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A study of mine scraper buckets and their efficiency

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A STUDY OF MINE SCRAPER BUCKETS
AND THEIR EFFICIENCY

BY

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A

THESIS

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

Rolla, Missouri

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* * *

Approved by J. D. Forrester
Professor of Mining Engineering

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A large number of operating companies and several scraper manufacturers were helpful in sending plans and other data relative to scraping practice.

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 Master of Science in Mining Engineering.

The results herewith reported were obtained by efficiency studies of mine scrapers on model scale. Bottomless scraper types in common use in underground mines, including two hoe types, a box type, and a crescent type, were tested.

The apparatus was built and the laboratory tests conducted during the first half of 1946 in the Missouri School of Mines mining laboratory.

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF GRAPHS

INTRODUCTION

The use of power drawn scrapers, often called "slushing", for the moving of ore, stope filling, and waste rock has become standard practice in many mining operations. Several types of scrapers have been developed by practical application or by trial and error methods. However, a direct comparison of these scraper types under identical conditions has not been noted in a review of literature on the subject of mechanical loading.

Written inquiries to authorities on scraping practice have brought replies that no previous comparisons of scraper types on a model scale have been attempted. Therefore, the following thesis problem was set up:

Purpose of Problem

The principal purpose of the thesis study of bottomless scraper scoops or buckets is to determine the comparable efficiency and applicability of the several types now in use as applied to different classes of earth and rock materials. It is hoped that these tests may form the basis for improved scraper design.

Problem Procedure

The main scraper types now in use at operating mines are: the hoe and modifications of it; the box; and the crescent, of which the V-type is a modification. Models of these types were constructed and tested in the laboratory under simulated operating conditions. A scale of one to six was considered an acceptable scale for model building. At this ratio the volumes of the full size and the model scrapers have a ratio of 1 to 216. The scrapers were tested on a horizontal plane and also on inclinations above and below horizontal.

The scrapers were activated by a small electrically driven hoist. A spring scale was used for measuring the rope torque applied in drawing the scraper. The weight of material moved per a given number of scraper passes was determined. Each scraper type was tried under the same set of conditions. The data thus collected is tabulated and summarized.

To set up this testing program the apparatus was first collected or built. No hoist of the appropriate scale was available for purchase. One was designed and built especially for the problem in the Missouri School of Mines shops.

REVIEW OF LITERATURE

History of Scraping

The first written record[1] of power scraping as successfully applied to the moving of mine muck is believed to be a description of tunneling at the Bunker Hill and Sullivan Mining Company mine near Kellogg, Idaho in 1898. U. B. Hough wrote an article, "The Kellogg Tunnel" describing this operation and it was published in Mines and Minerals, October, 1901 by Engineering News.

The Kellogg Tunnel operation consisted of a slip scraper of the horse-drawn type pulled by a small air hoist up a loading ramp to dump into track cars. The scraper was pulled back to the muck pile and guided by hand on the return trip. Two or three scraper loads filled a car. Five men were required for the work; one man at the hoist, one handling cars, and three men loading and handling the scraper. The loading rate varied from 4 to 5.5 tons per man hour.

Also in 1898[2], a slip scraper was used to fill square set stopes at the Badger mine in Wisconsin. A small air hoist was used that had

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[1] 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. 210-212.

[2] Jackson, Chas. F.; Underground scraping Practice in Metal Mines, U.S. Bureau of Mines Manuscript Report No. 1, March 1933, pp. 8-9.

formerly been applied to moving mine timbers.

In the early 1900's[3] J. George Leyner of Denver, Colorado, was working on plans for an improved type of portable hoist that might be applied to scraping or other uses. He did not offer the plans for sale immediately for lack of market. His drawings were filed away and later became the basis of the Ingersoll-Rand "Little Tugger" hoist, which was introduced in 1912.

The original "Little Tugger" was a single drum 2½ horsepower air hoist. Its use for loading with a scraper meant that the scraper was moved back to the face or over the muck pile by manpower. Such a method was tiring to the man who dragged the scraper and, therefore, expensive. The hoist developed a pull of 800 to 1000 pounds and a rope speed of 80 to 90 feet per minute. The scraper it pulled moved about three cubic feet of muck and sometimes pushed as much as two additional feet ahead of the scraper load. The rate of loading, with frequent change of men on the scraper, was 10 to 14 tons per hour and the effective limit was about 50 feet from the chute.

Lucien Eaton[4] in 1921 described the above type of scraping as follows; "The advantages of this system are its simplicity and low cost. After the blast, no time is lost in rigging up, and, when the bulk of the broken ore has been moved, the edges of the pile and the ore scattered in other parts of the stope are easily cleaned up. The disadvantages are that the physical labor entailed is hard and only men of strong physique are able to make a success of it. Furthermore, the loading speed and the effective

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[3] Pierce, R. V., and Bryan, E. N.; Compressed Air Magazine, Vol. 47, No. 6, June 1942, pp. 6760-4.

[4] Eaton, Lucien; Compressed Air Magazine, Vol. 26, May 26, 1921, pp. 10065-10075.

radius are not large."

The first scraper installations in the Lake Superior iron district and the nearby Michigan copper mines were made in the 1915 to 1917 period of war demand for metals. These were followed by scraper trials in the Tri-State area in 1919. During this period the shortage of man-power and rising wages focused managerial attention upon labor-saving devices[5]. In the post-war years price reductions for both iron and non-ferrous metal further stimulated the search for mining cost reduction. Throughout the years 1923 to 1929 the installation of scraper equipment continued in large volume. An example of the savings made is the record of Gogebic County, Mich., where the output of iron ore per man day is reported[6] to have increased from 2.91 tons in 1923 to 5.96 in 1929.

By far the greatest number of machines were installed in the iron country of Michigan and Minnesota and to a lesser extent in Alabama, the peak being reached in 1929. The economic depression after 1929 affected the iron industry severely and installations of equipment had dropped, by 1933, to a fraction of the former level. Business recovery in 1935 and 1936 again increased the sale of scraping equipment. The table No. 1, of equipment added to mine plants, directly reflects the growth of scraping practice and also compares it with the use of power shovel loaders during the same period.

TABLE NO. I [7]

SCRAPER LOADERS AND SHOVELS ADDED TO EQUIPMENT UNDERGROUND IN METAL AND NON-METALLIC MINERAL MINES.*

Year	Scraper Loaders, Hoists or Complete Units	Shovel Loaders
1923	254	57
1924	341	18

(con't)

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[5] Jackson, Chas. F.; op.cit. under footnote 2

[6] Handbook of Scraper Mucking, Sullivan Machinery Company, 1933, p. 9

[7] Plein, L.N., Bergquist, F. E., and Tryon, F. G., Engineering and Mining Journal; Vol. 138, May 1937, pp. 138-39.

TABLE I continued

Year	Scraper Loaders, Hoists or Complete Units	Shovel Loaders
1925	373	15
1926	284	38
1927	414	51
1928	363	37
1929	645	58
1930	335	24
1931	126	2
1932	104	14
1933	62	12
1934	67	25
1935	135	47
1936	249	72
Total	3,752	470

* Figures pertain to mines in the continental United States, not including those installed by contractors on construction projects. Subject to revision.

In non-ferrous metal mining, one of the leading districts that uses scrapers has been the Copper Country of Northern Michigan. Scraper loading, along with power drilling, haulage concentration, and selective mining, has been one of the main economies that have enabled the mines of this district to continue operations at increasing depth[8].

Scraper loading did not come into full acceptance in the Tri-State lead-zine mines until as late as 1936. This situation is well described by Mr. S. S. Clarke[9] as follows:

"About 1922, slushing was tried in two or three mines. A rather clumsy two-drum, gear-and-pinion type hoist was used, belt-driven by an electric motor. The type blade used did not have the proper curvature at the top, and, as a result either buried itself or rode the top of the muck pile. Several types of loaders that were on the market at that time

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[8] Crane, W. R., Mining Methods and Practice in the Michigan Copper Mines, U. S. Bureau of Mines Bulletin 306.

[9] Clarke, S.S., Engineering & Mining Journal, Vol. 144, November 1943, pp. 80-80

and a few years later were tried. Their failure was due to several factors. First, the Tri-State shoveller was an institution; using a No. 2 scoop, a 60-to 75-can shoveller was the rule rather than the exception. ----------

"Late in 1936, a 3-drum slusher was mounted on a portable ramp built on a car frame. After several months of operation the advantages of slusher loading were evident, but the type of ramp was unsatisfactory. A ramp mounted on a caterpillar was then built. The same general scheme is now followed. - - - - - At present (1943) approximately 92 per cent of the hoisted tonnage is loaded by mechanical means".

During the man-power shortage and increased demand for metals of World War II, the use of mechanical loading was again forceably stimulated. As mentioned above, a large part of the ore mined in the Tri-State district was machine loaded and the same is believed to have been true in many other mining districts.

An editorial[10/] in January 1944 mentions the development of remote control for hoist operated underground scrapers which raised production in one or more cases by 50 per cent, largely because the scraper could be filled to capacity on each trip.

The present acceptance of mechanical scraper loading is well summarized by the following points:[11/]

1. Scraping eliminates hand moving or loading of ore and rock.
2. Scrapers move chunks too large for hand loading.

[10/] Editorial, Engineering and Mining Journal, Volume 145, January 1944, p. 70.

[11/] Pierce, R. V., and Bryan, R. H., The Mining Journal (London), Vol. 218, No. 5581, August 8, 1942, pp. 375-6.

3. War production required speed and more metal per man shift.
4. Comparatively inexperienced men can run a scraper.
5. Scraper loading has eliminated part of block holing.
6. Scrapers speed production so that ground need be kept open only a short time, thus saving timber and other supplies.
7. Workers are safer by less exposure to falling rock.
8. Scraper setups are flexible.
9. Ore is loaded directly into cars, skips, or elevators.

Operation Data on Scrapers

Applicability of Scrapers

Power scrapers are applied to nearly all phases of mining. An outline of these operations included the following:

- Cleaning of development workings
- Production from stopes
    - Open stopes
    - Room and pillar stopes (both coal and metal mines)
    - Cut and fill stopes
    - Sub-level caving stopes
    - Square set stopes
    - Shrinkage stopes
    - Top slicing stopes
    - Block caving stopes
    - Glory hole stopes
- Filling of stope space with waste or tailings
- Transfer of material along sublevels
- Scraping loose material in open pits
- Reclaiming material from stockpiles

Power Consumption of Slushers

Scraper hoists are now available in sizes ranging from 3.5 to 100 horse-power and with "pull" rope speeds as high as 450 feet per minute and "tail rope" speeds as high as 600 feet per minute. Compressed air and electricity are the types of power most commonly used.

Originally[12] direct current electric motors were used for the reason that they could be connected to the trolley lines of underground haulage systems. As more and more scrapers were installed separate power lines were required. It was found more economical to use alternating current motors, for the line loss on transmission of this type of current is much less than direct current. Now 220 and 440 volt motors are used on scrapers in the United States.

Matson[13] presents a study of comparative costs for electric and air hoists used on scraping. For 604,005 tons scraped by air hoists the costs were $0.034634 per ton and $0.45866 per hour compared with 91,124 tons scraped by electric hoists at costs of $0.004165 per ton and $0.057229 per hour. Other operators[14] report that power costs are 4 to 7 times greater for air than for electric hoists.

Jackson[15] reports that actual metered tests in scraping several thousands of tons of ore show an electric power consumption of as low as

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[12] Jackson, Chas. F., op. cit.

[13] Matson, Robert C., Scraping Practice in the Michigan Iron Mines of the Lake Superior District, Michigan College of Mining and Technology Bulletin 4, Vol. 2, 1929, 75 pp.

[14] Jackson, Chas. F., op. cit., p. 45

[15] Jackson, Chas. F., op. cit.

0.065 kilowatt hours per ton with short drags and favorable conditions. Under usual conditions the power requirement is below 0.5 kilowatt-hour per ton of ore scraped. The maximum power consumption reported by any operator was 2.0 kilowatt hours per ton.

The wattmeter graph (Fig. I) shows the distribution of power requirements per cycle in scraping. It is noted that the peak load occurs when the scraper is digging into the muck pile. The drag from the pile to the chute shows a rather constant power load and the return of the empty scraper requires the minimum power load.

Hoist Scraper Assemblies

Although originally there was little specialization in scrapers, today the wide range in size for scrapers and scraper hoists permits choosing the hoist and scraper for the work to be done. Large hoist-ramp assemblies mounted on track wheels are used for stope and tunnel mucking. A new development is the mounting of a hoist and scraper ramp on caterpillar treads. Portable hoist-scraper outfits are carried up into sublevels and stope floors to facilitate mucking into chutes or spreading of fill.

The scraper ramps are constructed to form an apron, with side guides, sloping downward toward the muck pile from above the car or hopper into which the scraper dumps. The hoist and draw cable are arranged in such a manner that the loaded scraper is drawn up this incline to the dumping point. The tail rope from the hoist goes to a sheave block fastened in the breast of the drift or stope and then back to the stern of the scraper.

