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Shaft Mucker Design

P. J.G du Toit

Report on
SHAFT MUCKER DESIGN

by
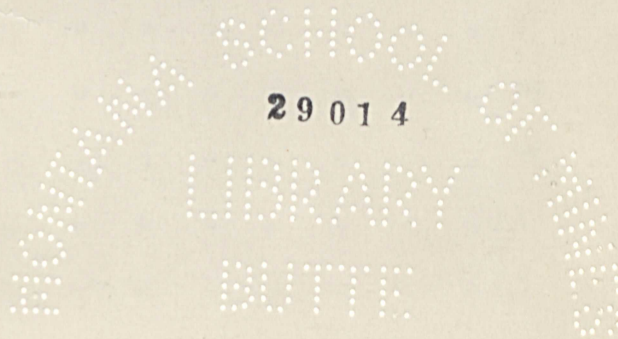P. J. G. du Toit

May 11, 1956
Montana School of Mines
Butte, Montana

Report on
SHAFT MUCKER DESIGN

Submitted to
Prof. Koehler Stout

by
P. J. G. du Toit

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS AND PHOTOS

Page

ABSTRACT

The mucking principle employed in the design of this mucking machine is that of a continuous operation instead of an intermittent one. The mucker was primarily designed for operation in shafts (vertical or inclined) and winzes but the mucker is not restricted to these. It could operate off any type of muckpile, as long as it is stabilized and mucking into a suitable container.

Several drawings were placed in the report to serve as explanatory material.

A working model of the mucker was constructed from on-hand materials. A lack of funds prevented the manufacturing of a full-scale prototype.

The performance of the model surpassed all previous expectations. Material two to three times the height of a scraper was mucked into the loading pan. Several photos were taken to demonstrate the construction of the model as well as the performance thereof. One photo was taken at a shutter speed of 1/2000 sec. and with a flashlight. Two other action shots were taken at speeds of 1/100 sec. and 1/200 sec. and the best one of these two was placed in the report.

The mucker holds good possibilities, and the performance of the model proved that the manufacturing of a full-scale prototype would be worth while.

INTRODUCTION

Continuous mucking operations instead of intermittent ones, have been in use in soft-rock and coal mines for quite some time. In abrasive-rock mines, shaft mucking is still an intermittent operation. There is no reason at all that prevents us from visualizing continuous operations in abrasive-rock mining.

The object of the design in this report, is that of designing a mucker which could be operated in shafts (vertical or inclined) and in winzes. If a full scale prototype could be built instead of a working model, as was done, the operation of the machine could be observed much better and the bugs straightened out.

The mucker may be found much more versatile than expected, since the design of the mucker does not confine it to shafts or winzes; as long as there is a muckpile and something to muck the material into, this mucker will muck!

A description of the mucker and model can be found on the pages following. The model is a working model. Some trial runs were made with the model and recorded. A good idea of the performance and application of the principle can be formed from the trials with the model.

DESCRIPTION

The mucker utilizes angle iron sections for scrapers and could be manufactured very inexpensively. A small horsepower motor drives the mechanism and the motor can be either an air-driven motor or a water-proof electric motor. An air motor would probably be the cheapest to employ, and the speed on an air motor could be easily controlled by a valve in the compressed-air line. The motor must preferably be reversable but this is not compulsory. The motor must be geared down to approximately 300 rpm. The mucking sprockets should rotate at 184.2 rpm.

Power is transmitted from the motor to the sprockets by means of a chain and sprocket. The scrapers discharge into the bucket by means of centrifugal force. The linear velocity of the scrapers should not exceed $\sqrt{xg}$ ft/sec. if the length of the bucket is x ft from the point where material is discharged from the scraper to the rear end of the bucket or pan. The mucker is attached to the bucket through medium of two arms hinged on the back part of the pan. The bucket or pan should be secured to a pin or similar device to prevent it from being pulled along the bottom. (See pp. 10 and 11 for explanatory drawings)

After the bucket or pan has been filled the contents can be dumped into the sinking bucket. In case of an inclined shaft

a short skip can be used to muck into and this skip can be hoisted to surface. The capacity of the mucker should be approximately 2.0 tons/min. if a 3.0 hp motor is used. If a faster linear chain velocity is used, then a screen plate can be attached to the rear of the loading pan to prevent the material from being discharged over the rear end of the pan. The capacity of the mucker can be increased by increasing the size of the scrapers, the number of scrapers, (with the necessary increase in hp of the motor) or by increasing the power of the motor only. The mucker can be hoisted either by a small tugger or by air cylinders attached to the timber above, and then lowered into the desired position.

