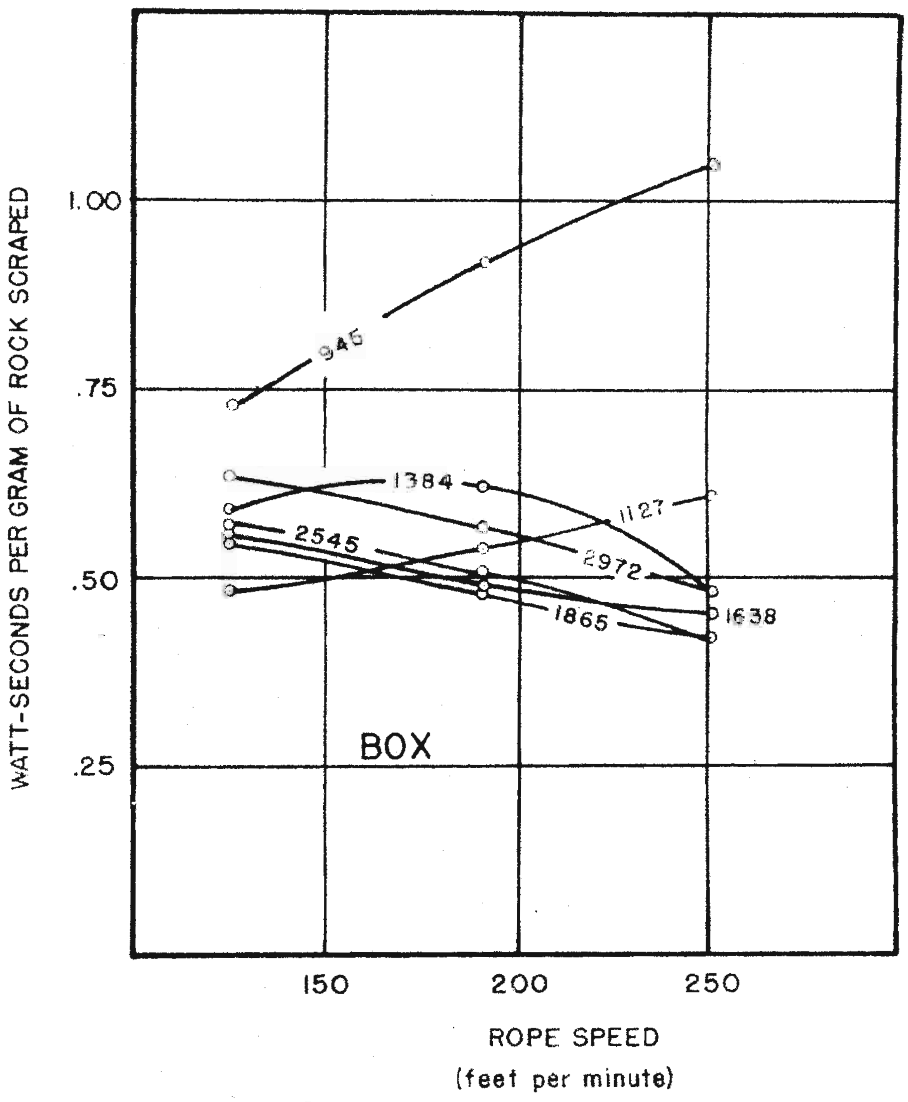
Graph 5 indicates that as more weight is added, the scraper moves a larger volume of rock; the two heaviest scrapers show theoretical capacities of over 120 per cent. In considering the volume of rock scraped, the efficiency of heavier weight box scrapers is not affected to any great degree by an increase in rope speed.

As noted in the power consumption curves (graph 6), the heavier weight scrapers are more efficient when operated at higher speeds. Observations revealed that this efficiency was probably due to the added power of the scraper when the scraper was first digging into the muck pile. The added power causes the scraper to dig under rocks that it would slide over if operated at slower speeds. The time used in scraping is also much less at higher speeds, and the time saved probably overbalances the higher rate of power.

Results of the moisture tests with the box scraper show that the efficiency drops with an increase in moisture content of the rock.



Graph 5. Relationship between per cent theoretical capacity and rope speed. Scraper weights in grams noted on curves.



Graph 6. Relationship between rope speed and power consumption. Scraper weights noted on curves.