For wide stopes where a lateral movement of the scraper is desired a three drum hoist is used with two of the drums occupied by two separate tail ropes. Two or more tail rope sheave blocks anchored at effective

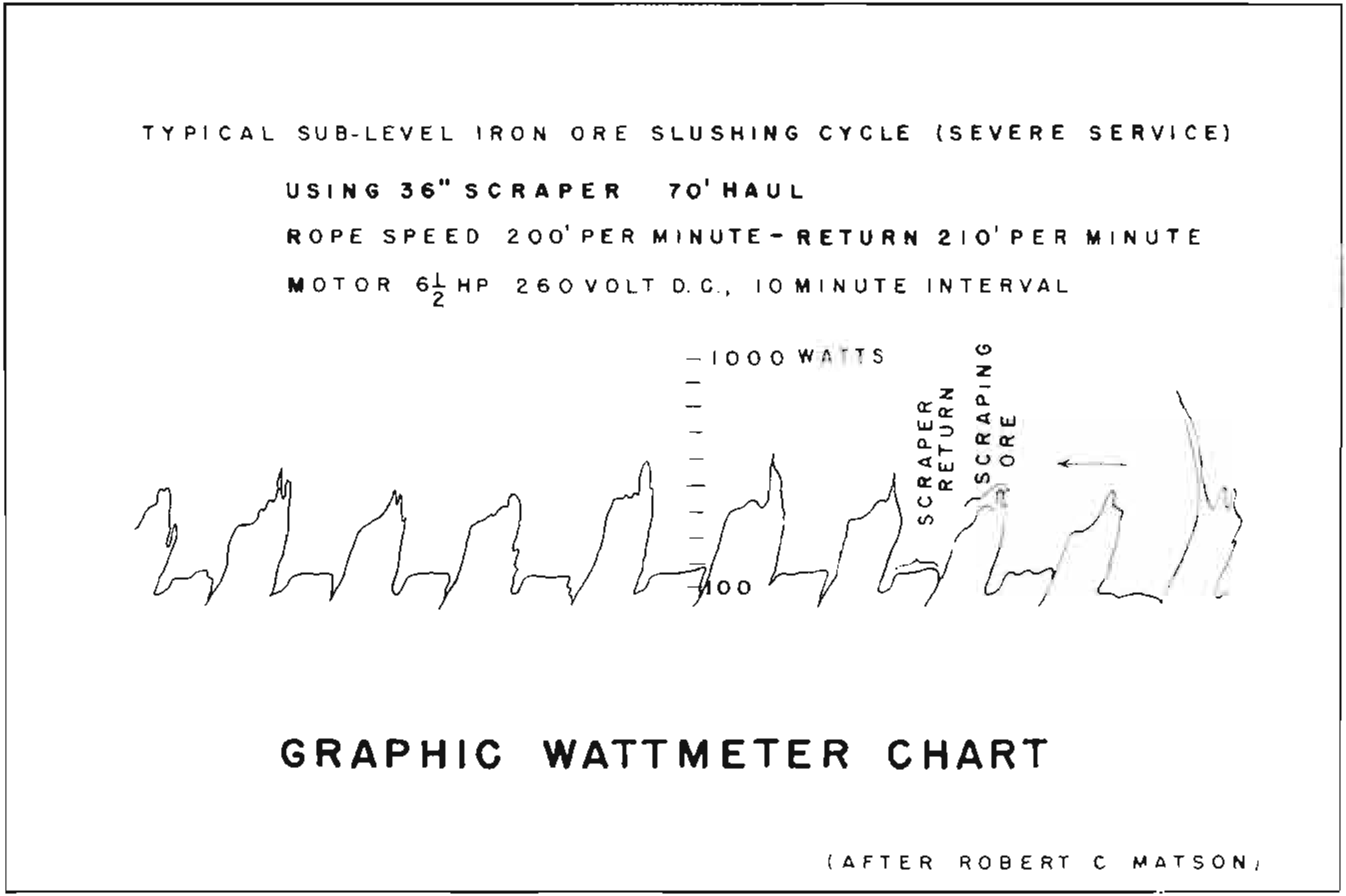

Figure No. I Graphic Wattmeter Chart

points in the stope walls permit moving the scraper to almost any spot in the stope. Some setups provide for moving the scraper around a 90 degree corner. By multiple sheave arrangements almost an infinite variety of scraper setups is possible. Ingersoll-Rand Company, Sullivan Machinery Company, and Gardner Denver Company publish illustrated catalogs showing many of these arrangements.

The use of portable scraper hoists that may be hooked on the compressed air line has done away with hand mucking in stopes to a great extent. Pierce and Bryan[16/] give a good conception of the labor saving value of a 250 pound double drum hoist and a 26 inch quarter box scraper weighing 235 pounds in the paragraphs below.

"In general, a hoist-scraper arrangement of the size under discussion will move from 12 to 17 tons an hour over a distance of 50 feet and from 8 to 10 tons an hour over distances ranging from 85 to 100 feet. Its hourly capacity is equivalent, roughly, to the tonnage a man will load and transport by wheelbarrow in a shift. ———

"As an example of what can be accomplished with a small hoist using air at from 75 to 80 pounds pressure, the following is cited: an average of 55 seconds is required for one round trip of the scraper on a 65- to 70-foot pull; that is, to deliver 600 pounds of ore (the equivalent of more than a wheelbarrow load) to the chute."———

In all these descriptions of scraper hookups very little space is given to comparing the effect of different types of scrapers. The main discussion is centered around the horsepower and velocity requirements for the hoisting which applied to the scrapers.

[16/] Pierce, R. V., and Bryan, R. N.; Compressed Air Magazine, Vol. 48, No. 3, March 1943, pp. 6971-7.

The best comparative data on scraper types that were found in a review of scraper studies is the table by Jackson (Table No. 2).

Table 2

Data on typical scraper installations

	Hoist		Details of Scraper					
Type of ore	Hp.	Rope Speed, f.p.m.	Type	Size, in.	Approximate weight, lbs.	Approximate load, cubic feet	Scraping distance, feet	Remarks
1. Soft iron ore	6½	125	Box	40	605	12	50, maximum	Level pull, to slide into cars.
2. Do.	15	180	Do.	42-48	...	13-18	75, maximum 25, average	Level pull to raises.
3. Both soft and hard iron ore.	15	180	Hoe; teeth one edge, lip other edge.	48	750	13	75, maximum	Do.
4. Soft iron ore	15	225	Box	34	...	10	100, maximum	Do.
5. Do.	15	200	Do.	42-48	...	13-18	75, maximum	Level pull to slide into cars
6. Soft and hard iron ore.	15	200	Hoe	48	750	13	60, maximum	Level pull to raises.
7. Soft iron ore.	15	240-280	Do.	48	750	13	75, maximum	Level pull to raises, 40 tons per hour.
8. Do.	15	240	Semihoe	42	800	14	75, maximum	Level pull to raises.
9. Do.	15 and 25	240-280	Box	48	...	18	60 to 150	Level pull to raises. Maximum loading rate, 60 tons per hour.
10. Hard and soft iron ore; some chunks.	15	240-280	Hoe	42	...	9	125, maximum	Pull down 30 to 35° slope.
11. Soft iron ore.	15	200	Box	42	450	13	75, maximum	Level pull to raises.
11-a. Do.	25	230	Do.	48	...	18	150, maximum	
12. Hard iron ore; breaks in large blocks.	25	230	Hoe	48	1,500	14	50 to 100	Down-grade pull to chutes.
13. Hard, chunky rock or soft iron ore.	25	230	Semihoe	54	900	16	50 to 150	25 tons per hour sucking tunnel cut into large cars
13-a. Soft iron ore.	15	200	Do.	50	...	7	75, maximum	Level pull to raises
13-b. Do.	10	200	Do.	50	...	7	75, maximum	Do.

Table 2 continued

Type of ore	Hoist Hp.	Hoist Rope speed, f.p.m.	Details of scrapers Type	Size, in.	Approximate weight, lbs.	Approximate load, cubic feet	Scraping distance, feet	Remarks
14. Large blocks of zinc ore, dolomite gangue.	25	200 h.s.	Arc-back hoe.	72	2,660	*2,000	400, maximum 175, average	Pulling down 20° dip to chutes, 50 tons per man-shift including operators, helpers, and repairmen.
15. Medium coarse zinc ore in dolomitic gangue.	10	200	Box	60	.....	12	300, maximum 75, average	Pull down slopes up to 40°, to chutes.
16. Coarse copper amygdaloid.	15	200-240	Patented semihoe.	48	750	13	200, maximum	Level pull to chutes; 40 tons per hour.
17. Coarse and fine; copper-bearing conglomerate.	35 (air)	...	Hoe	48	1,500	13	150, maximum	100 tons per shift loading cars on level. Much time lost changing cars.
18. Copper amygdaloid; coarse and fine muck.	25	230	Do.	48	.....	13	120, maximum	Pulling down 35° slope to chutes.
19. Friable, altered porphyry.	25	230	Do.	48	.....	18	100±	Loading in drifts and crosscuts; 30 tons per hour.
20. Very hard ore breaks in large, angular blocks; sp.g. 4.6.	60	...	Hoe, arc back	80	2,800	*10,000	150, maximum	Loading from scraper drifts over 36-inch grizzlies; 500 tons in 8 hours average performance.
21. Hard, siliceous ore; fine, sticky gangue.	15	240	Semihoe	40	650	*700	200, maximum	10 tons per hour with 200-foot pull, dragging into raises.
22. Hard, siliceous ore; flat slabs, chunks and fines	15	230	Do.	40	650	*700	100, maximum	70 tons per shift, 1 man loading into cars over a slide.
22-a. Do.	15	230	Do.	40	650	*700	75, maximum	35 tons per shift, 1 man in stopes.
22-b. Sand	15	230	Do.	40	650	*400	75, maximum	63 tons per shift, 1 man spreading fill.
23. Iron ore breaking in large slabs.	55	130-150	Box, with teeth.	48	3,100	*6,500	200, maximum	Average 300 tons per 8-hour shift, loading into cars.
24. Hard, blocky, magnetic iron ore.	25	200	Hoe	48	1,400	*2,240	330, maximum 180, average	27.3 tons per man-shift scraping into cars.
25. Large, heavy angular blocks.	150	190 return 170 pull	Do	84	3,600	*7,600 actual ore load	100, maximum 75, average	On transfer level average 96 tons per hour. Actual time operating 60%.

* Pounds.

Costs Compared for Scrapers, Mucking Machines, and Hand Loading

In the Tri-State lead-zinc district of United States, where hand loading has persisted until only recently, a comparison of loading costs shows the following: in 1942 sixty per cent of the total tonnage was mechanically loaded at a cost of $0.26 per ton and hand shovelling cost $0.39 per ton. Mr. S. S. Clarke[17/] gives a break-down of mechanical loading that compares scrapers with shovel loaders:

Mechanical Loading Performance
Capacity of Slusher Loaders

Type of Conveyance	Daily Average	Day's High Runs Tons
Loading into cans	158	186
Loading into 1-½ ton cars	116	172
Loading into trucks	142	269

Slusher-Loader Operation Costs

Type Mine	Sheet Ground L	Sheet Ground L	M Bed
Labor	$0.156	$0.097	$0.217
Repairs and Supplies	0.065	0.060	0.092
Power	0.014	0.026	0.015
Casualty Insurance	0.001	0.001	0.002
Total per ton	$0.236	$0.184	$0.326

Air-Shovel Operating Costs

Mine	E-1	B-2	E-2
Labor	$0.178	$0.198	$0.250
Repairs and Supplies	0.026	0.011	0.029
Power	0.019	0.014	0.024
Casualty Insurance	0.001	0.001	0.006
Total Cost per ton	$0.224	$0.224	$0.309

[17/] Clarke, S. S., op.cit.

"The actual cost of slusher hoist repair parts only, is $0.004 per ore ton. Scraper blades will handle 5,500 tons before being scrapped. Scrapers are rebuilt about every 25,000 tons and the ramps are lined approximately every 50,000 tons."

Comparison between Scraping and Chute and Grizzly Ore Transfer

Costs[18] compared for a scraper system and a chute and grizzly system at the Climax Molybdenum Mine, Climax, Colorado, show the use of scrapers to have a definite advantage. These costs give the ratios quoted in the following table:

Costs Ratios Between Slushers and Chute-Grizzly Ore Transfer

Operation	Ratio of	
	Slusher System	Chute and Grizzly System
Investment Costs		
Development, drifting and raising	100	163
Chute, grizzly and slusher installations	100	224
Concreting	100	67
Stoping	100	108
total	100	120
Operating Costs		
Handling	100	132
Repair	100	71
Total	100	116
Total cost ratio	100	118

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[18] Henderson, Robert, A.I.M.E., Mining Technology, T.P. 1715, May 1944.

Another example where the installation of slushing has reduced loading costs over hand mining is a description of bauxite mining in Arkansas by Mr. Julian Fuller[19]. A three drum 30 horsepower hoist is mounted on two separate trucks to accomodate very sharp curves in the mine. This hoist pulls a ½ yard crescent scraper up a light weight steel ramp to dump directly into ore cans on trucks beneath the ramp.

"Over a four-month period the scraper has cut the cost per ton by 40 per cent compared to present hand mucking. At the present time (1944) 55 per cent of the ore is being mined with this machine and the company is considering the installation of another."

Summary Discussion of Operation

In summary of scraper operation for moving mine rock it may be suggested that scraper loading is more economical than either hand loading or many instances of gravity loading. Mr. Lucien Eaton[20] listed the following points a quarter century ago and they still are applicable:

Advantages of scraping over hand shovelling

1. Greater capacity
2. Lower cost
3. Less manual labor, permitting use of less powerful men.

Advantages of scraping over power shovels

1. Lower first cost.
2. Lower maintenance charges
3. Greater mobility and flexibility

Disadvantages of any kind of mechanical shovelling and loading

1. Cost of equipment
2. Impossibility of sorting
3. Interruption of drilling operations

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[19] Fuller, Julian A., Mining Congress Journal, Jan., 1945, pp. 38-9.
[20] Eaton, Lucien, Comp. Air Mag., Vol. 26, No. 5, pp. 10065-10075

Design of Scrapers

Types

As before noted, the original scrapers applied to mining were of the horse drawn slip scraper type borrowed from surface earthwork. As late as 1921[21] the slip scrapers were considered applicable to ore slushing, as Eaton classified scrapers as in two divisions: "1) Those in which the material is carried in and on a scraper, and 2) those in which the material is dragged along the floor of a drift or stope in front of the scraper, as dirt is moved with a hoe. Scrapers in the second class can be further divided as (A) those without sides and (B) those with sides".

At present three main types of scrapers in the hoe class are in use, namely: the hoe, the box, and the crescent. There are a number of modifications of each type such as side plates for the hoe scrapers, teeth added to the cutting edge, and counterweights to produce the desired balance.

The slip scrapers are now little used for several reasons, namely; they require a man to guide and fill them, they do not dump automatically, and the bottom plate is subject to rapid wear.

Size and Weight

Scrapers vary in size and capacity from "junior" models weighing 200 lbs. with a ½ cubic yard load to "mammoth" 11,000 lb., 15 cubic yard buckets used in surface pits. The tables 3A, 3B, and 3C list comparative sizes, weights, and capacities for the three main scraper types.

Table 3A	Hoe Type Scrapers
Table 3B	Box Type Scrapers
Table 3C	Crescent Type Scrapers

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[21] Eaton, Lucien, *op. cit.*, footnote 20.