The scrapers can be welded to the chains, or bolted onto the chains, or attached to the chain as was done in the construction of the model. This latter method will add more weight to the mucker and will require more materials, both of which are undesirable circumstances.

CALCULATIONS

Distance material is projected

Neglect air resistance
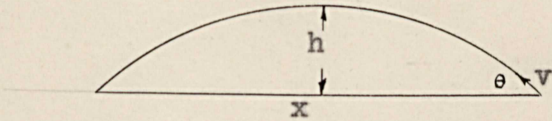
v = initial velocity

$v \sin \theta$ = Vertical component

$v \cos \theta$ = Horizontal component

t = Time

θ = Angle of projection

$x = (v \cos \theta)\, t + \frac{1}{2} at^2$

$\frac{1}{2} at^2 = 0$

$\therefore x = v \cos \theta . t$ ------------(1)

t_1 = time to reach highest point

$u = v + at.$ $a = -g$ (up positive)

$0 = v \sin \theta - gt_1$

$\therefore v \sin \theta = gt_1$

$\therefore t_1 = \dfrac{v \sin \theta}{g}$

$h = (v \sin \theta\, t_1 - \frac{1}{2} gt_1^2$

$= gt_1^2 - \frac{1}{2} gt_1$

$\therefore h = \dfrac{gt_1^2}{2}$ -------------(2)

$t = 2t_1$ since time to rise equals time to fall

$x = vt_1 \cos \theta$ from (1)

$$= 2 \, vt_1 \cos \theta$$

$$= 2v \, \frac{(v \sin \theta)}{g} \cos \theta$$

$$= 2 \, v^2 \, \frac{\sin \theta \cos \theta}{g}$$

$$\therefore x = \frac{v^2 \sin 2\theta}{g}$$

and $h = \frac{v^2}{2g} \sin^2 \theta$

if $\theta = 45°$ then x will be maximum

if $x = 4$ ft

then $4 = \frac{v^2}{g}$

$\therefore v^2 = 128.8$

$v = 11.33$ ft/sec.

$= 679.8$ ft/min.

A chain speed of 680 ft/min. will project the material over the rear of the loading pan if the distance from the point of projection to the rear plate of the loading pan is 4 ft. As stated before: If the linear chain velocity exceeds 680 ft/min. a plate can be added to the loading pan to deflect the discharged material into the loading pan.

Chain & Sprockets

Selected chain pitch = 3" = P

Number of teeth = 13 = N

P D = Pitch diameter = $\dfrac{P}{\dfrac{\sin 180°}{N}}$

$$= \frac{3}{\sin \frac{(180)^{\circ}}{(13)}}$$

$$= \frac{3}{\sin 13.85^{\circ}}$$

$$= \frac{3}{0.2395}$$

PD = 12.53 in.

Length of chain

Distance of 4 ft selected as distance between sprockets centers
i.e., sprockets driven by same chain.

∴ Chain length = (x 12.45) + 48 + 48 in.

= 135.1"

= 11 ft 3.1 in.

To accomodate 3" pitch in chain, select 11 ft 3 in.

∴ Center to center distance = $\frac{108 - 12.45}{2}$

= 47.95 in.

For symmetrical purposes the number of 44 chain sections is
selected.

Chain length = 132"

= 11 ft

∴ Center to center distance = $\frac{132 - 39.1}{2}$

= $\frac{92.9}{2}$

= 46.45 in.

If a scraper is placed every 1 ft, then the number of scrapers = 11.

Scraper Dimensions

Different cases involving different chain velocities and different scraper dimensions are investigated by means of calculations on the pages following.