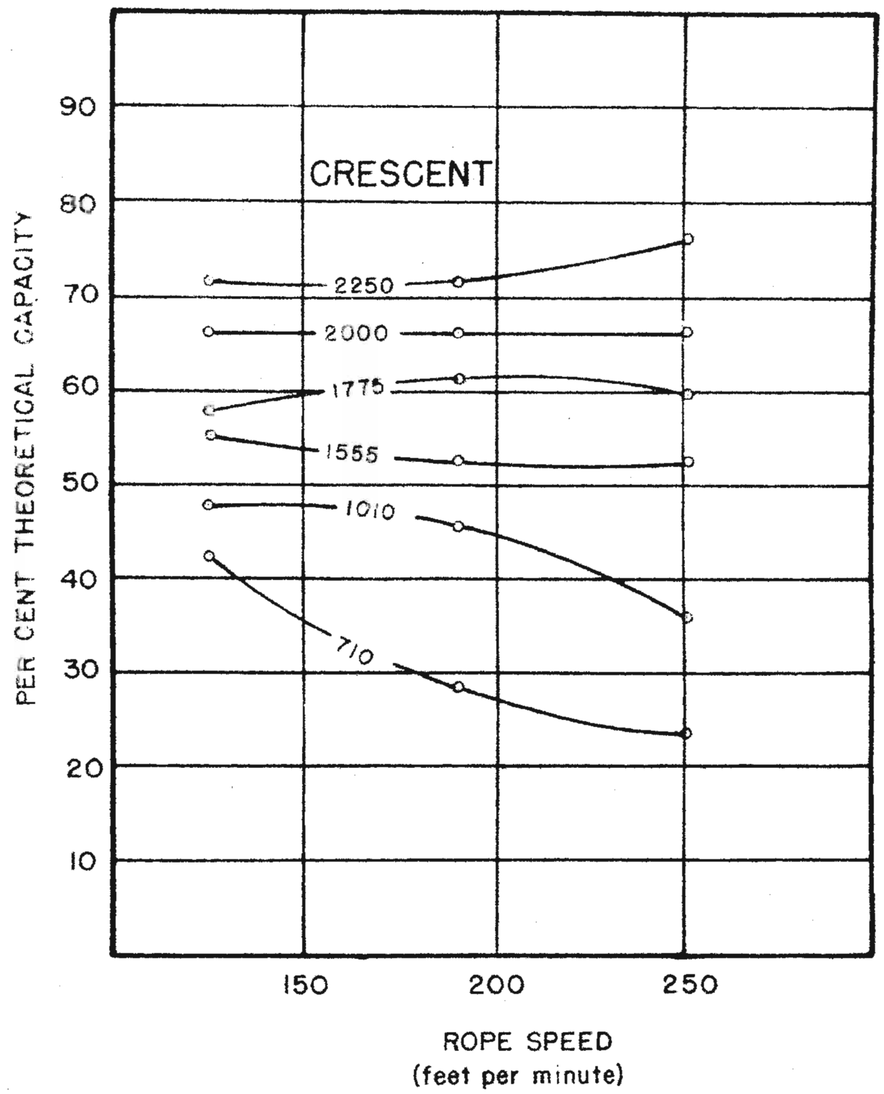
This was probably due to the inability of the scraper to dig into the compacted, fine rock. The moisture tests were run with the scraper at a constant weight and a constant rope speed, and more comprehensive moisture tests should reveal much additional information concerning the effect of moisture on the box scraper.