TABLE A — HOE TYPE SCRAPER DIMENSIONS

HOLCOMB "WESTEECO" SCRAPERS
(By permission of M.D. Holcomb)

Capacity	Weight	Width	Depth	Length	Pull Req'd.	Back Wts.
Class AA Single Hook						
2 cu. ft.	269 lb.	26"	22"	47"	450 lbs.	None
Class A Type 0, Open Hoe Short Harness						
5 cu. ft.	461	30	24	52	1000 lbs.	164 lbs.
6	502	36	24	52	1100	164
7	545	36	25½	52	1200	164
8	543	42	24	52	1300	164
9	670	42	25½	52	1400	164
10	668	48	24	52	1500	164
11	775	48	25½	52	1600	164
12	795	48	27	52	1700	164
Class A Type 1, Open Hoe Long Harness						
7	494	30	24	60	1300	164 (set 2)
8	535	36	24	60	1400	164
9	578	36	25½	60	1500	164
10	576	42	24	60	1600	164
11	622	42	25½	60	1700	164
12	620	48	24	60	1800	164
13	754	48	25½	60	1900	164
14	828	48	27	60	2000	164
15	851	54	25½	60	2100	164
16	915	54	27	60	2200	164

TABLE A — HOE TYPE SCRAPER DIMENSIONS (con't)

Class C Type 5, Open Hoe Long Harness

Capacity	Weight	Width	Depth	Length	Pull Req'd.	Back Wts.
15	925 lb	42"	32"	72"	2500 lbs.	218 lbs. (set 2)
17	925	48	32	72	2700	218
19	1008	48	33½	72	2800	218
17	1626	48	32	72	3600	218
19	1709	48	33½	72	3800	218
21	1206	54	32	72	3100	218
23	1269	54	33½	72	3200	218
25	1210	60	32	72	3400	218
27	1389	60	33½	72	3600	218
29	1357	66	32	72	3800	218
32	1436	66	33½	72	4000	218

TABLE B —— FULL BOX TYPE SCRAPER DIMENSIONS

HOLCOMB "WESTEECO" SCRAPERS
(by permission of M. D. Halcomb)

Class A Type 3AA, Short Harness 32" Side Plates

Capacity	Weight	Width	Depth	Length	Pull Req'd.	Back Wts.
10 cu.ft.	707 lb	36"	24"	52"	1650	164 lbs. (set 2)
11	750	36	25½	52	1750	164
12	753	42	24	52	1850	164
13	798	42	25½	52	1950	164
14	801	48	24	52	2050	164
15	851	48	25½	52	2150	164
18	890	48	27	52	2250	164

Class A Type 4B, Long Harness 40" Side Plates

Capacity	Weight	Width	Depth	Length	Pull Req'd.	Back Wts.
15	735	36	24	60	2400	164
16	778	36	25½	60	2500	164
17	781	42	24	60	2600	164
18	826	42	25½	60	2700	164
19	829	48	24	60	2800	164
20	879	48	25½	60	2900	164
21	918	48	27	60	3000	164
22	946	54	25½	60	3100	164
23	1010	54	27	60	3200	164

Class C Type 6AA, Long Harness 50" Side Plates

Capacity	Weight	Width	Depth	Length	Pull Req'd.	Back Wts.
23	1357	48	32	72	3500	218 lbs. (set 2)
25	1400	48	33½	72	3700	
29	1670	54	32	72	4100	218
32	1733	54	33½	72	4300	218
35	1695	60	32	72	4700	218
38	1764	60	33½	72	4800	218
40	1734	66	32	72	5200	218
42	1813	66	33½	72	5500	218

TABLE C —— CRESCENT TYPE SCRAPER DIMENSIONS

SAUERMAN BROTHERS SCRAPERS
(By permission of Sauerman Brothers, Inc.)

Lightweight Crescent

Capacity	Type	Width	Depth	Length	Weight	Load Cable
¼ cu. yd.	1	36 in.	15 in.	32½ in.	190 lbs	3/8"
1/3	1	42 3/4	17¼	37 3/4	220	1/2
½ cu. yd.	1	47 3/4	19 3/4	42 1/4	260	1/2
3/4 cu. yd	1	53½	21 3/4	49 1/2	380	5/8
1 cu. yd.	1	60½	23 1/4	52	580	5/8
1½ cu. yd.	1	67½	27	59	865	3/4
2 cu. yd.	2	72	35 3/4	75 3/4	1815	3/4
2½ cu. yd.	2	76 3/4	38	81	2000	7/8
3 cu. yd.	2	81 3/4	40 1/2	87	2300	7/8
4 cu. yd.	2	91 1/4	45	95	2800	1
5 cu. yd.	2	99	47 1/2	103¼	3850	1 1/8

Heavyweight Crescent

Capacity	Type	Width	Depth	Length	Weight	Load Cable
1/3 cu. yd.	2	42 3/4	19 1/4	40 3/4	290	1/2
1/2 cu. yd.	2	49	20 1/4	44 3/4	400	1/2
3/4 cu. yd.	2	57 1/4	23	51 3/4	640	5/8
1 cu. yd.	2	61 1/2	31 1/4	59 1/4	1000	3/4
1½ cu. yd.	2	69 1/4	28 3/4	67 1/2	1200	3/4
2 cu. yd.	3	71	36	75	2150	7/8
2½ cu. yd.	3	65 1/4	38 1/2	79 3/4	2300	7/8
3 cu. yd.	3	81 3/4	40 1/2	85 1/4	3050	1
4 cu. yd.	3	91 1/4	45 1/2	92 3/4	3250	1 1/8
5 cu. yd.	3	111 1/4	48 1/2	101 3/4		
6 cu. yd.	3	117 1/4	57 1/2	106 1/2		

TABLE C —— CRESCENT TYPE SCRAPER DIMENSIONS (continued)

Capacity	Type	Width	Depth	Length	Weight	Load Cable
8 cu. yd.	3	127¼	61¼	117½		
10 cu. yd.	3	137¼	68	125½		
12 cu. yd.	3	129¼	68	129		
14 cu. yd.	3	139	75 3/4	132¼		

Digging Angle and Shape of Scraper Blades

The angle made by the blade of the scraper with the surface of the pile when the pull rope is under maximum tension is known as the digging angle. Van Barneveld[22/] explains that the theoretical maximum digging effect should occur when the plane of the scraper edge and blade lies along the resultant of the rope pull and the force of gravity. The force applied to the pull rope varies as the scraper strikes obstructions in its movement toward the unloading point. Therefore, the resultant of rope pull and gravity will change.

By actual experience[23/] scraper blade angles between 30° and 60° are found most satisfactory. An angle of 45° will most successfully meet a variety of conditions.

A low digging angle has been found more successful with box-type scrapers than for the hoe and rake types. Some box scrapers have two or more sets of bolt holes for varying the scraping angle of the blade.

Where a scraper is used in soft ore with no floor, a provision is needed to keep the blade from digging itself in to such a depth that the hoist can not pull it. A foreword curvature at the top of the blade or a baffle plate fastened to the top of the blade prevent digging in too deep. (See Figure VII) When the scraper is filled to capacity the lifting action against the baffle plate prevents further digging. In late models of hoe type scrapers the upper part of the blade is curved over toward the bail. In the crescent type scrapers an upper section of the scoop is sloped toward the front to provide the same lifting action.

Line of pull

The position of the line of pull for scrapers depends upon what

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[22/] Van Barneveld, Charles, E., op.cit.
[23/] Jackson, Charles F., op. cit.

performance is desired. For hoe type scrapers a number of holes spaced vertically in the end of the bail allow a change of angle at which the scraper blade functions. For hoe type scrapers with the bail sloped downward toward the front, like a question mark lying on its side, the line of pull may be very little above the digging edge of the scraper.

Scrapers with a low line of pull are likely to ride over large pieces without moving them. Therefore, in coarse material a higher position is desirable for engaging the chunks.

Balance of Scrapers

The proportions and balance of scrapers are of considerable importance. The ability of a scraper to maintain its load, to ride the surface of the material, and to travel in a straight path both loaded and empty depends upon proper balance and construction.

Generally speaking, the field of application of the hoe-type scraper is in coarse chunky material on short hauls. In coarse material the box and crescent types do not fill readily because the side plates ride up over the chunks. In fine material the hoe loses part of its load by side casting from the blade. However, if the hoe works in a self-made trench this difficulty is overcome.

Crescent and box scrapers hold loads of fine material quite well over long hauls.

In general, the height of the scraper at the blade should be about half the cutting edge length, and the bail should be one and one half times the cutting edge length.

For hoe and box scrapers (formed by adding side plates to hoe scrapers) the bail should be long and heavy enough so that it will rest on the ground when the scraper is not under tension from the pull rope. If the back overbalances the bail the cutting edge of the scraper will not ride at the desired angle and the bail may jam into overhead timbers or the back. Counterweights are provided for custom made scrapers to supply the proper balance and digging weight. These are fastened at the foreward end of the bail or, in the case of digging weights, to the upper back side of the scraper blade.

The forward shoulders of the scraper bail should be rounded so that corners will not become fouled against timbers or other obstructions along the side of the scraper's path.

Scraper bails that are curved downward toward the foreward end help to maintain a constant digging angle and thus prevent the scraper from losing its load. This type bail has a disadvantage in coarse lumpy material in that it rides up on lumps and reduces digging efficiency. Once the lumps are inside the bail, however, the bail helps to confine the load in the scraper.

Scraper Teeth

Teeth are added to crescent type scrapers to aid in digging compacted materials. In addition to aiding in digging, the teeth add extra weight and provide renewable cutting surface for the scraper lip.

For ore that breaks in large flat pieces a toothed hoe scraper is advantageous. However, for average mine muck a straight edge is more satisfactory than one with auxillary teeth.

Many hoe and box scrapers are now supplied with renewable plain cutting edges that bolt to the blade. For fine material or where a smooth floor is provided for a scraping surface a plain cutting edge is most desirable for a scraper.

Construction of Scrapers

The most modern factory made scrapers of hoe and box types are made of cast steel with all parts bolted together and made with replaceable parts.

Many mining companies prefer to make their own scrapers in their company shops. These shop made scrapers may be riveted, bolted, or welded together. Modern welding methods have facilitated the welded type of scraper construction.

Crescent scrapers are welded and riveted together. At present there is only one manufacturer of crescent type scrapers.

The cutting edges of scraper blades are usually made of especially hardened steel. Even with this provision for wear the blade must be renewed frequently. Some operators prefer to weld stellite on the wearing edge of the scraper blades.

The scrapers of any type should be made with rugged construction, suitable for rough usage. The points of maximum wear are the front and bottom of the bail, the bends in the bail, the corners of the blade, and the upper back corners of the blade. These points may well be doubly reinforced.

Recapitulation of Scraper Design

From the foregoing discussion, the important points on scraper design are believed to be:

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.
    a. Abrasive action of ore.
    b. Sudden shock.

Description of Preparation of Apparatus for Scraper Tests

In the preparation of model scraper equipment for test purposes, first of all, the scale was established at one to six. The average mine scraper is about four feet wide whether hoe, box, or crescent. Therefore, eight inches was believed a proper scraping width for the models and four types were proportioned from this width (See Figs. II, III, IV, and V). Data for scraper designs were secured from a review of literature on scraping practice and by writing to many large operating companies and scraper manufacturers.

A model scraper of eight inches width was estimated from data on full sized scrapers to require a maximum pull of 40 to 50 pounds when loading. At the rate of 50 pounds on a speed of 100 feet per minute, 5000 foot pounds would be required. Dividing 5000 foot pounds by 33,000 indicates a requirement of 0.15 horsepower. A quarter horsepower, split phase, electric motor for 60 cycle AC 115 volt current was used and is considered suitable to furnish the motive power for the scraper models.

A three drum hoist with double faced friction clutches was designed and built. (See Figure VI). The drums were turned from aluminum blocks and mounted on a three-quarter inch line shaft set in ball bearing pillow blocks. The drive from the 1750 RPM motor was belted to a twelve inch pulley on a jack shaft. A three step cone pulley on the other end of the jack shaft was belted to a similar pulley on the hoist drum shaft. This

FIGURE II

Photograph of Hoe Type Straight
Bail Scraper.

This eight-inch model has the blade bolted at a 45 degree direction to the line of pull.

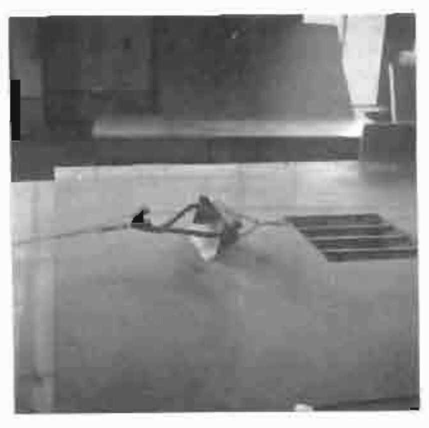


FIGURE III

Photograph of Hoe Type Slope
Bail Scraper.

This eight-inch model has a blade adjustable to 30, 45, or 60 degrees to the line of pull.

FIGURE IV

Photograph of Box Type Scraper.

This eight-inch model has the blade bolted at 45 degrees to the line of pull. The blade may also be set at 30 degrees.

FIGURE V

Photograph of Crescent Type Scraper.

This model Sauerman or crescent scraper is eight inches wide across the front points.

FIGURE VI

Photograph of Electric Hoist
Assembly Used to Pull Model Scrapers.

combination of pulleys and belts reduces the speed of the motor to 155, 211, 233, 317, 429, 475, and 646 RPM at the hoist drum (see Appendix E, Part 3.). The diameter of the centers of the first lap of 1/16th inch cable on the drum is three inches. The rope speeds available therefore, on the first lap of the drum are near 122, 166, 183, 249, 337, 373, and 507 feet per minute. Clutch slippage will probably reduce this rope speed to some extent. Time tests taken on a ten foot scraping length indicate a twenty foot round trip in twelve seconds or near to 100 feet per minute.

A wire cable, rated at 150 pounds pull, one sixteenth of an inch in diameter and made up of five strands of seven wires each and a cotton cord center was secured to draw the scrapers. A half inch cable is commonly used on four foot mine scrapers.

In order to measure the rope torque used in pulling the scrapers a spring scale was fitted with a ball bearing pulley three inches in diameter. It is fastened (see Fig. VI) in the rear of the hoist so that the draw cable passes from the hoist drum to the pulley and back beneath the drum to the scraper bail. A 50 pound scale was used. The pull registered by the scale is twice the actual pull because of the two cables acting on it; the one from the hoist and the one from the scraper.

The table upon which the scraper tests were run was surfaced with rough Masonite fiber board to give a uniform coefficienet of friction. This coefficient was determined at 0.5 by dragging a twenty pound weight across the table top with a spring scale. The table is arranged so that the end away from the hoist may be inclined above or below horizontal if so desired. The table is 15 feet long and five feet wide. Two feet from the end of the table next to the hoist mounting is an opening one foot square equipped with a three inch grizzly of brass rails. Below the grizzly is an inclined slide to direct the scraped material from below the grizzly into a receiving pan. Sheave wheel supports are mounted at the opposite end of the long table from the hoist.

Four types of rock, including granite, dolomite, sphalerite-fluorite ore, and barite were selected for test purposes. The granite tested is unaltered and was freshly crushed, splintery, and therefore, abrasive and hard to scrape. The dolomite is partly weathered and soft enough to crumble to finer particles by repeated handling. The sphalerite-fluorite ore contains quartz and some small flakes of shaly wall rock. This ore closely approached heavy sulphide ore common in many mines. The barite ore is nearly pure barite. The smaller pieces were round but in larger pieces the barite was somewhat tabular.

Each type of rock was classified into six size ranges as follows: minus 3/16 inch, minus 1/2 plus 3/16, minus 1 plus 1/2, minus 1 1/2 plus 1, minus 2 plus 1 1/2, and plus 2 to 6 inch. These sizes on model scale are supposed to represent sizes of six times greater diameter for full scale scraping.

The specific gravity of each of the four types of material used was measured by weighing a number of two inch pieces in air and then immersing them in water in a liter graduate to find their combined volume. The figures thus obtained are: for granite, 2.72; for sphalerite-fluorite, 3.16; for barite, 3.80; and for dolomite, 2.50. All rock was used in a dry state so that no correction need be made for moisture content.

To facilitate calculation of weight and volume relations for the scraper models, the scrapers, counterweights, and material moved were weighed in grams and measured in cubic centimeters.

The theoretical volume of material moved by each scraper was established by filling the scraper with minus 3/16 inch sand and then dragging it three feet along the flat table top to dump into the grizzly and chute. The sand passed to a pan below the chute was then measured with a 1000 c.c. glass measuring graduate. This process was repeated three times to give an average theoretical volume per scraper pass (see record in Appendix E, Part I).