Specific Gravity of Material

A specific gravity of 135 lb/ft^3 is assumed for the material being mucked. This figure requires 14.8 ft^3 of material to weigh 1 ton (ST). A good average weight, of ore in place, is 10 ft^3/ton. If 14.8 ft^3 is the volume of broken rock, then the expansion of the rock would be 48%. Therefore, the assumption that the broken material weighs 135 lb/ft^3 is a safe assumption.

Case 1

Scraper dimensions: 21 x 5 in.

Volume of material moved by scraper = $\frac{5 \times 5 \times 21 \text{ in.}^3}{2}$

$$= 0.152 \text{ ft}^3$$

Chain velocity (=velocity of discharged material)

= 930 ft/min. (selected)

Capacity of mucker = 930 x 1 x 0.152 cu. ft/min.

$$= 140 \text{ ft}^3/\text{min.}$$

Weight of a ft^3 of material = 135 lbs (assumed)

Capacity = $\frac{140 \times 135}{2000}$ tons/min.

= 9.45 tons/min.

Horsepower required (100% efficiency)

$$hp = \frac{force \times speed}{33000}$$

$$= \frac{5.5 \times 0.152 \times 135 \times 930}{33000}$$

$$= \underline{3.18}$$

$$rpm = \frac{930 \times 12}{\pi \times 12.45} = \underline{128.6}$$

Case 2

Chain velocity = 300 ft/min.

Scraper dimensions: same as in case 1.

$$Capacity = \frac{300 \times 1 \times 0.152 \times 135}{2000}$$

$$= \underline{3.08} \text{ tons/min.}$$

$$Horsepower = \frac{5.5 \times 0.152 \times 135 \times 300}{33000}$$

$$= \underline{1.025}$$

$$rpm = \frac{300 \times 12}{\pi \times 12.45} = \underline{92.1}$$

Case 3

Scraper dimensions: 21 x 4 in.

Volume of material moved by scraper

$$= \frac{4 \times 4 \times 21}{288 \times 12} \text{ ft}^3$$

$$= \underline{0.0972} \text{ ft}^3$$

Chain velocity = 300 ft/min.

$$\text{Capacity} = \frac{300 \times 1 \times 0.0972 \times 135}{2000}$$

$$= 1.97 \text{ tons/min.}$$

$$\text{Horsepower} = \frac{5.5 \times 0.0972 \times 135 \times 300}{33000} = 0.655$$

$$\text{rpm of sprockets} = \frac{300 \times 12}{\pi \times 12.45}$$

$$= 92.1$$

Case 4

Scraper dimensions: same as in case 3

Chain velocity = 900 ft/min.

$$\text{Capacity} = 1.97 \times 3$$

$$= 5.91 \text{ tons/min.}$$

$$\text{Horsepower} = 0.656 \times 3$$

$$= 1.968 \text{ tons/min.}$$

$$\text{rpm of sprockets} = 92.1 \times 3 = 276.3$$

Case 5

Scraper dimensions: same as cases 3 and 4

Chain velocity = 600 ft/min.

$$\text{Capacity} = 1.97 \times 2$$

$$= 3.94 \text{ tons/min.}$$

$$\text{Horsepower} = 0.656 \times 2$$

$$= 1.312$$

$$\text{rpm of sprockets} = 92.1 \times 2$$

$$= 184.2$$

Case 6

Dimensions of scraper: 3 x 21 in.

Chain velocity = 600 ft/min.

Volume of material per scraper = $\dfrac{3 \times 3 \times 21}{2 \times 144 \times 12}$