Crescent Type Scraper Tests

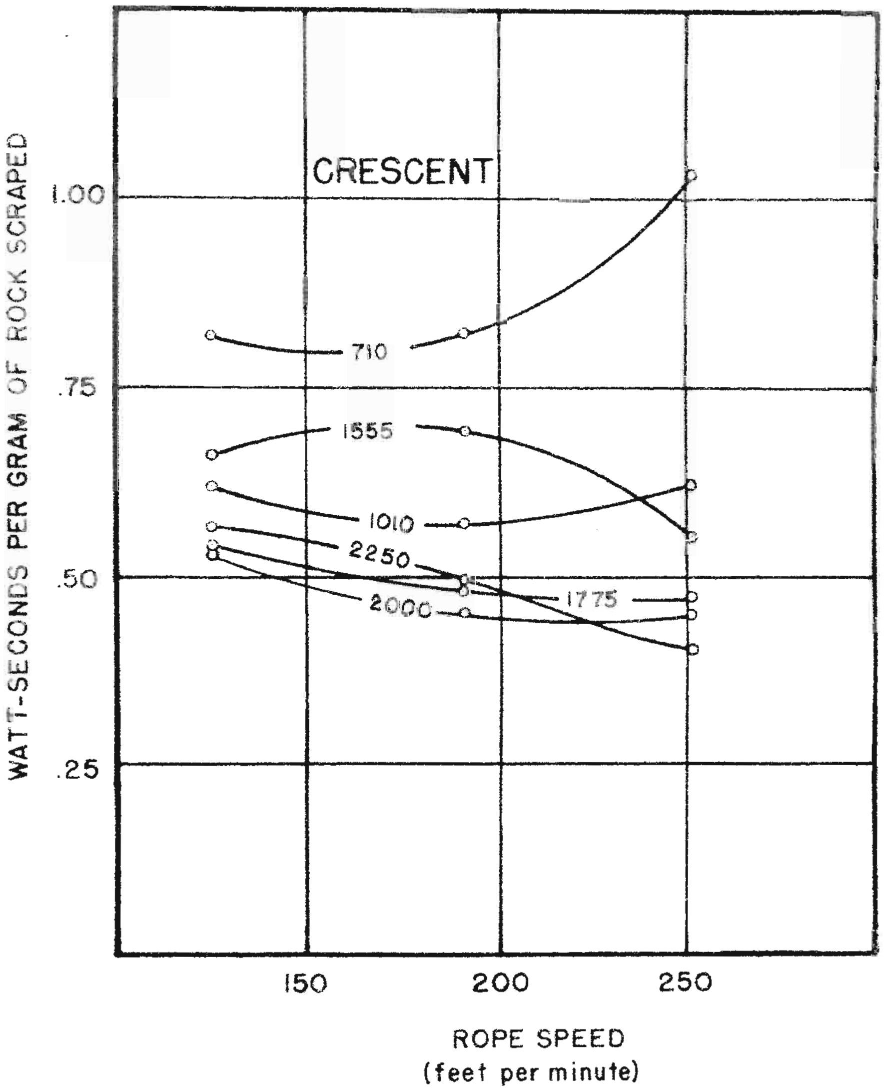
The crescent scraper is affected by a variation in weight and rope speed in much the same manner as the box scraper. The curves in graph 7 and 8 show the lighter weight scrapers to be the least efficient. The addition of weight to the scraper gradually increases the efficiency of the scraper with regard to volume of rock scraped. Increased rope speeds have little effect on the scraper as far as volume moved is concerned. However, graph 8 shows a slightly lower power consumption in the heavier scrapers at the higher rope speeds. As is the case with the box scraper, this slight power consumption drop may be due to the greater force in digging or in the time saved in scraping.

Graphs 9 and 10 show that during moisture tests, the efficiency of the crescent scraper dropped with the addition of water up to about 15 per cent and then increased as more water was added. With respect to grams of rock scraped per gram weight of scraper, the crescent type is equally efficient at moisture contents of 0 and 20 per cent. However, the power consumption curve shows less power to be used when the moisture content of the rock is 0.