To measure the weight and volume of the crushed rock and sand scraped through the grizzly, two galvanized sheet iron pans were used that measure 9 by 53 by 53 centimeters inside. The average depth of material in the pan was measured by first leveling off the top of the pile in the pan then taking eight measurements down from the top of the pan around the sides of the pan. The average of the eight measurements was subtracted from nine. The pans and contained muck were weighed with an Ohaus 20 kilogram balance scale.

DESCRIPTION OF MODEL SCRAPER TESTS

In conducting tests on model scrapers it was considered best to run the simplest ones first to discover basic principles involved in scraping. Therefore, scraping was started with a level uniform surface, using material of known size and specific gravity. The scraper was pulled over the muck pile to the chute and back over the muck pile in as nearly a straight line as it would follow. The trips or passes were counted by a peg board (see Figure VI). After 20 passes the material run through the chute to a metal pan was measured for volume and weight. On some tests the pan filled several times during the 20 passes, and it was necessary to stop and weigh the panfull before continuing.

After completing some ninety tests with straight line scraping on sized material, forty additional tests were run on mixed ore sizes with two tail ropes (See Appendices A, B, C, and D). This triple drum hoist operation provided for spotting the scraper at any point where a maximum load might be taken. For large pieces of rock the hoe scraper (plus added counterweights) functioned very well with three drum manipulation but with straight line scraping it either lodged behind pieces too heavy for the hoist to pull or else climbed over the pile, taking no load.

Scraper tests were compared on slopes above and below horizontal using sphalerite-fluorite ore of mixed sizes. The relative pull required per average load is best described by table No. 4.

TABLE NO. 4

SLOPE SCRAPING TRIALS ON SPHALERITE AND FLUORITE ORE OF MIXED SIZES

Slope Angle		Hoe, Straight Bail			Hoe, Slope Bail			Box Scraper			Crescent Scraper		
	Blade	Wt.	Load	Pull	Wt.	Load	Pull	Wt.	Load	Pull	Wt.	Load	Pull
Downgrade													
10°	30°							940	930	1361			
	45°	815gr.	1880gr	1814gr	750g	1950gr	1814gr						
	60°	815	1410	1814							715	1690	1361
Level													
	30°							940	1360	1814			
	45°	815	2800	2721	750	1755	1814						
	60°										715	1810	22668
Upgrade													
10°	30°	815	2600	3629				940	1030	2721			
	45°	815	1850	3629	750	2020	3629				715	1300	3629
	60°	815	1050	1814									

As the size of particles is increased the weight of the scraper must also be increased to give it digging power. Fine material flows before the scraper by a process of individual particles being lifted and then falling forward. As larger and larger pieces are dealt with individual particles more and more tend to remain at their original level and move by rolling, in place of being lifted. This rolling motion allows the scraper blade to pass over the uniform coarse particles more easily than uniform finer particles and therefore, more weight is required to force the blade beneath them.

For all the scrapers a baffle plate (see diagram figure VII) at the upper edge of the blade was found helpful. This foreward curving plate prevents the blade from continuing to dig into a soft muck pile, where there is no floor, after the scraper is full, and thus burying itself.

By adding weight gradually to the model scrapers it was learned that there is a maximum efficiency for the scraper on a given size of rock. By adding more weight the efficiency of the scraper, per foot pound of work expended on it, begins to decline. In all the scraper tests the rope pull, after the scraper is loaded and out of the muck pile, depends mainly upon the weight of the scraper and its load rather than the type of scraper. This observation of a maximum point for a given rock size leads to the belief that the graphic diagram (Figure VIII) illustrated the weight relation picture for hoe type scrapers.

Large pieces of ore embedded in fine muck are much more easily scraped than all large pieces of one size. The fine material wedges the larger pieces in place to prevent their rolling and at the same time provides a lubrication for a sliding action of the large pieces. The large pieces, on the other hand, by their ridgity and greater mass force themselves down into the fine material and lift it to where the scraper blade will catch it. In this respect the large pieces act as teeth might if fastened to the scraper edge.

If the scraper is so light that the larger pieces lift it and escape by rolling under it then the fine material escapes entirely, for the blade edge does not come low enough to touch it.

The hoe types of scrapers lose part of their load on the first several trips from the muck pile by its pouring out the sides to leave two ridges,

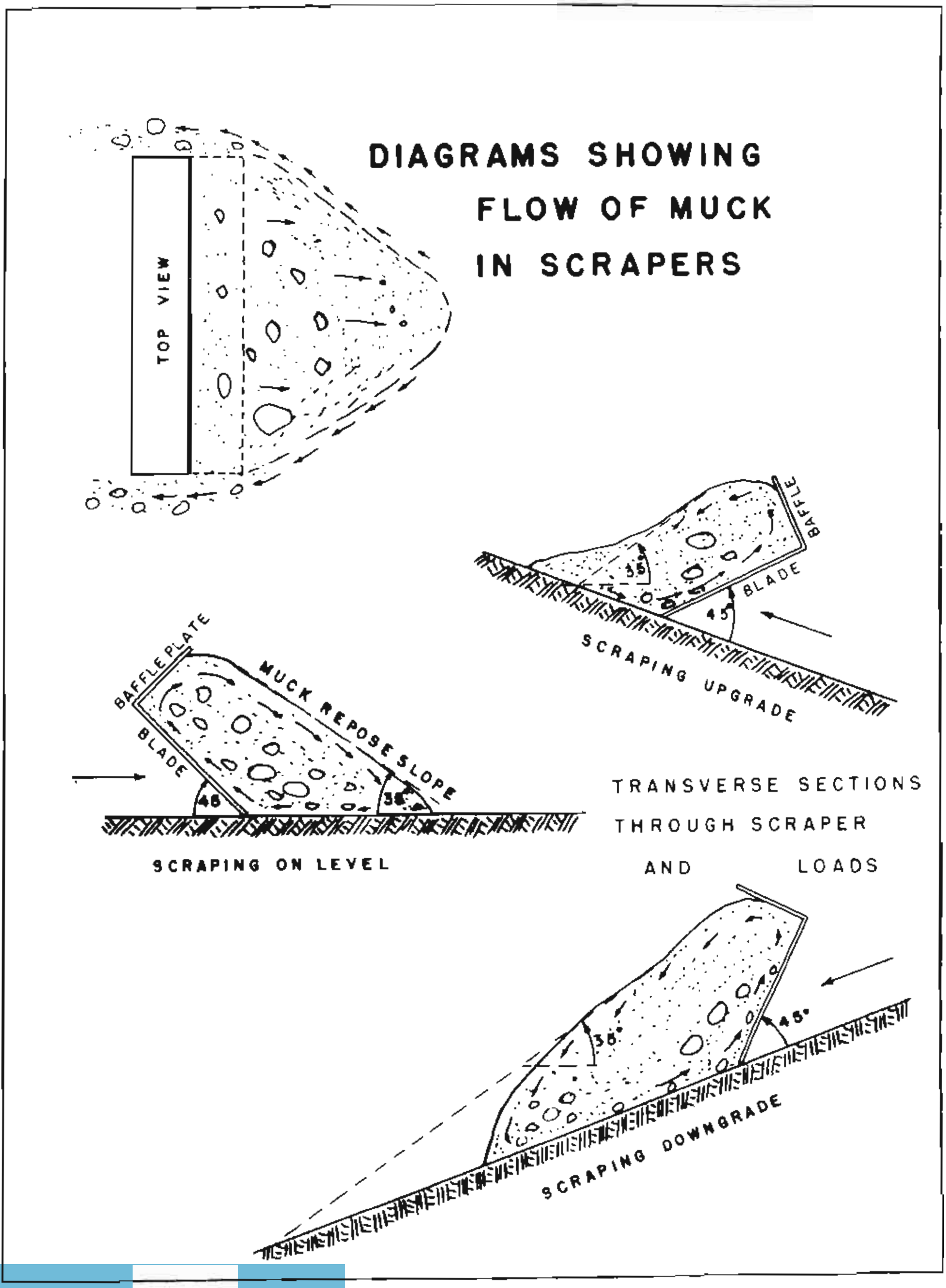


Figure No. VII Diagrams showing flow of muck in scrapers

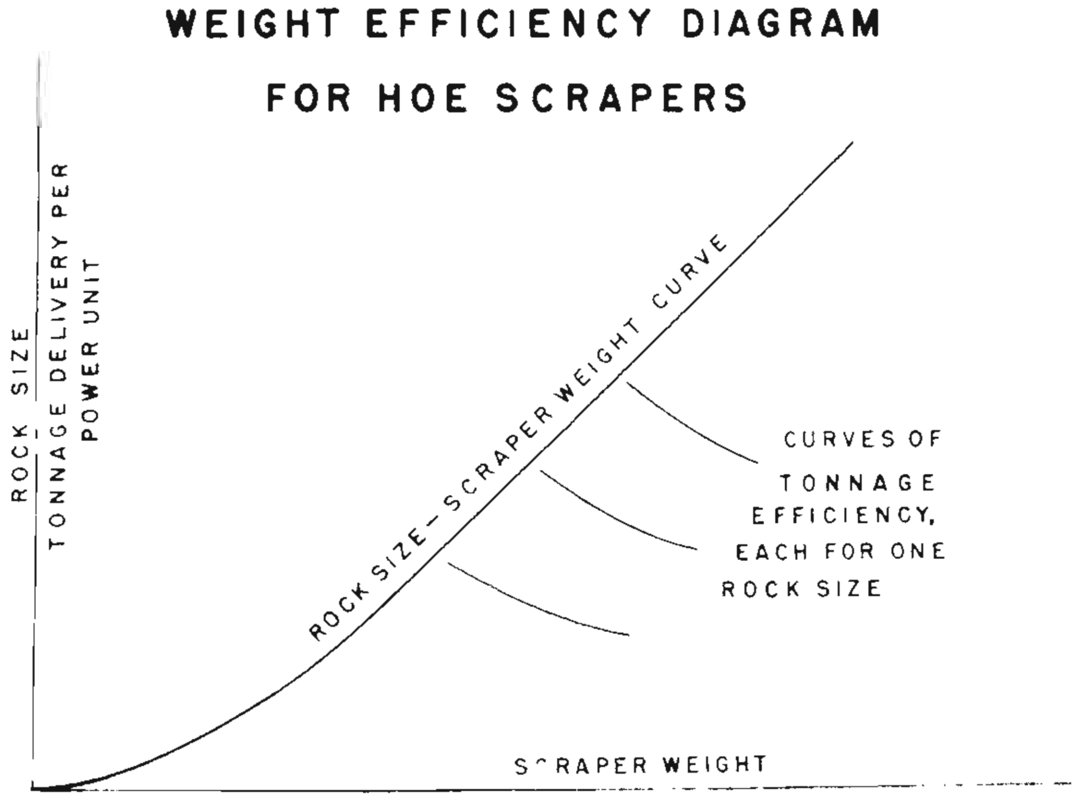


Figure VIII - Weight efficiency diagram for hoe scrapers.

one on either side of the scraper path. After several passes along the same path these ridges (see Figures IX and X) build up to such a height that they serve as supports to hold the load in the scraper on later passes. In some cases the scraper may push a quantity of ore ahead of its full load if confined in such a trench.

The effect of varying rope speed on scraping was not thoroughly investigated. From a few experimental trials it appears that high speed is not effective for loading the scraper. The peak load of any scraping cycle is at the instant of digging into the muck pile (see Figure I). Speed would serve to increase this power demand. However, after the load is settled in the scraper and broken out of the muck pile, the efficiency of reducing the trip time to the chute and back to the pile is very obvious.

The shape of rock particles being scraped has an influence on the efficiency of a scraper. Of the four types of rock used in these trials the granite proved difficult to scrape in the half inch to inch sizes and the barite in the two inch sizes. The granite grains were flat and splintery in the sizes mentioned while the other rock particles were rounded. The barite in the larger sizes was platy.

For applicability the hoe scrapers show a wider range than the box or crescent scrapers. The hoe with sloped bail does good work from fine material up to moderately coarse rock. In larger pieces the sloped bail rides up on chunks of rock and lifts the blade to where it will not load.

The recapitulation table No. 5 of maximum scraper efficiencies obtained by the laboratory tests gives an idea of the applicability as well as individual performace of each scraper tested.

FIGURE IX

Photograph of Hoe Scraper and Load.

This straight bail hoe is moving barite ore of minus two inch plus one inch size.

FIGURE X

Photograph of Slope Bail Hoe
Scraper and Load.

The barite ore being scraped is of minus half inch plus three sixteenths inch size.

TABLE 5

RECAPUTULATION OF SCRAPER TESTS ON SIZED MATERIALS

Figures given represent maximum efficiency ratios of weight of scraper to average scraper load in 20 trips.

Material	Size	Scraper Types (Two drum operation)			
		Crescent	Box	Hoe, St. Bail	Hoe, Slope Bail
Barite	3/16"	3.34	1.46	1.86	4.43
Dolomite	3/16	3.39	1.15	2.22	2.20
Granite	3/16	1.90	1.39	0.91	0.61
ZnS-CaF$_2$	3/16	3.42	2.70	3.67	3.40
	Totals	12.05	6.70	8.66	10.64
	Averages	3.01	1.70	2.16	2.66
Barite	3/16-½"	1.21	1.00	1.88	2.50
Dolomite	"	1.27	0.99	0.82	0.78
Granite	"	0.78	0.63	0.61	0.61
ZnS-CaF$_2$	"	1.22	0.89	1.53	1.88
	Totals	4.48	3.51	4.84	5.77
	Averages	1.12	0.88	1.42	1.44
Barite	½-1"	low	0.30	0.86	0.57
Dolomite	" "	low	0.30	0.56	0.56
Granite	" "	0.30	0.52	0.79	0.51
ZnS-CaF$_2$	" "	low	0.90	0.57	0.95
	Totals	0.30	2.02	2.78	2.59
	Averages	0.07	0.51	0.69	0.65
Barite	1-2"		none	0.52	0.20
Dolomite	" "		none	0.39	0.11
Granite	" "		0.09	0.40	0.30
ZnS-CaF$_2$	" "		none	0.60	0.36
	Totals		0.09	1.91	0.97
	Averages		0.02	0.48	0.24
Barite	2-8"			0.62	(Three drum operation)
Dolomite	2-8"			0.45	
Granite	2-8"			0.49	
ZnS-CaF$_2$	2-8"			0.98	
	Total			2.54	
	Average			0.64	

Sphalerite-Fluorite Ore Mixed in Weighed proportions as follow:
2-8": 2%, -2/1½": 3%, -1½/1": 5%, -1/½":10%, -½/3/16": 25%, and -3/16" 55%.
Three Drum Operation