$$= 0.0575 \text{ ft}^3$$

Capacity of mucker = $\dfrac{600 \times 0.0575 \times 135 \times 1}{2000}$

$$= 2.31 \text{ tons/min.}$$

Horsepower = $\dfrac{5.5 \times 0.0575 \times 135 \times 600}{33000}$

$$= 0.775$$

rpm of sprockets = $\dfrac{600 \times 12}{\pi \times 12.45}$

$$= 184.5$$

SUMMARY

	Scraper dim.	Chain velocity	Capacity	Hp	Rpm
Case 1	21 x 5 in.	930 ft/min.	9.45 tons/min.	3.18	128.6
Case 2	21 x 5 in.	300 "	3.08 "	1.025	92.1
Case 3	21 x 4 in.	300 "	1.97 "	0.656	92.1
Case 4	21 x 4 in.	900 "	5.91 "	1.968	276.3
Case 5	21 x 4 in.	600 "	3.94 "	1.1312	184.2
Case 6	21 x 3 in.	600 "	2.31 "	0.775	184.2
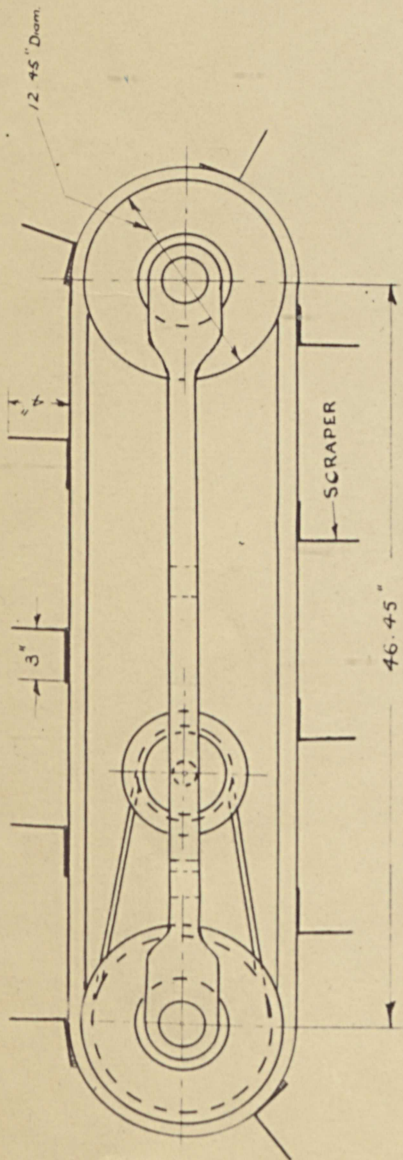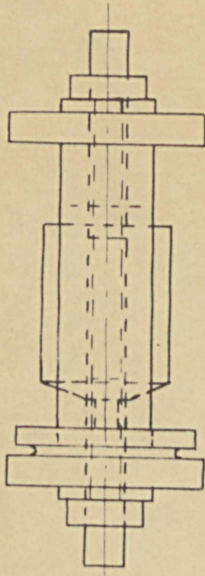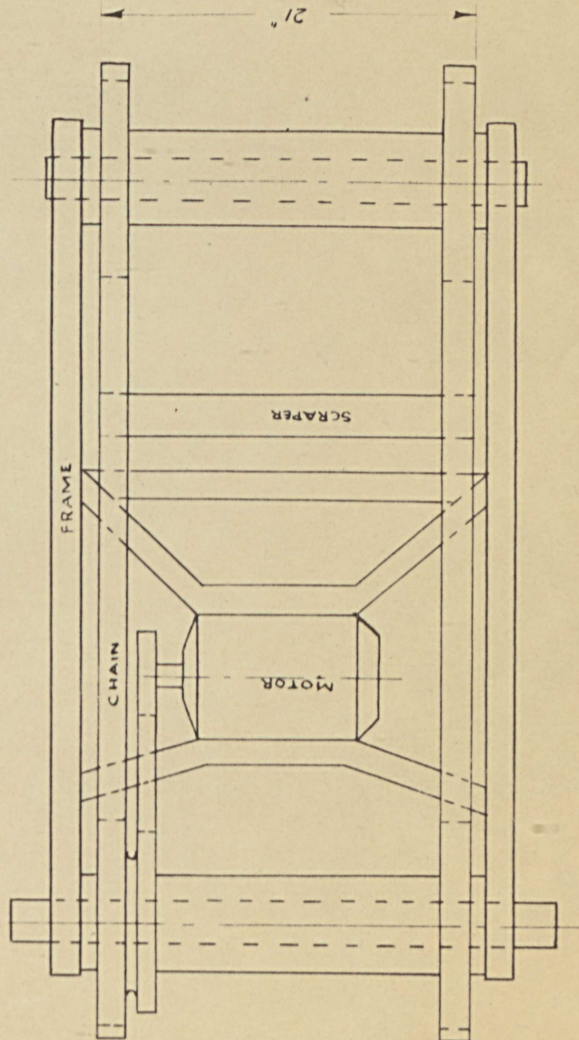
SIDE VIEW

SCHEMATIC DRAWING
OF
MUCKER

SCALE: 1" = 1'

12.45" Diam.