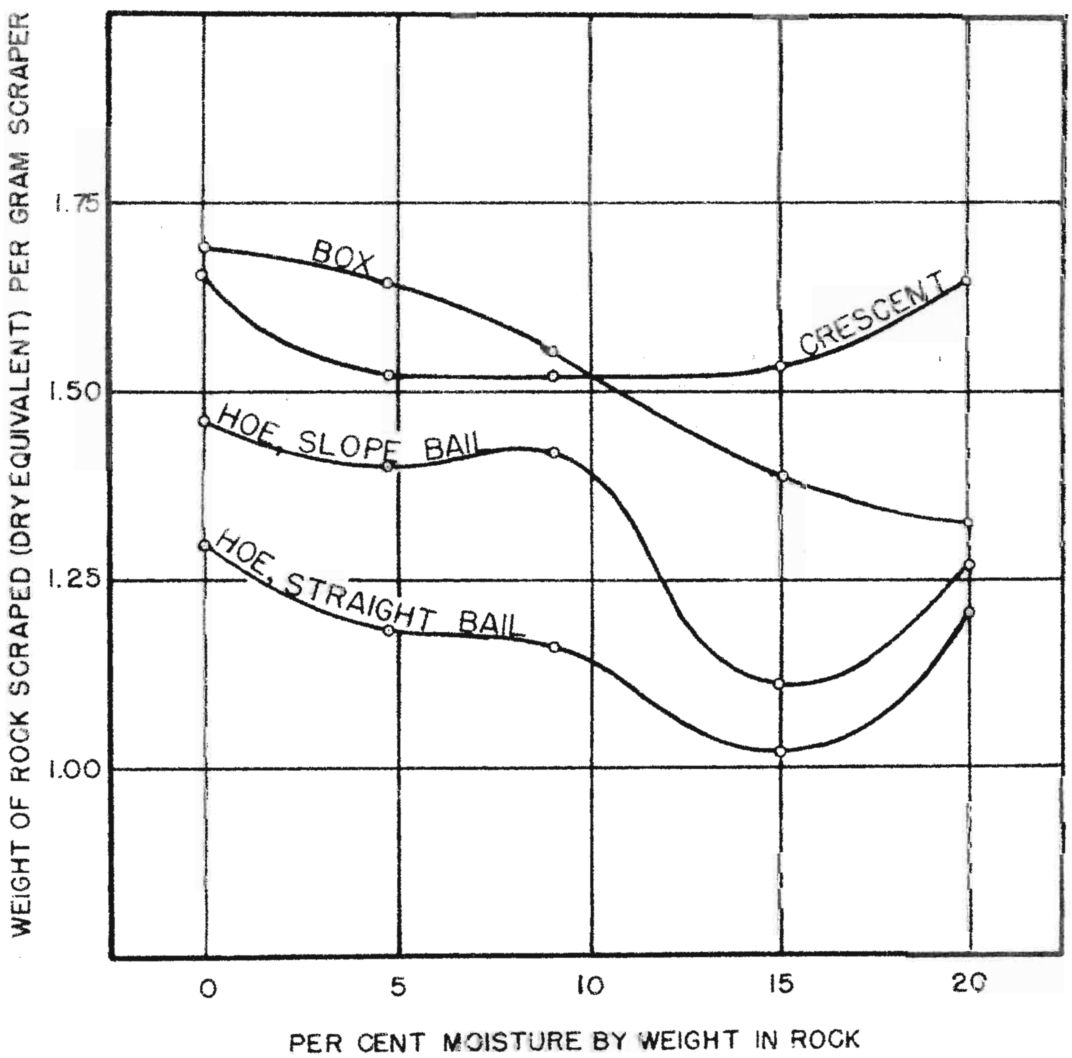
As is the case with the box scraper, further moisture tests should give more complete information about the action of the cres-