Crescent	Box	Hoe, St. Bail	Hoe, Slope Bail
2.53	1.94	3.44	2.34

HOE TYPE SCRAPERS

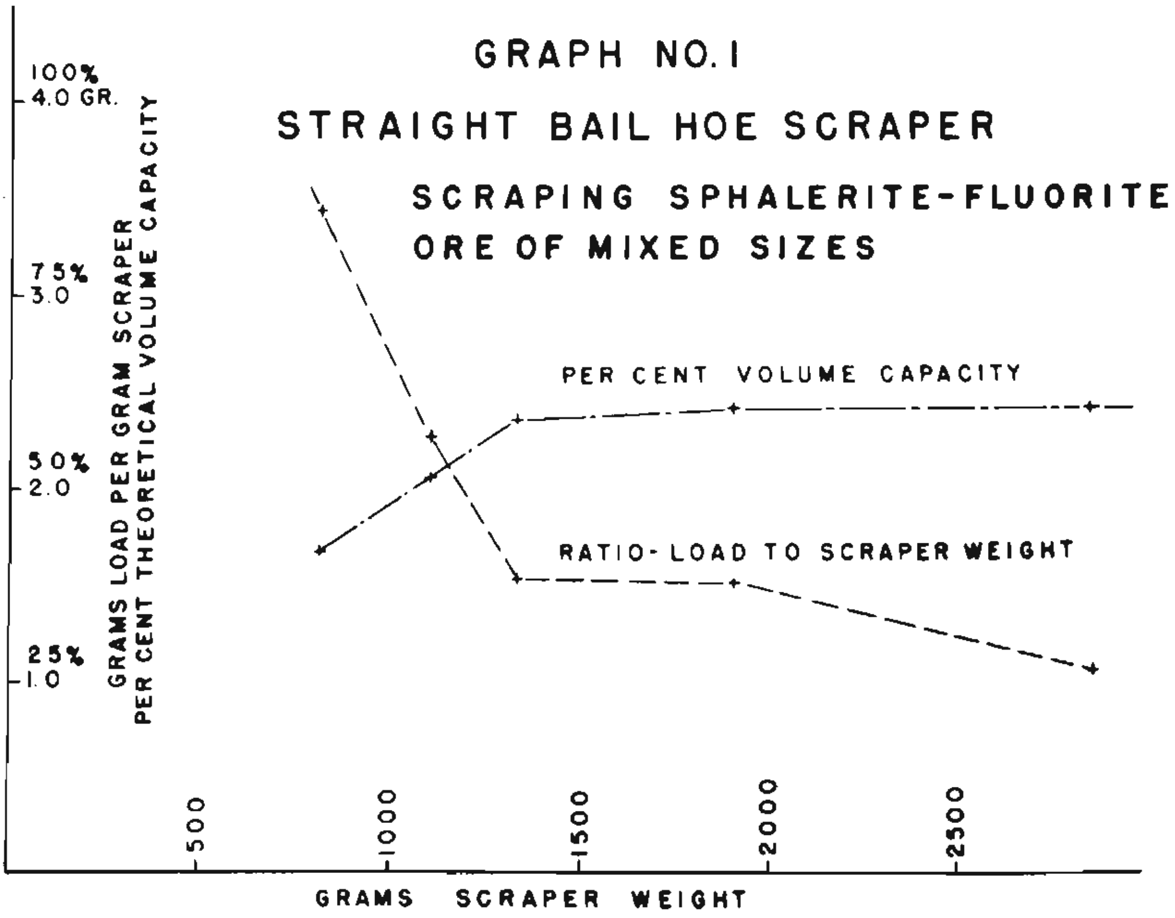
Both the slope bail and straight bail hoe scrapers were built with adjustable blades (see Figures II and III) so that they could be tested at 30, 45, and 60 degree angles with the line of pull or the floor of the stope.

The hoe type scrapers were tested first to check the most effective digging angle. At 60 degrees the scraper demanded a higher pull from the hoist than at 45 degrees. The muck was pushed forward without much tendency to slide up the blade to fill the scraper. At 30 degrees the scraper has an inclination to dig too deep in the muck pile. After the 30 degree scraper is filled and out of the muck pile on a level floor it pulls no harder than a 45 degree scraper with the same load. The recorded rope pulls (see Appendix) illustrate this point.

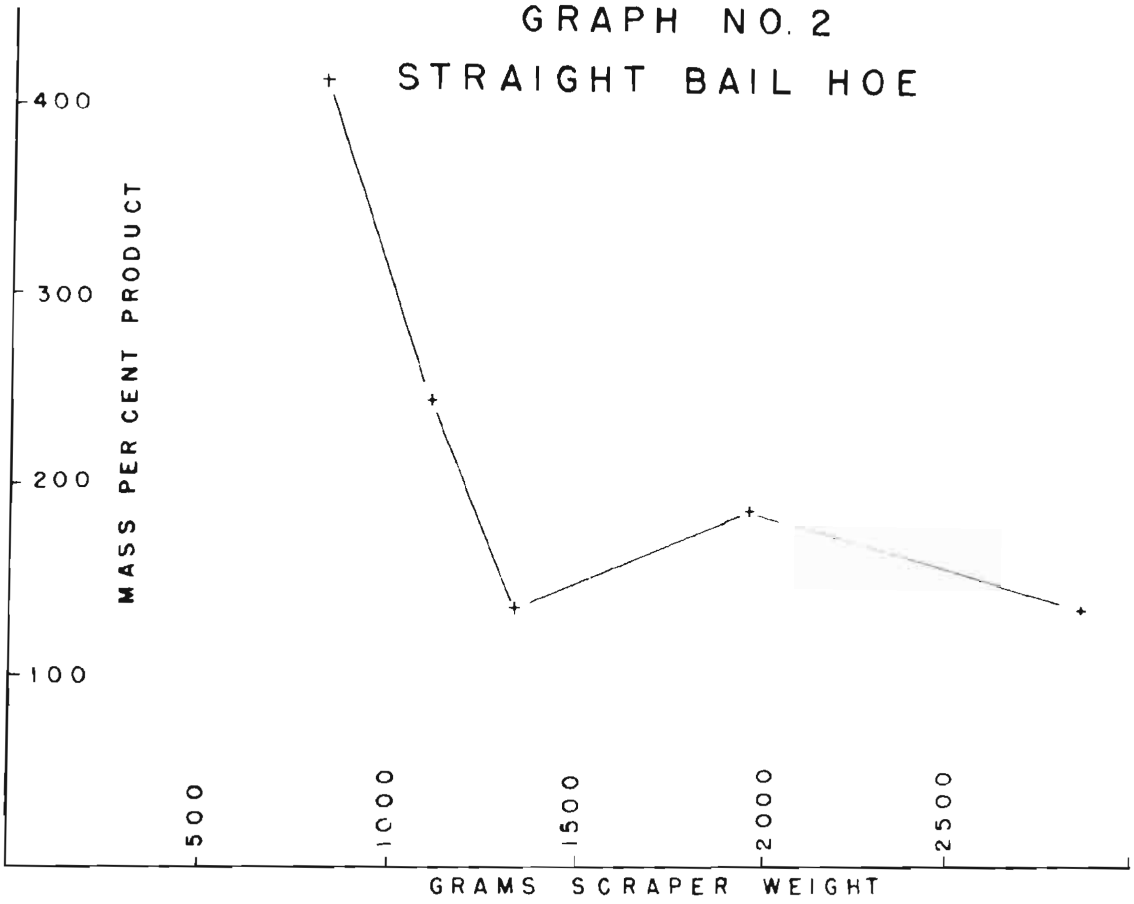
For both the slope and straight bail hoe scrapers the most effective angle is 45 degrees inclination of the blade to the line of pull. The slope bail scraper is the steadier of the two types by reason that its line of pull is lower and more nearly at the level of the scraper cutting edge.

The effect of varying the weight of the scrapers by bolting counterweights at the heel of the blade and at the front of the bail was tried. These tests show that for both scraper types the bail weight must slightly overbalance the heel weight. Since the bail weight has a longer lever arm from the fulcrum at the blade edge, less actual weight is required on the bail than on the blade. The weight on the blade applies the digging power of the scraper to the muck pile and the bail weight holds the blade at as near a steady angle as possible.

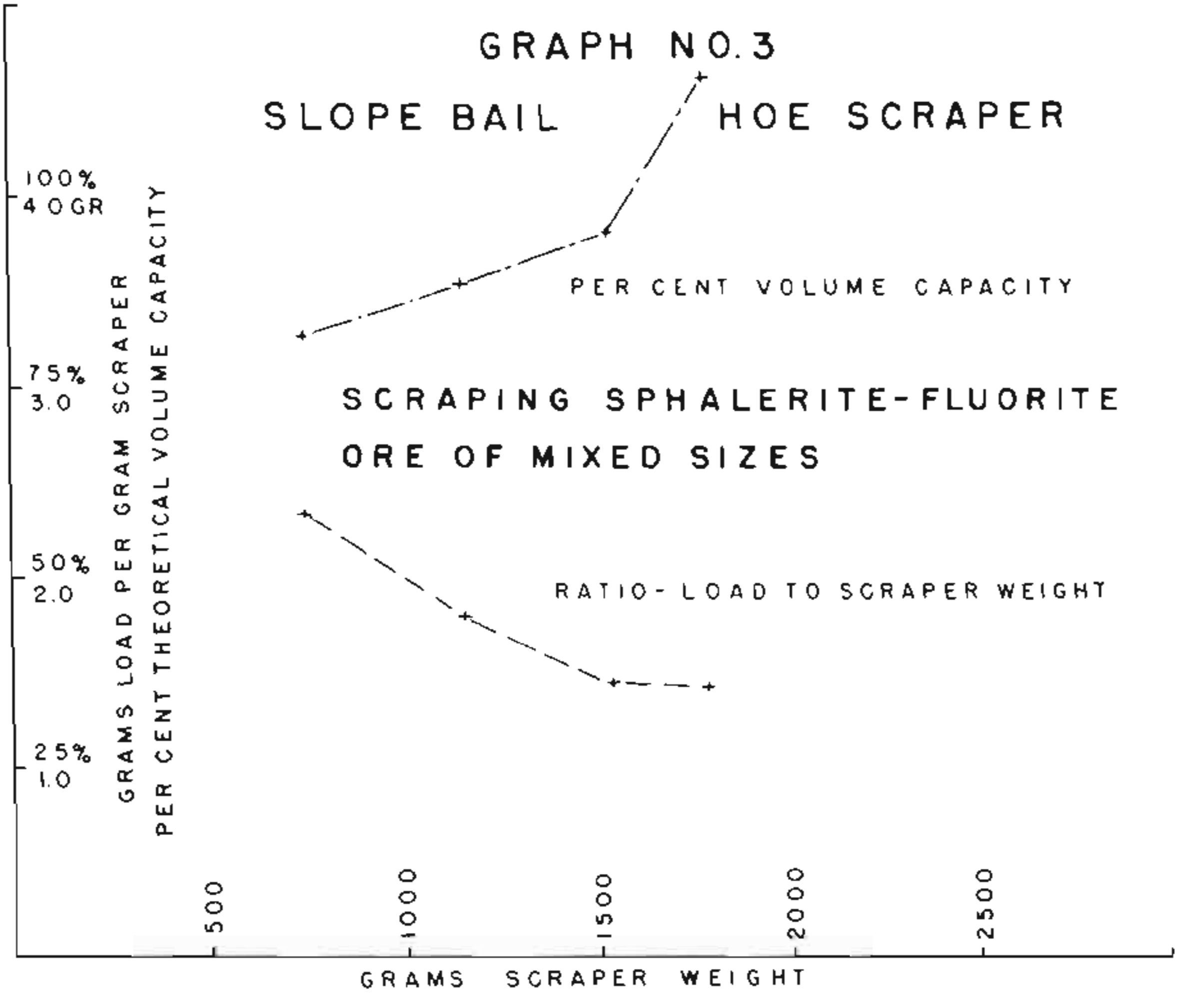
For the hoe type scrapers a minimum weight beyond that for structural durability is most efficient for fine material. For progressively larger



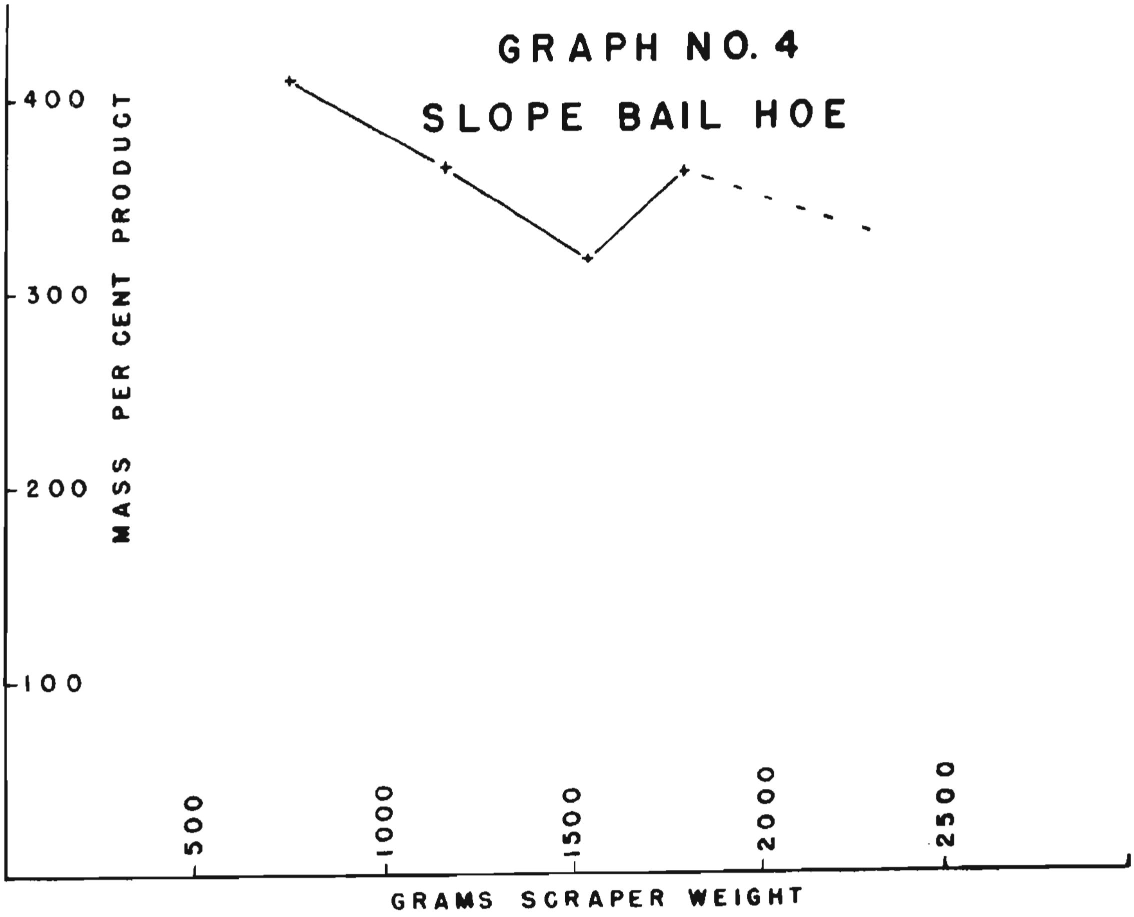
Graph No. 1 - Straight bail hoe, scraping sphalerite-fluorite ore of mixed sizes.



Graph No. 2 - Straight bail hoe, ore mass-scraper weight efficiency.



Graph No. 3 - Slope bail hoe scraper, scraping sphalerite-fluorite ore of mixed sizes.