3"

46.45"

SCRAPER

FRONT VIEW

21"

FRAME

CHAIN

SCRAPER

MOTOR

PLAN

SPROCKET

SCALE : 1" = 5"

SECTION AA'

SECTION BB'
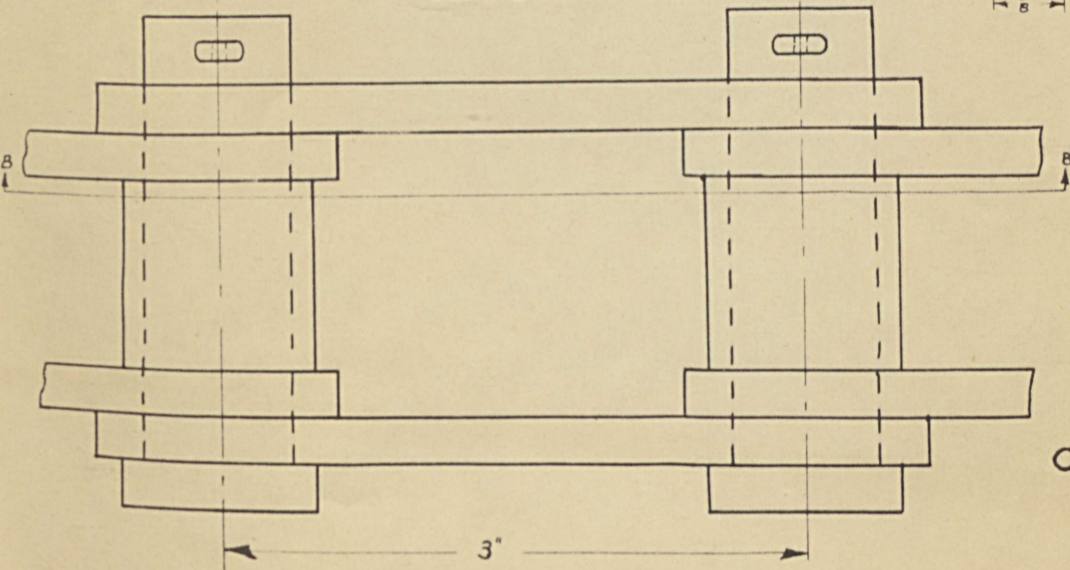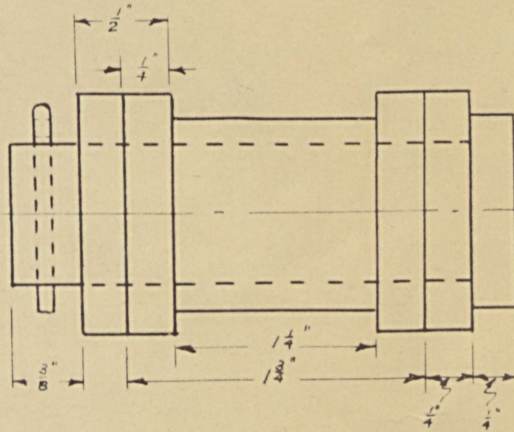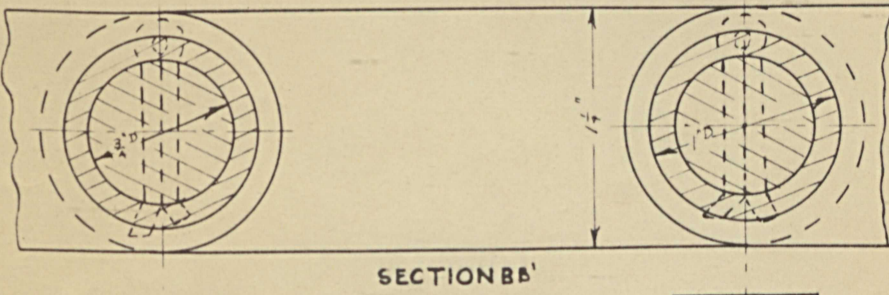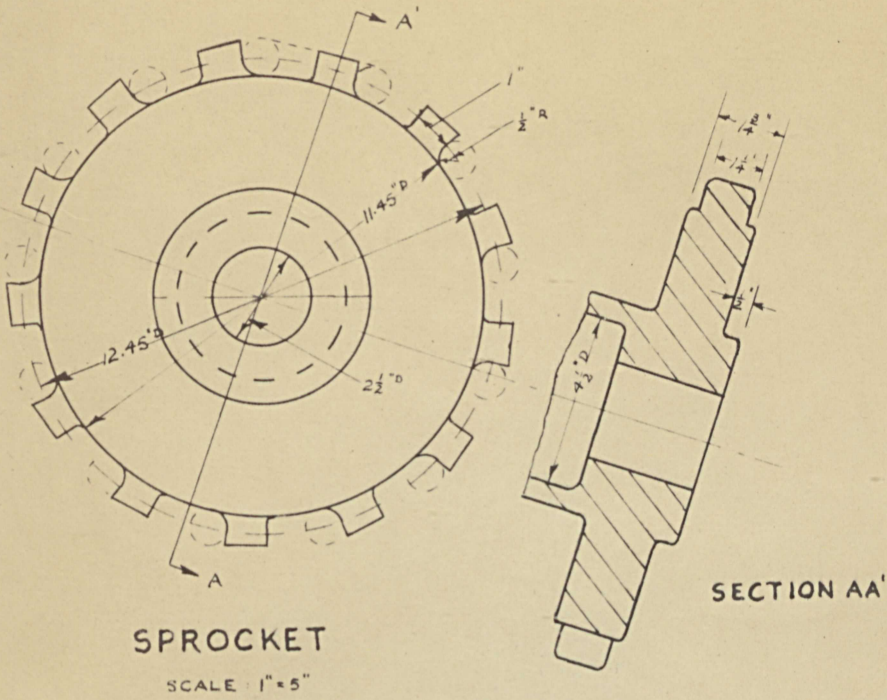
CHAIN ASSEMBLY