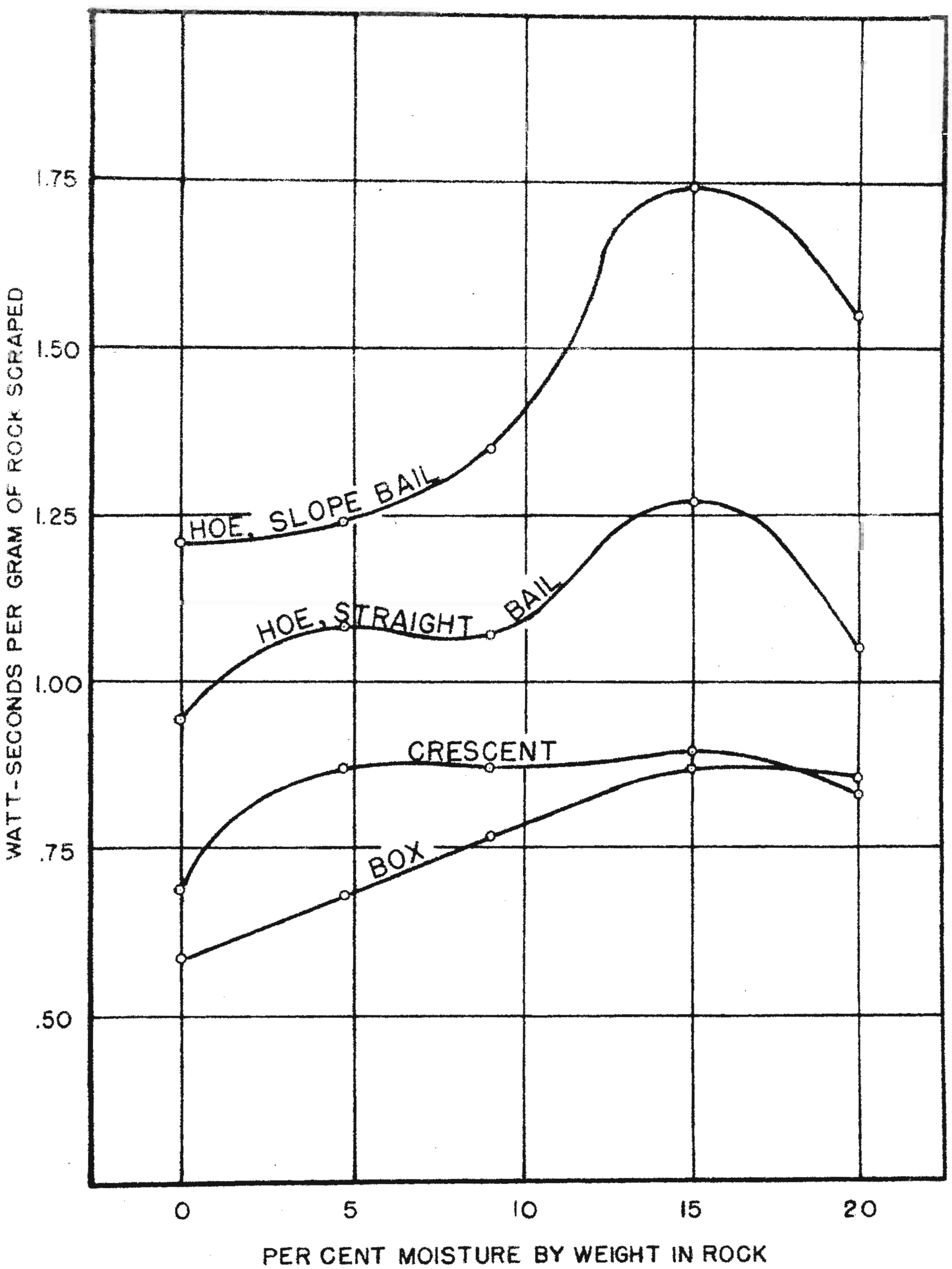
Graph 7. Relationship between per cent theoretical capacity and rope speed. Scraper weights in grams noted on curves.



Graph 8. Relationship between rope speed and power consumption. Scraper weights in grams noted on curves.



Graph 9. Relationship between moisture content of rock and weight of rock scraped. Rope speed, 126 fpm. Scraper weights: Hoe, st. bail, 1571 gms.; Hoe, sl. bail, 1149 gms; Box, 2065 gms.; Crescent, 1780 gms.



Graph 10. Relationship between moisture content of rock and power consumption. Rope speed, 126 fpm. Scraper weights: Hoe, St. bail, 1571 gms.; Hoe, Sl. bail, 1149 gms; Box, 2065 gms.; Crescent, 1780 gms.

cent scraper when moving wet muck.

CONCLUSIONS DRAWN FROM STUDY OF MODEL SCRAPERS TESTED

1. Inasmuch as the efficiency of a given scraper varies with the weight of the scraper, the efficiency is at a maximum at a definite weight.

2. Variations in efficiencies between lighter weight scrapers are greater than the variations between the heavier ones; therefore, too much weight is better than too little.

3. The efficiency of any scraper is at a maximum at a definite rope speed. For all types except the straight bail hoe scraper, the optimum rope speed is about 340 feet a minute; the straight bail hoe scraper operates best at 250 feet a minute.

4. The amount of rock scraped per pass does not necessarily establish the best operating conditions for a given scraper. These conditions can be arrived at only after a coordinated study of the amount of rock scraped and the amount of power consumed.

5. The addition of moisture to rock scraped does not increase the efficiency of scrapers.

SUMMARY OF SCRAPER TESTS

Four model scrapers were tested to determine their relative power consumption when operated under identical conditions. The scrapers were constructed on a scale of 1 to 6 and were 8 inches wide. The models tested were the straight bail hoe, the slope bail hoe, the box, and the crescent. Crushed granite of mixed size grades was used in all tests. Tests were conducted on a 15-foot table, and the three-drum hoist was powered by a quarter horsepower electric motor. A recording wattmeter was used to trace graphs of the power consumed in each test. Relative efficiencies of the various scrapers were judged on the basis of amount of power used for scraping a given weight of rock.