Graph No. 4 - Slope bail hoe, ore mass-scraper weight efficiency.

rock sizes more weight must be added to the scraper, but beyond a certain maximum weight the tonnage efficiency of the scraper begins to decline. Graphs 1 and 3 show that although the volumetric efficiency increased by adding weight, at the same time the ratio of ore weight moved to scraper weight decreases. The power required to pull a loaded scraper depends directly upon the weight of the scraper plus its load, therefore, it is desirable to keep the scraper weight as low as possible. Graphs 2 and 4 show the combined effect of weight and volume of ore moved platted against actual weight of a fixed size of scraper. These graphs also show the drop in efficiency with added weight.

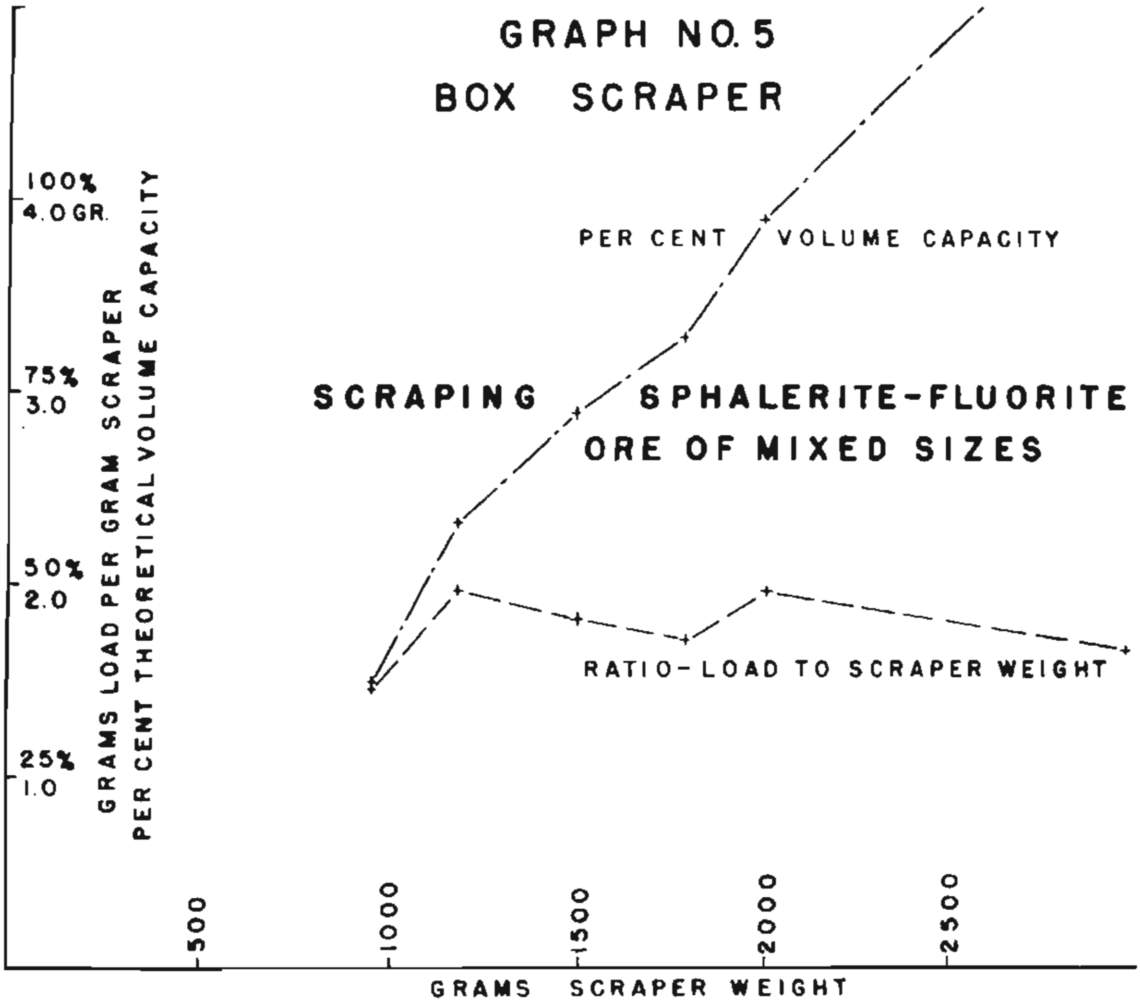
BOX TYPE SCRAPER TESTS

The box type scraper works best on relatively fine material. However, it is not as efficient as the crescent scraper on the same material. Blade angles of 45 and 30 degrees were tried. At 30 degrees the box moved more muck per pass than for the same scraper weight at 45 degrees.

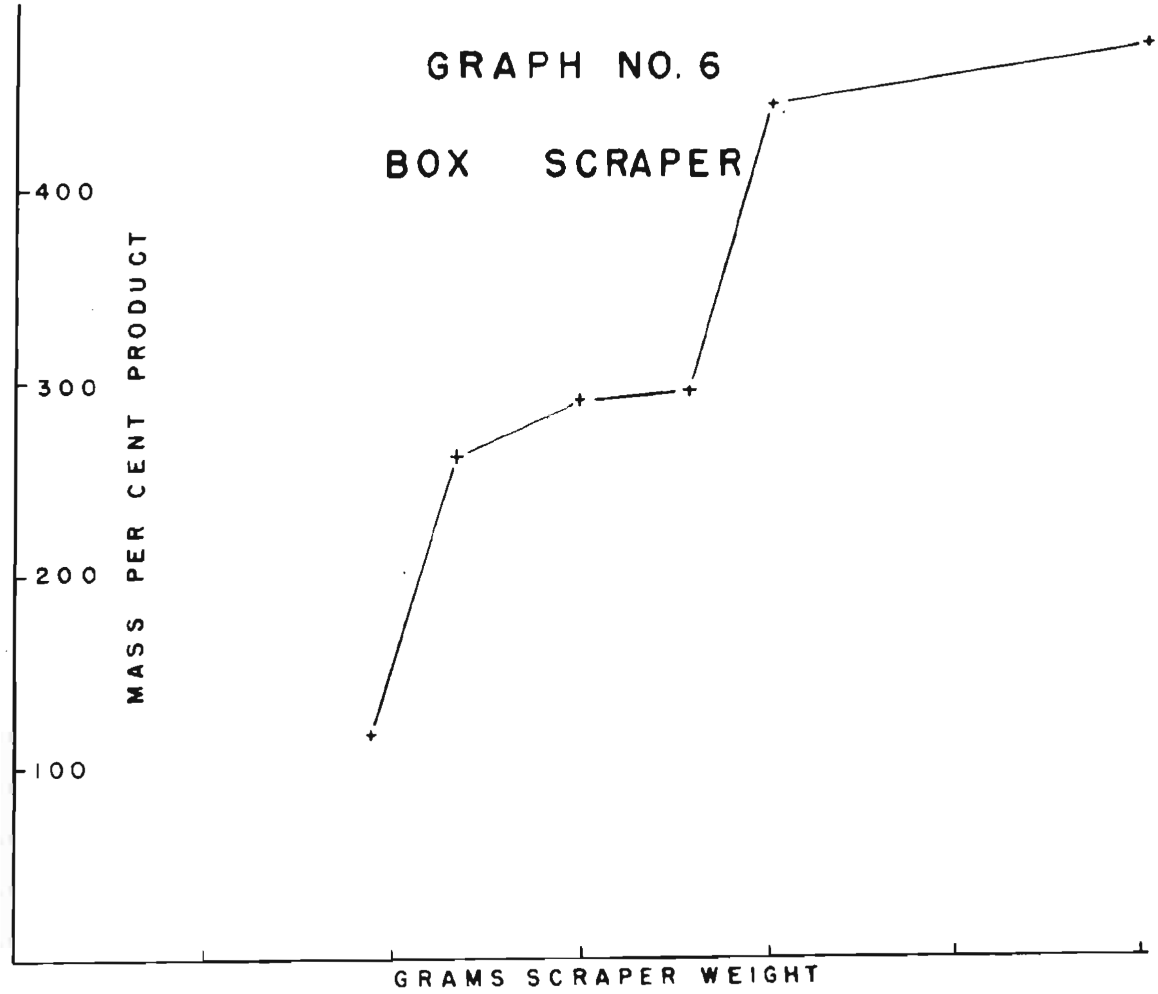
For the same muck material used for trials with the hoe and crescent type scrapers the maximum efficiency for the box model was less than for either the hoe or crescent at the same weight. In contrast with the graphs of the hoe types the weight efficiency graph (see Graph 6) shows an increase of efficiency with continued increase in weight.

The position of counterweights for the box scraper, similarly to the hoe type, is of importance. If too much weight is placed on the forward end of the scraper it will drag so heavily that the blade will lift easily whenever it strikes an obstruction and spill its load. If the back of the box is too heavy the blade will tip backwards until almost parallel with the direction of the pull while the front kicks up in the air.

The side plates of the box help confine the load when scraping fine



Graph No. 5 - Box scraper, scraping sphalerite-fluorite ore of mixed sizes.



Graph No. 6 - Box scraper, ore mass-scraper weight efficiency.

material. In material where pieces are large enough to roll, individual grains will roll along under the edge of the side plates and vibrate the whole scraper. The vibration is enough to allow the scraper load to sift under the blade and escape behind.

CRESCENT SCRAPER TYPE TRIALS

The crescent model scraper exhibited the best ability to move fine material of any of the types tried. It loses very little of its load between the muck pile and chute (see Figure XI) and it rides very evenly. The lack of variable digging angle of the crescent is made up for somewhat by the crowding and scooping action it produces. The side points push the muck toward the center and the rear angle lifts it to fill the scraper. Where there is a variation in size of rock in the muck pile the crescent scoops up the loose coarse pieces off the top of the pile first. On the next trip over the same path it digs up the finer muck.

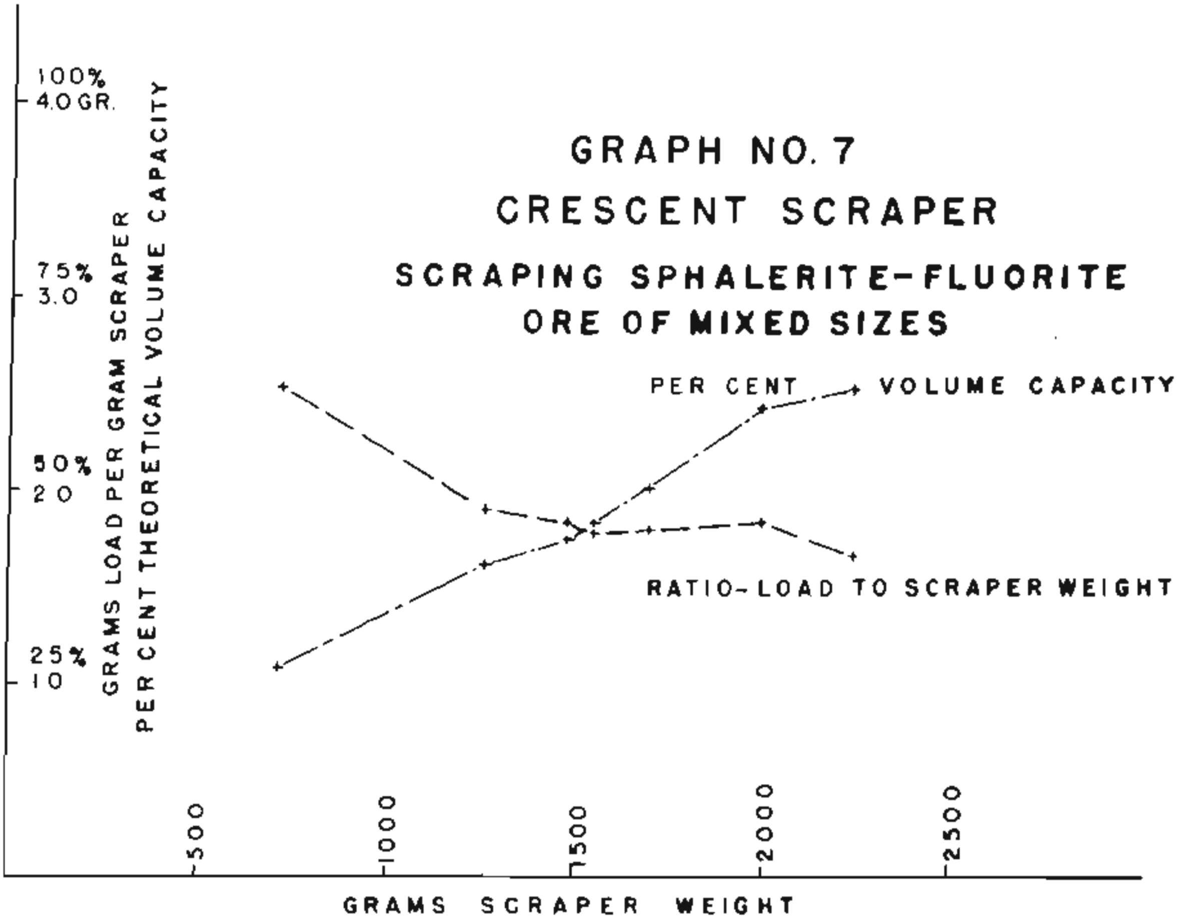
The crescent has the same difficulty as the box scraper for holding a load in uniform moderately coarse material. Rolling particles under the crescent points shake out the load. This difficulty may be partly overcome by adding weight to the scraper.