FULL SCALE

SUMMARY

Case 5 is selected as the intended design of the mucker. To insure good operation of the mucker a 3 hp motor should be utilized. This includes a safety factor of better than 2.

The attachment of the mucker to the bucket or loading pan is shown on p. 14. Also on p. 14 is a construction showing the volume of material moved during one run.

The volume of material which the mucker should be capable of moving during one run is calculated below. Angle of repose assumed is 60°. If a smaller angle of repose was assumed, a larger volume of material would be available. Therefore, a 60° angle is a safe assumption.

Calculations

$$\text{Volume} = \left(\frac{3.0 \times 3.6 \times 1.75}{2}\right) + \left(2 \times \frac{3.0 \times 1.45}{2} \times 3.6 \times \frac{1}{3}\right)$$

$$= 9.45 + 5.22$$

$$= 14.67 \text{ ft}^3$$

$$\text{Weight of material} = \frac{14.67 \times 135}{2000}$$

$$= \underline{1.0 \text{ ton}}$$

Loading pan dimensions

Dimensions: $2.25 \times 1.5 \times X = 14.67 \text{ ft}^3$

$$X = \frac{14.67}{2.25 \times 1.5}$$

= <u>4.34 ft</u>

With the loading pan dimensions equal to 2.25 x 1.5 x 4.00 ft, the volume of the pan will be 13.5 ft^3. If the material heaps up a little higher than just level with the top of the loading pan, then the capacity of the loading pan can easily reach that of 14.8 ft^3 or 1 ton.

1.5'

4.0'
(NOT TO SCALE)

45°

A   4.2'   B

3.6'

3.7'

3.0'