Seventy-nine rope speed tests were run. During these tests rope speeds ranged from 126 to 340 feet a minute, and weights of the different scrapers were varied. Tests showed 340 feet a minute to be the best operating speed for all scraper types except the straight bail hoe, which operates best at a rope speed of about 250 feet a minute.

When scraper weights were varied, it was found that a scraper's efficiency is at a maximum at a definite weight.

Twenty moisture tests were run, in which the moisture content of the muck was varied from 0 to 20 per cent. Results of these tests revealed that the efficiency of any type scraper is at a maximum when the moisture content of the muck is 0.

In determining the overall efficiency of a given scraper, conclusions drawn from a study of amount of rock scraped may be misleading. Tests showed that some scrapers were more efficient from the standpoint of power used than are other scrapers which moved more rock per pass. Therefore, the optimum operating conditions for any given scraper should be determined by studies which include power consumption tests.

APPENDIX A

ROPE SPEED TESTS AT 126 FPM

Three rope operation--dry granite on level floor--10 ft. distance

Type scraper	Wt. scraper	% theor. capacity	Gms. rock per gr. scraper	Gms. rock per cc. rock	Watt-sec. per cc. rock	Watt-sec. per gr. rock
Hoe, st.*	805	37.3	1.84	1.71	2.19	1.26
Hoe, st.	1185	39.2	1.38	1.79	2.32	1.29
Hoe, st.	1402	41.0	1.22	1.79	2.20	1.13
Hoe, st.	1652	45.8	1.13	1.74	1.70	0.98
Hoe, st.	2715	49.5	0.73	1.73	1.81	1.04
Hoe, sl.**	742	82.1	1.84	1.62	2.54	1.57
Hoe, sl.	1127	103.0	1.60	1.72	2.08	1.22
Hoe, sl.	1340	105.5	1.37	1.70	2.14	1.26
Hoe, sl.	1500	106.8	1.25	1.71	1.72	1.00
Hoe, sl.	1750	101.2	1.22	2.06	2.15	0.98
Box	945	63.7	1.95	1.70	1.24	0.73
Box	1174	80.3	1.88	1.62	0.77	0.48
Box	1384	94.1	1.95	1.69	0.99	0.59
Box	1638	102.5	1.87	1.76	0.98	0.56
Box	1865	101.0	1.82	1.98	1.08	0.55
Box	2545	117.3	1.38	1.76	1.00	0.57
Box	2972	117.7	1.14	1.69	1.07	0.63
Crescent	710	42.1	2.76	1.79	1.46	0.82
Crescent	1010	47.5	2.26	1.65	1.15	0.62
Crescent	1555	55.0	1.60	1.74	1.14	0.66
Crescent	1775	57.8	1.41	1.66	0.90	0.54
Crescent	2000	65.9	1.45	1.69	0.90	0.53
Crescent	2250	71.3	1.40	1.69	0.97	0.57

* st.--straight bail
** sl.--slope bail

APPENDIX B

ROPE SPEED TESTS AT 191 FPM

Three rope operation--dry granite on level floor--10 ft. distance

Type scraper	Wt. scraper	% theor. capacity	Gms. rock per gr. scraper	Gms. rock per cc. rock	Watt-sec. per cc. rock	Watt-sec. per gr. rock
Hoe, st.*	805	32.1	1.56	1.75	2.05	1.17
Hoe, st.	1185	33.1	1.19	1.84	2.15	1.17
Hoe, st.	1402	43.5	1.33	1.83	1.63	0.89
Hoe, st.	1652	48.7	1.21	1.77	1.31	0.74
Hoe, st.	2715	51.3	0.81	1.86	1.46	0.78
Hoe, sl.**	742	71.3	1.66	1.75	2.02	1.16
Hoe, sl.	1127	75.4	1.28	1.85	2.02	1.09
Hoe, sl.	1340	100.0	1.29	1.69	1.62	0.96
Hoe, sl.	1500	84.8	1.02	1.76	1.81	1.03
Hoe, sl.	1750	93.1	0.97	1.78	1.85	1.04
Box	945	47.8	1.39	1.62	1.49	0.92
Box	1174	70.2	1.76	1.73	0.91	0.53
Box	1384	83.5	1.80	1.75	1.19	0.62
Box	1638	100.0	1.78	1.71	0.85	0.49
Box	1865	95.0	1.55	1.79	0.86	0.48
Box	2545	126.0	1.48	1.75	0.89	0.51
Box	2972	123.0	1.24	1.75	1.00	0.57
Crescent	710	28.1	2.76	1.79	1.46	0.82
Crescent	1010	45.4	2.05	1.76	1.01	0.57
Crescent	1555	52.4	1.57	1.78	1.24	0.69
Crescent	1775	61.0	1.54	1.72	0.84	0.48
Crescent	2000	65.9	1.45	1.69	0.76	0.45
Crescent	2250	71.3	1.40	1.69	0.83	0.49