For the model tests counterweights were bolted above the points (see Figure X) and above the heel of the crescent. The weights bolted above the points were most effective for increasing the scraper's loading ability (see Graph 8). Unless the weight above the points were counterbalanced by some heel weight, eventually added weight makes the forward part of the scraper topheavy. The topheavy scraper catches its points in the muck when loading and tips forward so that the rear end stands in the air. The heavyweight Sauerman scrapers have weight added to them by fastening it around the outside angle of the blade like a belt on a fat man, thus giving them

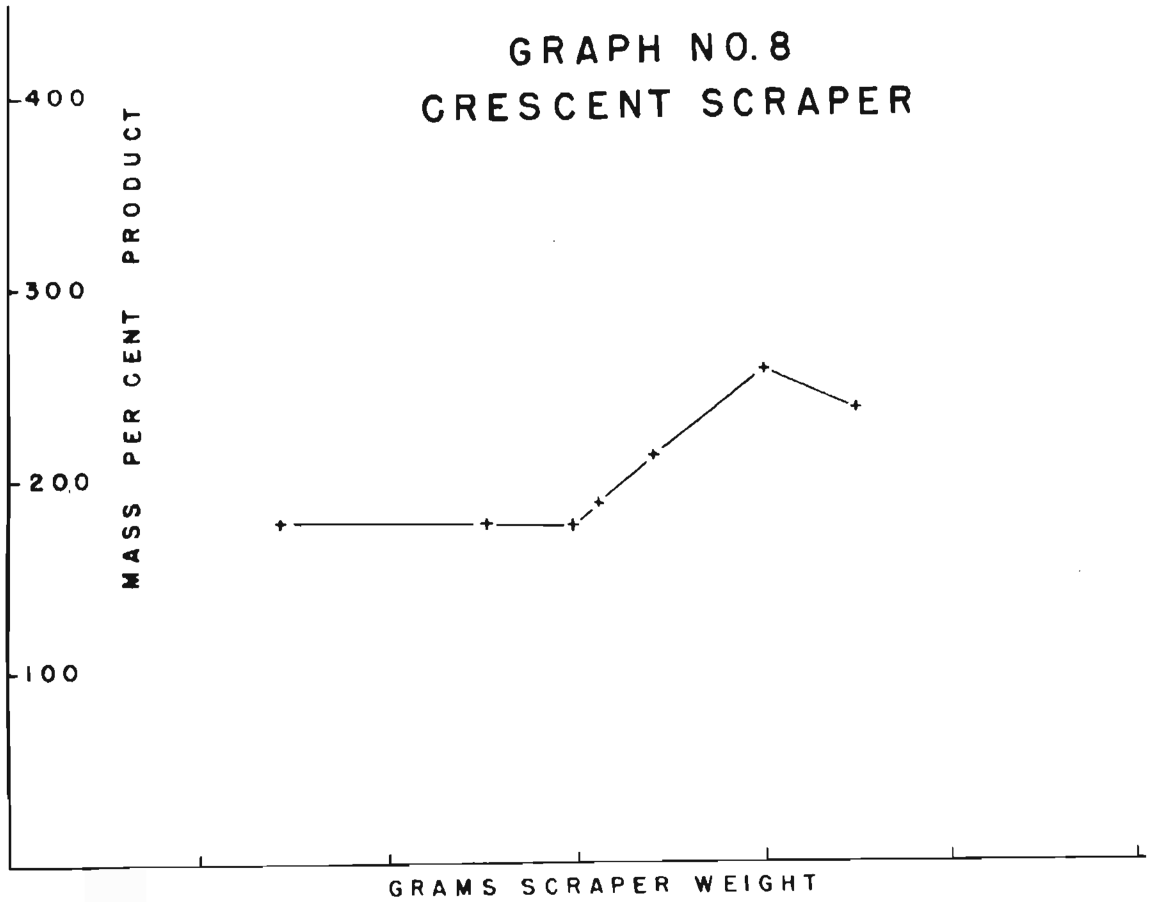
FIGURE XI

Photograph of Crescent Scraper.

The scraper is moving barite ore of minus half inch plus three sixteenths inch size.



Graph No. 7 - Crescent scraper, scraping sphalerite-fluorite ore of mixed sizes.



Graph No. 8 - Crescent scraper, ore mass-scraper weight efficiency.

a low center of gravity.

Similarly to the hoe scrapers the volumetric efficiency of the crescent increases by adding weight and the ratio of rock weight moved per unit weight scrapers decreases (see Graph 7). However, the overall result (Graph 8) of adding weight to the crescent scraper is an increase in efficiency.

Conclusions Drawn From Study of Scale Model Scrapers

1. The pull required to draw a loaded scraper depends directly on the weight of the scraper plus its load and upon the digging angle of the scraper blade.
2. The efficiency of a given scraper is at a maximum at a definite weight of scraper for any one type and size of material. Either too little or too much weight will reduce this efficiency ratio of material delivered per power units required.
3. Scrapers must be properly balanced to give maximum efficiency. Either too much weight on the bail or too much weight on the heel of the blade will reduce riding ability and delivery.
4. For moving finely divided material the scrapers tested rank in the following order: crescent, slope bail hoe, straight bail hoe, and box.
5. For intermediate rock sizes the scrapers' efficiencies rank in the following order: slope bail hoe, straight bail hoe, crescent, and box.
6. For very coarse material the straight bail hoe is the only scraper applicable.
7. A baffle plate at the top of the scraper blade helps prevent the scraper from continuing to dig after it has a full load.

SUMMARY OF SCRAPER TESTS

Four bottomless types of mine scrapers (straight bail hoe, slope bail hoe, box, and crescent) were tested as laboratory models to compare their efficiency for moving ore from a muck pile to a chute. The scale used for the models was one to six, and eight inches is the width that was given to all four scrapers.

The scrapers were put through a series of trials on four different kinds of rock, namely; barite, granite, sphalerite-fluorite ore, and dolomite. The rock in each class was sized in six different diameters, ranging from 3/16 inch to 2 inches. Ninety trials were run on the sized material with the scrapers activated by two ropes. Forty-five more tests were run on sphalerite-fluorite ore of mixed sizes, with the scrapers activated by a pull rope and two tail ropes.

For a level floor and 100 feet per minute rope speed it was determined that the crescent scraper is most effective in moving fine material. The slope bail hoe gives good results on fine to moderately coarse material. The straight bail hoe has the widest range of applicability. It is moderately good in fine and medium sized rock and it is the only scraper applicable to very coarse material. The box scraper is applicable to fine material but is not as effective as either the crescent or slope bail hoe.

For all scrapers it was learned that there is a weight where the scraper reaches its maximum effectivness in a given rock size.

By using counterweights on the model scrapers it was indicated that the bail must slightly overbalance the rear of the scraper to give good results.

A baffle plate or forward curve at the top of a scraper blade prevents it from continuing to dig after the scraper is loaded.

The present study of scrapers on model scale has shown that much more useful information may be obtained by continued research with models. Very little has been written on the subject of size proportions of run-of-mine ores. If a study of the average ore size distribution for any one mine or any given number of mines were made, then model scraper tests could be run to show the type, size, and weight scraper most applicable to this average ore. Also from this study it might be determined that a given mine operation could save on powder costs by breaking ore sizes only fine enough for good scraper loading and not finer than necessary. It may be cheaper to grind the ore at the mill than to pulverize it with explosive.

Appendix A

STRAIGHT BAIL HOE TESTS

Hoe, Straight Bail (Two rope operation) on Level Floor—10 ft. distance, 100 fpm speed

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes -3/16"	½-3/16	1-½	1½-1	2-1½	8-2	% Theor. Capacity	Gms.Rock per Gr. Scraper	Gms.Rock per CC.	Lbs Rope Pull Max	Ave	
815	45°	Dolomite	100%						54.3	2.22	1.43	14	—	
815	45°	"		100					24.2	1.15	1.66	8	—	
1266	45°	"		100					33.2	0.816	1.33	?	—	
2760	45°	"			100				51.3	0.56	1.30	20	—	
2760	30°	"				100			70.5	0.39	1.54	16	—	
2760	45°	"				100			70.5	0.39	1.48	20	—	
2760	30°	"					100		41.2	0.34	1.34	20	—	
2760	45°	"					100		36.1	0.42	1.38	18	—	
2760	60°	"					100		35.1	0.39	1.48	23	—	
2865	45°	"						100	48.0	0.45	1.16	25	5	(3 ropes)
815	45°	$ZnS-CaF_2$	100						66.4	3.67	1.93	17	—	
815	45°	"		100					30.1	1.53	1.78	10	4	
2065	45°	"			100				45.3	0.57	1.12	12	6	
2760	45°	"				50	50		36.2	0.60	1.96	20	6	
2760	45°	"						100	40.5	0.51	1.49	25	10	
2760	45°	"						100	71.0	0.98	1.63	25	15	(3 ropes)
815	45°	Barite	100						65.0	1.86	1.88	15	5	
1107	45°	"	100						87.5	1.84	1.81	24	6	
1446	45°	"		100					39.2	0.81	1.28	12	4	
1107	45°	"		100					36.1	1.59	2.09	23	4	
815	45°	"		100					27.2	1.88	2.43	16	4	
2760	45°	"			100				51.3	0.86	1.98	25	7	
2870	45°	"				50	50		24.1	0.52	2.53	25	10	
2865	45°	"						100	40.0	0.62	1.90	25	5	(3 ropes)
815	45°	Granite	100						24.1	0.91	1.31	8	—	
1114	45°	"		100					28.9	0.61	1.38	8	—	
2870	45°	"			100				66.4	0.79	1.47	24	10	
2865	45°	"				50	50		45.2	0.40	1.09	25	8	

Hoe, Straight Bail (Two Rope Operation) on Level Floor (continued)

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes -3/16"	½/3/16	1/½	1½/1	2/1½	8/2	% Theor. Capacity	Gms.Rock per Gr. Scraper	Gms.Rock per CC.	Lbs Rope Pull Max	Ave	
2865	45°	Granite						100	22.8	0.49	1.31	24	5	(3 ropes)
Hoe, Straight Bail (Three Rope Operation) on Level Floor—12 feet distance, 100 fpm														
815	45°	ZnS-CaF$_2$	55	25	10	5	3	2	42.1	3.44	2.85	15	6	
1107	45	"	55	25	10	5	3	2	51.3	2.27	2.10	16	8	
1396	45	"	55	25	10	5	3	2	58.8	1.54	1.50	25	8	
1905	45	"	55	25	10	5	3	2	60.3	1.51	2.04	25	8	
2870	45	"	55	25	10	5	3	2	60.3	1.05	2.14	25	12	
Scraping upgrade to grizzly - 10° slope														
815	30°	"	55	25	10	5	3	2		3.18	2.24	20	8	
815	45	"	55	25	10	5	3	2		2.27	2.20	24	8	
815	60	"	55	25	10	5	3	2		1.28	2.48	16	4	
Scraping downgrade to grizzly / 10° slope														
815	45°	"	55	25	10	5	3	2		2.39	2.31	17	4	
815	60	"	55	25	10	5	3	2		1.72	2.21	20	4	

Appendix B

SLOPE BAIL HOE TESTS

Hoe, Slope Bail (Two rope operation) on Level Floor—10 ft. distance, 100 fpm speed

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes -3/16"	¼/3/16	1/½	1½/1	2/1½	8/2	% Theor. Capacity	Gms.Rock per Gr. Scraper	Gms.Rock per CC. rock	Lbs. Rope Pull Max	Lbs. Rope Pull Ave
750	45°	Dolomite	100%						110	2.2	1.47	16	—
1715	45	"		100					110.6	0.78	1.19	10	—
2695	45	"			100				116.2	0.56	1.25	12	—
2800	45	"				50%	50%		16.1	0.11	1.84	25	5
1049	45	Granite		100					41.1	0.61	1.52	8	—
2805	45	"			100				95.8	0.51	1.45	16	7
2805	45	"				50%	50		64.5	0.30	1.25	20	8
750	45	$ZnS-CaF_2$	100						137.0	3.40	1.82	16	4
1042	45	"	100						110.0	2.39	2.21	19	6
750	45	"		100					68.5	1.88	2.02	10	4
1042	45	"		100					89.2	1.55	1.77	10	4
1319	45	"			100				68.5	0.90	1.16	15	4
1541	45	"			100				68.5	0.76	1.67	15	4
1785	45	"			100				82.4	0.95	2.01	17	6
1785	45	"				50	50		43.8	0.36	1.41	10	3
2695	45	"				50	50		50.3	0.25	1.30	7	—
750	45	Barite	100						164.5	4.43	2.02	23	8
1152	45	"	100						162.5	2.58	1.79	16	6
750	45	"		100					72.1	2.50	2.54	12	4
1152	45	"		100					133.7	1.65	1.38	20	5
1541	45	"		100					102.8	1.23	1.80	24	5
2805	45	"			100				75.3	0.57	2.07	25	8
2805	45	"				50	50		27.3	0.20	1.99	25	8
On Level Surface		(Three rope operation) 12 ft. cycle											
750	45	$ZnS-CaF_2$	55	25	10	5	3	2	82.0	2.34	2.09	8	4
1159	45	"	55	25	10	5	3	2	89.2	1.80	2.28	24	8
1541	45	"	55	25	10	5	3	2	96.0	1.46	2.26	24	8
1785	45	"	55	25	10	5	3	2	116.5	1.44	2.15	23	9

Hoe, Slope Bail (Three rope operation) 12 ft. cycle distance, 100 fpm rope speed

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes -3/16"	½+3/16	1+½	1½+1	2+1½	8+2	% Theor. Capacity	Gms.Rock per Gr. Scraper	Gms.Rock per CC. rock	Lbs. Rope Pull Max	Ave
Upgrade to grizzly — 10° slope													
750	45	$ZnS-CaF_2$	55	25	10	5	3	2	——	2.70	2.22	20	8
Downgrade to grizzly + 10° slope													
750	45	$ZnS-CaF_2$	55	25	10	5	3	2	——	2.60	2.32	10	4

Appendix C
BOX SCRAPER TESTS

Box Scraper (Two rope operation) on Level Floor—10 ft. distance, 100 fpm speed

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes -3/16"	½/3/16	1/½	1½/1	2/1½	8/2	% Theor. Capacity	Gms. Rock per Gr. Scraper	Gms. Rock per CC. rock	Lbs. Rope Pull Max	Ave
940	30°	Dolomite	100						41.3	1.15	1.54	10	—
1635	45	"		100					80.7	0.99	1.22	12	—
2545	45	"			100				34.0	0.30	1.38	16	—
940	45	Granite	100						51.0	1.39	1.55	10	—
1391	45	"		100					43.8	0.63	1.25	6	—
2991	30	"			100				70.2	0.52	1.31	15	6
2991	45	"			100				51.0	0.47	1.67	12	6
2991	45	"				50	50		14.3	0.09	1.18	20	5
940	45	$ZnS-CaF_2$	100						63.8	2.15	1.92	9	—
1169	45	"	100						68.2	2.70	2.15	?	—
1391	45	"	100						89.3	2.06	1.95	10	—
1635	45	"	100						93.6	1.80	1.91	11	—
1850	45	"	100						110.0	1.88	1.91	12	8
1169	45	"		100					44.6	0.89	1.41	9	5
1391	45	"		100					42.6	0.70	1.39	8	4
1827	45	"			100				59.7	0.90	1.67	16	6
940	45	Barite	100						46.8	1.46	1.78	16	6
1169	45	"	100						39.2	1.45	1.86	15	7
1391	45	"	100						45.2	1.83	2.42	17	4
1857	45	"	100						71.0	1.34	1.19	20	8
940	45	"		100					0	—	—	—	—
1169	45	"		100					0	—	—	—	—
1391	45	"		100					25.0	0.57	1.88	12	3
1391	30	"		100					45.4	1.09	1.96	12	6
1635	30	"		100					45.5	0.99	2.1	12	5
2996	30	"			100				26.8	0.30	1.98	20	6

Box Scraper (Three rope operation) — 12 ft. distance

Wt. Scraper	Blade Angle	Rock	-3/16"	½/3/16	1/½	1½/1	2/1½	8/2	% Theor. Capacity	Gms. Rock per Gr. Scraper	Gms. Rock per CC. rock	Lbs. Rope Pull Max	Ave
940	30	$ZnS-CaF_2$	55	25	10	5	3	2	37.2	1.45	2.16	10	4
1169	30	"	55	25	10	5	3	2	57.8	1.94	2.32	10	5
1491	30	"	55	25	10	5	3	2	72.4	1.82	2.20	12	4

Box Scraper (Three rope operation) on Level Floor—12 ft. distance, 100 fpm speed (continued)