C
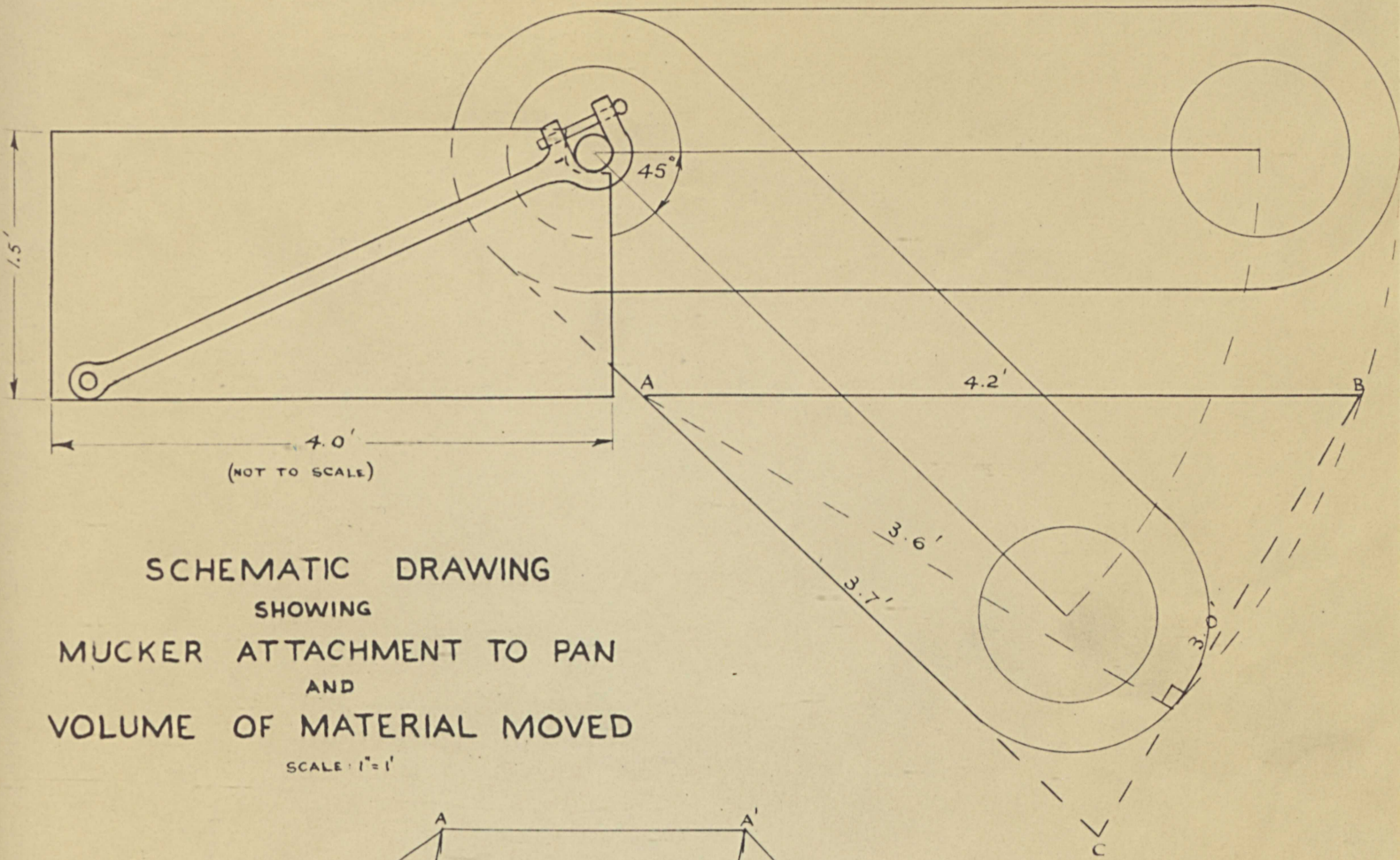
SCHEMATIC DRAWING
SHOWING
MUCKER ATTACHMENT TO PAN
AND
VOLUME OF MATERIAL MOVED
SCALE 1"=1'

A   A'

4.2'

D   1.45'   B   1.75'   B'   1.45'   D'

60°

3.0'   3.0'