* st.--straight bail
** sl.--slope bail

APPENDIX C

ROPE SPEED TESTS AT 252 FPM

Three rope operation--dry granite on level floor--10 ft. distance

Type scraper	Wt. scraper	% theor. capacity	Gms. rock per gr. scraper	Gms. rock per cc. rock	Watt-sec. per cc. rock	Watt-sec. per gr. rock
Hoe, st.*	805	28.3	1.48	1.81	1.98	1.09
Hoe, st.	1185	29.6	1.00	1.72	1.92	1.11
Hoe, st.	1402	42.5	1.26	1.80	1.30	0.72
Hoe, st.	1652	51.0	1.24	1.74	1.04	0.60
Hoe, st.	2715	58.5	0.82	1.65	1.02	0.62
Hoe, sl.**	742	57.5	1.32	1.66	2.18	1.32
Hoe, sl.	1127	69.8	1.14	1.77	1.86	1.05
Hoe, sl.	1340	91.8	1.20	1.71	1.37	0.80
Hoe, sl.	1500	87.7	1.01	1.68	1.38	0.82
Hoe, sl.	1750	89.0	0.89	1.70	1.40	0.82
Box	945	42.2	1.47	1.95	2.02	1.05
Box	1174	52.8	1.36	1.78	1.08	0.61
Box	1584	91.6	2.03	1.80	0.87	0.48
Box	1638	101.5	1.83	1.73	0.78	0.45
Box	1865	101.5	1.65	1.78	0.75	0.42
Box	2545	121.5	1.44	1.75	0.74	0.42
Box	2972	120.0	1.18	1.72	0.82	0.48
Crescent	710	23.2	1.46	1.72	1.77	1.03
Crescent	1010	35.7	1.61	1.75	1.08	0.62
Crescent	1555	52.5	1.39	1.59	0.87	0.55
Crescent	1775	59.5	1.42	1.62	0.76	0.47
Crescent	2000	65.9	1.45	1.69	0.76	0.45
Crescent	2250	76.0	1.53	1.73	0.69	0.40

* st.--straight bail
** sl.--slope bail

APPENDIX D

ROPE SPEED TESTS AT 340 FPM

Three rope operation--dry granite on level floor--10 ft. distance

Type scraper	Wt. scraper	% theor. capacity	Gms. rock per gr. scraper	Gms. rock per cc. rock	Watt-sec. per cc. rock	Watt-sec. per gr. rock
Hoe, st.*	805	22.3	1.10	1.71	2.36	1.38
Hoe, st.	1185	26.6	0.91	1.75	2.22	1.27
Hoe, st.	1402	33.3	1.02	1.85	1.57	0.85
Hoe, st.	1652	44.0	1.09	1.76	1.27	0.73
Hoe, st.	2715	42.0	0.65	1.82	1.69	0.93
Hoe, sl.**	742	42.5	0.69	1.53	2.59	1.71
Hoe, sl.	1127	42.5	0.61	1.58	2.30	1.45
Hoe, sl.	1340	76.0	1.04	1.75	1.15	0.65
Hoe, sl.	1500	91.7	1.05	1.66	1.15	0.68
Hoe, sl.	1750	94.6	0.92	1.67	1.11	0.66