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes -3/16"	½/3/16	1/½	1½/1	2/1½	8/2	% Theor. Capacity	Gms.Rock per Gr. Scraper	Gms.Rock per CC. rock	Lbs. Rope Pull Max	Ave
1779	30	$ZnS-CaF_2$	55	25	10	5	3	2	82.7	1.68	2.13	24	8
2001	30	"	55	25	10	5	3	2	97.2	1.94	2.36	20	8
2996	30	"	55	25	10	5	3	2	144.7	1.64	2.00	24	12
Upgrade to grizzly—10° slope													
940	30	$ZnS-CaF_2$	55	25	10	5	3	2		1.10	2.25	10	6
Downgrade to grizzly — 10° slope													
940	30	$ZnS-CaF_2$	55	25	10	5	3	2		0.99	2.64	6	3

Appendix D

CRESCENT SCRAPER TESTS

Crescent Scraper (Two rope operation) on Level Floor, 10 ft. distance, 100 fpm rope speed

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes						% Theor. Capacity	Gms. Rock per Gr. Scraper	Gms. Rock per CC. rock	Lbs. Rope Pull Max	Ave
			-3/16"	½/3/16	1/½	1½/1	2/1½	8/2					
715	60°	Dolomite	100						54.0	3.39	1.71	10	—
715	60	"		100					32.4	1.18	1.07	4	—
1555	60	"		100					44.8	1.27	1.70	12	—
1711	60	"			100				0	—	—	—	—
715	60	ZnS-CaF$_2$	100						43.3	3.42	2.17	7	—
1260	60	"	100						55.0	2.18	1.95	8	6
1489	60	"	100						67.6	2.3	1.95	16	12
1711	60	"	100						56.7	1.83	2.12	16	8
1955	60	"	100						70.3	1.95	2.08	17	9
2170	60	"	100						75.7	1.85	2.37	18	10
2694	60	"	100						89.1	1.78	2.78	20	12
1260	60	"		100					35.1	1.22	1.68	8	5
1905	60	"			100				0	Topheavy			
715	60	Barite	100						46.0	3.34	2.00	16	4
1260	60	"	100						75.7	2.90	1.86	16	8
1555	60	"	100						67.7	2.09	2.06	17	8
715	60	"		100					9.45	0.64	1.84	5	2
1555	60	"		100					35.1	1.21	2.07	9	6
1777	60	"		100					35.1	0.98	1.90	10	6
2687	60	"			100				0	—	—	—	—
715	60	Granite	100						37.7	1.9	1.38	8	—
1010	60	"		100					21.6	0.78	1.39	8	—
2465	60	"			100				21.6	0.30	1.33	12	9
Crescent Scraper (Three rope operation) 12 ft. distance													
715	60	ZnS-CaF$_2$	55	25	10	5	3	2	27.0	2.53	2.58	16	5
1260	60	"	55	25	10	5	3	2	40.5	1.91	2.28	12	5
1489	60	"	55	25	10	5	3	2	45.9	1.75	2.19	14	6
1555	60	"	55	25	10	5	3	2	46.2	1.78	2.30	15	8
1701	60	"	55	25	10	5	3	2	51.3	1.80	2.30	16	7

Crescent Scraper (Three rope operation) on Level Floor, 12 ft. distance, 100 fpm speed (continued)

Wt. Scraper	Blade Angle	Rock	Particle (Diameter) Sizes						% Theor. Capacity	Gms. Rock per Gr. Scraper	Gms. Rock per CC.	Lbs. Rope Pull	
			-3/16"	½/3/16	1/½	1½/1	2/1½	8/2				Max	Ave
2006	60	ZnS-CaF$_2$	55	25	10	5	3	2	60.8	1.83	2.32	21	8
2250	60	"	55	25	10	5	3	2	62.8	1.65	2.28	24	8
Upgrade to grizzly — 10° slope													
715	60	ZnS-CaF$_2$	55	25	10	5	3	2	——	1.82	2.12	24	8
Downgrade to grizzly ∠ 10° slope													
715	60	ZnS-CaF$_2$	55	25	10	5	3	2	——	2.36	1.92	6	3
1260	60	"	55	25	10	5	3	2	——	2.04	2.15	12	5

APPENDIX E PART I
SCRAPER DATA SHEET

MAXIMUM CAPACITY OF SCRAPERS (Measured with -3/16" dry dolomite)

Crescent Type	8 inches wide 60°	-	2600 cc.
Hoe Type	8 inches wide -	Straight Bail	
	Angle Blade 30°	-	1700 cc.
	Angle blade 45°	-	2330 cc.
	Angle blade 60°	-	2000 cc.
Hoe Type	8 inches wide -	Slope Bail	
	Angle blade 30°	-	1000 cc. (scoop action)
	Angle blade 45°	-	1025 cc.
	Angle blade 60°	-	1200 cc.
Box Type	8 inches wide -		
	Angle blade 30°	-	1700 cc.
	Angle blade 45°	-	1650 cc.

(All measured on level floor)

WEIGHT OF SCRAPERS

Box Type (with chain)	- 940 grams	(no counterweights)	
Crescent Type (chain)	- 715 grams	" "	
Hoe Type (with chain)	- 815 grams	" "	straight
Hoe Type (with chain)	- 750 grams	" "	slope

COUNTERWEIGHTS

Bail weight for hoe type	70 grams	(with screws)
" " " " "	110 grams	" "
" " " " "	270 grams	" "
Back weight for hoe or box	222 grams	(with screws)
" " " " " "	229 grams	" "
" " " " " "	695 grams	" "
" " " " " "	910 grams	" "

(Above back weights also front weights for crescent)

Front counterweight cross brace for crescent 545 grams (with screws)

Back counterweight for crescent 295 grams

PANS FOR ROCK MEASUREMENT (Galvanized Pans)

Pan #1 Weight ~~3800~~ 3745 grams- 53 x 53 x 9 cm. (vol. 25, 281 cc.)
area bottom 2809 sq. cm.

Pan #2 Weight ~~3720~~ 3690 grams- dimensions same as #1.

APPENDIX E PART II

SCRAPER EFFICIENCY GRAPH CALCULATIONS
ZnS and CaF_2 Ore of Mixed Sizes

Hoe, Straight Bail

Weight	Gr./Gr. Scr. x % Cap.	x Gr./cc. Ore
815	144.8	4120
1107	116.5	2450
1336	90.7	1360
1905	91.2	1860
2870	63.2	1355

Hoe, Slope Bail

Weight	Gr./Gr. Scr. x % Cap.	x Gr./ cc. Ore
750	192.0	4010
1159	160.5	3660
1541	140.2	3170
1785	168.0 (ore pushed)	3620

Box Scraper

Weight	Gr./Gr. Scr. x % Cap.	x Gr./cc. Ore
940	53.9	1165
1169	112.1	2602
1491	131.8	2900
1779	139.0	296.0
2001	188.2	4450
2996	237.5	4750

Crescent Scraper

Weight	Gr./Gr. Scr. x % Cap.	x Gr./cc. Ore
715	68.6	1770
1260	77.5	1768
1489	80.3	1758
1555	82.2	1890
1701	92.5	2130
2006	111.0	2575
2250	104.0	2370

APPENDIX E PART III

CALCULATION OF ROPE SPEEDS FROM PULLEY RATIOS

(Motor speed 1750 RPM)

D_1 = 2.125 inches Pulley #1 (on motor)

D_2 = 11.75 inches Pulley #2 (on jack shaft)

D_3 = 3.75, 2.8125, and 1.875 Pulley #3 (on jack shaft)

D_4 = 3.8125, 2.8125, and 1.875 Pulley #4 (on hoist axel)

Velocity ratios from formula $VR = \frac{D_2 \times D_4}{D_1 \quad D_3}$

$$VR_1 = \frac{11.75 \times 3.815}{2.125 \times 1.875} = 11.25 \qquad \frac{1750}{11.25} = 155.5 \text{ RPM}$$

$$VR_2 = \frac{11.75 \times 2.8125}{2.125 \times 1.875} = 8.29 \qquad \frac{1750}{8.29} = 211.1 \text{ RPM}$$

$$VR_3 = \frac{11.75 \times 3.815}{2.125 \times 2.8125} = 7.50 \qquad \frac{1750}{7.50} = 233.3 \text{ RPM}$$

$$VR_4 = \frac{11.75 \times 2.8125}{2.125 \times 2.8125} = 5.52 \qquad \frac{1750}{5.52} = 317.0 \text{ RPM}$$

$$VR_5 = \frac{11.75 \times 2.8125}{2.125 \times 3.815} = 4.08 \qquad \frac{1750}{4.08} = 428.9 \text{ RPM}$$

$$VR_6 = \frac{11.75 \times 1.875}{2.125 \times 2.8125} = 3.68 \qquad \frac{1750}{3.68} = 475.5 \text{ RPM}$$

$$VR_7 = \frac{11.75 \times 1.875}{2.125 \times 3.815} = 2.71 \qquad \frac{1750}{2.71} = 645.7 \text{ RPM}$$

Winding drum 3 inches in diameter is ~~0.7854~~ 0.8017 ft. in circumference

Combination #1 is ~~0.7854~~ 0.8017 x 155.5 = 122.0 124 ft. per minute rope speed

Combination #2 " " x 211.1 = 166 169 " " " " "

Combination #3 " " x 233.3 = 183 187 " " " " "

Combination #4 " " x 317.0 = 249 254 " " " " "

Combination #5 " " x 428.9 = 337 344 " " " " "

Combination #6 " " x 475.5 = 373 381 " " " " "

Combination #7 " " x 645.7 = 507 518 " " " " "

BIBLIOGRAPHY

1. BOOKS

   a. Given, Ivan A., Mechanical Loading of Coal Underground, 1st Ed., 1943, Section 7, Pages 247-263; McGraw-Hill, N.Y.

   b. Peele, Robert, and Church, John A., Mining Engineer's Handbook., 3rd Ed., N.Y., Wiley, 1941, Section 27, Pages 11-12.

2. Periodicals

   a. Clarke, S. S., Mining Methods of the Tri-State. Engineering and Mining Journal, Vol. 42, Nov. 1943, pp. 80-86.

   b. Eaton, Lucien, Mechanical Loading in Metal Mines in 1929. Mining Congress Journal, July 1929, p. 536.

   c. Eaton, Lucien, The Use of Scrapers in Metal Mines. Compressed Air Magazine, Vol. 26, May 26, 1921, pp. 10065-10075.

   d. Editorial. Postwar Mining Costs Must Come Down. Engineering and Mining Journal, Vol. 145, January 1944, p. 70.

   e. Fuller, Julian A., Slushing Adapted to Bauxite Mining. Mining Congress Journal, January 1945, pp. 38-39.

   f. McDermid, A. J., Underground Scraping Practice. Engineering and Mining Journal, Vol. 130, pp. 390-392.

   g. Pierce, R. V., and Bryan, R. N., Scraping and Loading in Mines. Compressed Air Magazine. Vol. 47, No. 6, June 1942., pp. 6760-4. Also: Mining Journal (London), Vol. 218, No. 5581, August 8, 1942, pp. 375-6.

   h. Pierce, R. V., and Bryan, R. N., Small Air Hoists Increase Vital Mineral Output. Compressed Air Magazine, Vol. 48, No. 3, March 1943, pp. 6971-7.

i. Plein, L. N., Berquist, F. E., and Tryon, F. G., Mechanical Loading Underground, Engineering and Mining Journal, Vol. 138, May 1937, pp. 241-2.

j. Waterland, T. M., Slushing at Britannia Mines. Compressed Air Magazine, Vol. 49, No. 8, August 1944, pp. 210-11.

3. Publications of Learned Societies

a. Coy, H. A., and Noble, James A., Mining Methods at Moscot, Tennessee. American Institute of Mining and Metallurgical Engineers, Transactions Vol. 122, p. 67.

b. Henderson, Robert., A Comparison Between the Chute and Grizzly System and The Slusher System at the Climax Mine. American Institute of Mining and Metallurgical Engineers, Mining Technology, T. P. 1715, May 1944.

c. Tillson, Benjamin Franklin, Mine Plant, American Institute of Mining and Metallurgical Engineers, 1st Ed., New York, 1938, pp. 302-303.

4. U. S. Government Publications

a. Anderson, Carl N., Mining Methods and Costs at the Interstate Zinc and Lead Company's Hartley-Mine, Tri-State Zinc and Lead District. United States Bureau of Mines Information Circular No. 6656, p. 8.

b. Crane, W. R., Mining Methods and Practice in the Michigan Copper Mines. United States Bureau of Mines Bulletin No. 306, pp. 93-94, 154-156.

c. Jackson, Chas. F., Underground Scraping Practice in Metal Mines. United States Bureau of Mines Manuscript Report No. 1 (Printed by Sullivan Machinery Company), 1933, pp. 1-88.

d. Mosier, McHenry, and Steinmesch, J. H., Mechanical Shovelling in Underground Metal Mines. United States Bureau of Mines Bulletin No. 423, 1940, pp.5-6.

5. State Publications

a. Matson, Robert C., Scraping Practice in the Michigan Iron Mines of the Lake Superior District. Michigan College of Mining and Technology, Bulletin 1928-1929, Vol. 2, No. 4, pp. 1-75.

6. Foreign Publications

a. Muir, W. L. G., Some Applications of Scraper Loading to Mining. Transcations of the Institution of Mining and Metallurgy (London) Vol. 43, 1934, pp. 523-544.

b. Pierce, R. V., Multiplying Manpower with Scrapers. Canadian Institute of Mining and Metallurgy, Transactions Vol. 46, 1943, pp. 402-422.

Also:

American Institute of Mining and Metallurgical Engineers, Mining Technology, Vol. 7, No. 4, T. P. 1603, July 1943, pp. 1-18.

7. Catalogs from Manufacturers

a. Alloy Steel and Metals Company. Pacific Slushing Scrapers. Bulletin No. 95, pp. 5-6.

b. Gardner Denver Company. Airslushers. Bulletin AS-1, 1945.

c. Holcomb, M. D., The Original Holcomb "Westeeco" Scrapers. Catalog No. 3, (Twin City Iron Works) 1941.

d. Ingersoll Rand Company. Modern Methods for Scraper Mucking and Loading. 1939, pp. ~~3-9~~. 3-32.

e. Sauerman Brothers, Incorporated. Crescent Scraper Buckets. Catalog 19, Section J., Page 1.

f. Sauerman Brothers, Incorporated. Power Drag Scrapers, Catalog 19, Section A.

INDEX

INDEX (Continued)

INDEX (Continued)

INDEX (Continued)

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The author, Austin Bond Clayton, was born May 29, 1911 at Admire, Kansas. His elementary schooling was completed in Sanders County, Montana and he was graduated in 1929 from Sandpoint High School, Bonner County, Idaho. In 1934 he was graduated from the University of Idaho School of Mines, Moscow, Idaho, with the degree Bachelor of Science in Geology.

After two years experience in the Coeur d'Alene lead-zinc-silver mines of North Idaho, Clayton joined the staff of the Cerro de Pasco Copper Corporation at Cerro de Pasco, Peru, as a mine shift boss. In 1939 he was offered a better position in Bolivia as a mining engineer with the Bolivian Tin and Tungsten Mines Corporation at Huanuni, Bolivia. In 1942 he returned to the United States. After three months employment in Montana with Anaconda Copper Mining Company developing chrome ore bodies he joined the U. S. Bureau of Mines on a War Service Appointment in Tennessee. At the end of the war he was released to accept an appointment as Research Fellow at Missouri School of Mines.

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