* st.--straight bail
** sl.--slope bail

APPENDIX E

MOISTURE TESTS

Three rope operation at 126 fpm--mixed-size granite--10 ft. distance

Type scraper	Weight scraper	% moist. by wt.	% theor. capacity	Gms. rock (wet) per gr. scraper	Gms. rock (dry) per gr. scraper	Gms. rock per cc. rock	Watt-sec. per gr. rock (wet)	Watt-sec. per gr. rock (dry)
Hoe, st.*	1571	0.00	49.5	----	1.29	1.77	----	0.94
Hoe, sl.**	1149	0.00	93.2	----	1.46	1.76	----	1.21
Box	2065	0.00	114.0	----	1.66	1.78	----	0.58
Crescent	1780	0.00	65.3	----	1.69	1.77	----	0.69
Hoe, st.*	1571	4.76	53.6	1.23	1.18	1.54	1.04	1.08
Hoe, sl.**	1149	4.76	107.0	1.47	1.40	1.68	1.18	1.24
Box	2065	4.76	133.4	1.75	1.64	1.59	0.64	0.68
Crescent	1780	4.76	68.5	1.60	1.52	1.60	0.84	0.87
Hoe, st.*	1571	9.09	52.4	1.24	1.16	1.59	1.00	1.07
Hoe, sl.**	1149	9.09	107.0	1.49	1.42	1.56	1.29	1.35
Box	2065	9.09	123.7	1.64	1.55	1.61	0.72	0.77
Crescent	1780	9.09	68.5	1.61	1.52	1.61	0.82	0.87
Hoe, st.*	1571	15.00	43.4	1.12	1.02	1.74	1.16	1.27
Hoe, sl.**	1149	15.00	76.6	1.18	1.11	1.72	1.64	1.74
Box	2065	15.00	120.5	1.67	1.38	1.68	0.73	0.87
Crescent	1780	15.00	68.5	1.66	1.53	1.65	0.82	0.82
Hoe, st.*	1571	20.00	49.5	1.35	1.21	1.64	0.95	1.05
Hoe, sl.**	1149	20.00	89.1	1.39	1.27	1.75	1.43	1.58
Box	1780	20.00	104.0	1.45	1.32	1.69	0.77	0.85
Crescent	2065	20.00	71.8	1.81	1.65	1.73	0.76	0.83

* st.--straight bail
** sl.--slope bail

APPENDIX F

Scraper Data Sheet

Maximum Capacity of Scrapers (measured with 3/16" dolomite)

Hoe Type Straight Bail

8 inches wide .... Blade angle 30° - 1700 cc.
Blade angle 45° - 2330 cc.
Blade angle 60° - 2000 cc.

Hoe Type Slope Bail

8 inches wide .... Blade angle 30° - 1000 cc.
Blade angle 45° - 1025 cc.
Blade angle 60° - 1200 cc.

Box Type

8 inches wide .... Blade angle 30° - 1700 cc.
Blade angle 45° - 1650 cc.

Crescent Type

8 inches wide .... Blade angle 60° - 2600 cc.

Weight of Scrapers

Hoe Type, Straight Bail (with chain) .... 805 gms.
Hoe Type, Slope Bail (with chain) .... 742 gms.
Box Type, (with chain) .... 945 gms.
Crescent Type, (with chain) .... 710 gms.

Counterweights

Bail weight for hoe types .... 98 gms.
Bail weight for hoe types .... 260 gms.
Back weight for hoe or box .... 210 gms.
Back weight for hoe or box .... 217 gms.
Back weight for hoe or box .... 681 gms.
Back weight for hoe or box .... 897 gms.

Pans for Rock Measurement

Pan No. 1 - 53 x 53 x 9 cm. (vol. 25,281 cc.) area of bottom 2809 sq. cm.

Pan No. 2 - Dimensions same as above.

APPENDIX G

Calculation of Rope Speeds

Speed of hoist shaft (by counting):

160 RPM
242 RPM
319 RPM
430 RPM

Winding drum 3.02 inches in diameter is .7902 ft. in circ.

Rope speed No. 1 is 0.7902 x 160 = 126.4 ft. per minute
Rope speed No. 2 is 0.7902 x 242 = 191.3 ft. per minute
Rope speed No. 3 is 0.7902 x 319 = 252.2 ft. per minute
Rope speed No. 4 is 0.7902 x 430 = 339.9 ft. per minute

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VITA

Stanley Francis Johnsen was born May 3, 1924 in Bonne Terre, Missouri. He received his elementary schooling in Flat River, Missouri and Bonne Terre, Missouri. He was graduated from Bonne Terre High School in May, 1942 and entered Missouri School of Mines and Metallurgy in June, 1942. He left school in February, 1943 to enter the armed forces and spent the next two and one-half years in the U. S. Air Forces, where he served as navigator. He spent seven months in the European Theater of operations and was discharged in September, 1945 with the rank of 1st Lieutenant.

He resumed his schooling at Missouri School of Mines and Metallurgy in February, 1946 and was graduated in June, 1948 with a degree of Bachelor of Science in Mining Engineering, Mining Geology Option.