C   C'
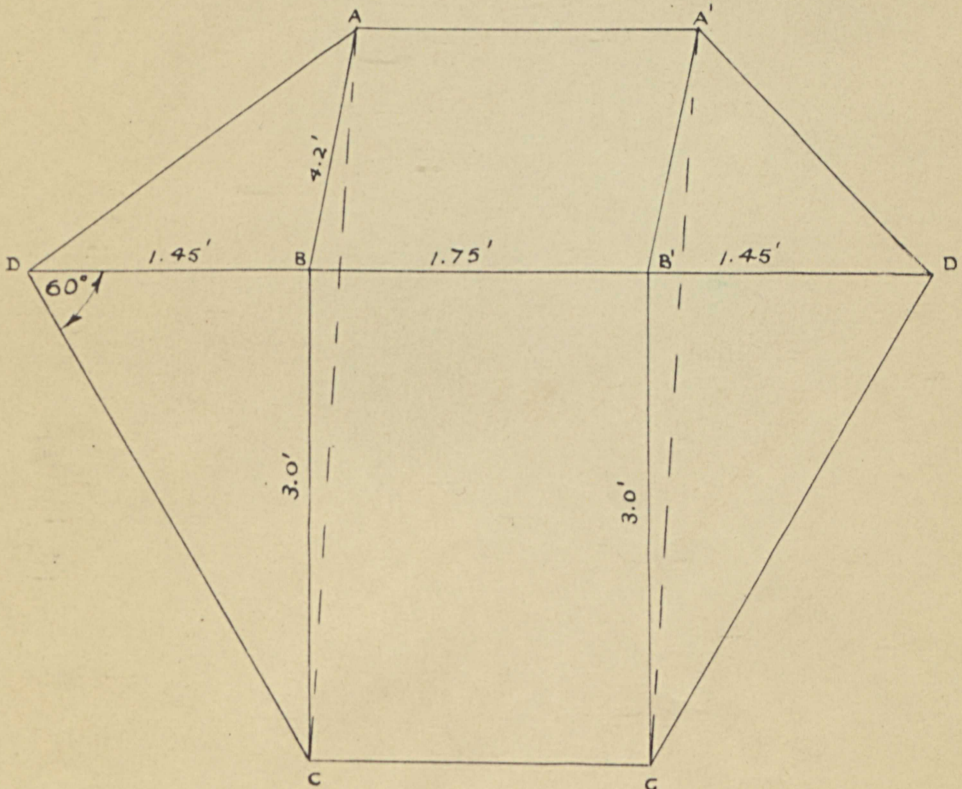
THE MODEL

INTRODUCTION

The working model does not quite resemble the intended appearance of the mucker. The model is very bulky in appearance, because it had to be manufactured from on-hand materials. The sprockets and chains are from bicycles (used parts). The motor used is an old juice-extractor motor. The rest of the material was obtained from scrap pieces in the workshop. The reason why such materials had to be utilized is the age-old reason: Lack of funds!

A good idea of the model and its construction can be formed from the photos on pp. 19, 20, 21 and 22.

The trials were run on crushed tungsten ore.

RESULTS

Center to center distance (sprockets) : 9.15 in.

Pitch diameter of sprockets : 3.25 in.

Scraper spacing (3 per ft) : 4.0 in.

Number of buckets : 7.0

Chain length 7 x 4 : 28.0 in.

Scraper dimensions : 3.3 x 0.75 in.

Motor (110 Volts - 1 Amp: 110 Watts = 0.148 hp) : $\dfrac{1}{6.78}$ hp $\dfrac{(1)}{(7)}$

Volume of material in loaded pan : 0.141 ft^3

Weight of material in loaded pan : 13.75 lb

Rpm of mucker when running free : 217.0

Rpm of mucker when mucking : 192.5

Time to fill loading pan : 28.6 sec.

Linear velocity of scrapers $= 192.5 \times \dfrac{3}{12} \times$

$$= 151 \text{ ft/min.}$$

Capacity of model $= 13.75 \times \dfrac{60}{28.6}$

$$= 28.8 \text{ lb/min.}$$

Specific gravity of material $= \dfrac{13.75 \times 1.0}{0.141}$

$$= 97.5 \text{ lb/ft}^3$$

Volume of material moved per minute $= \dfrac{28.8}{97.5}$

$$= 0.295 \text{ ft}^3$$

Number of scrapers per ft = 3

Volume of material moved per scraper = $\dfrac{0.295 \times 1728}{151 \times 3}$

$$= 1.125 \text{ in.}^3$$

If the shape of the body of material moved by a scraper is that of a triangular prism, then the dimensions of the prism are:

X x X x 3.3 in.
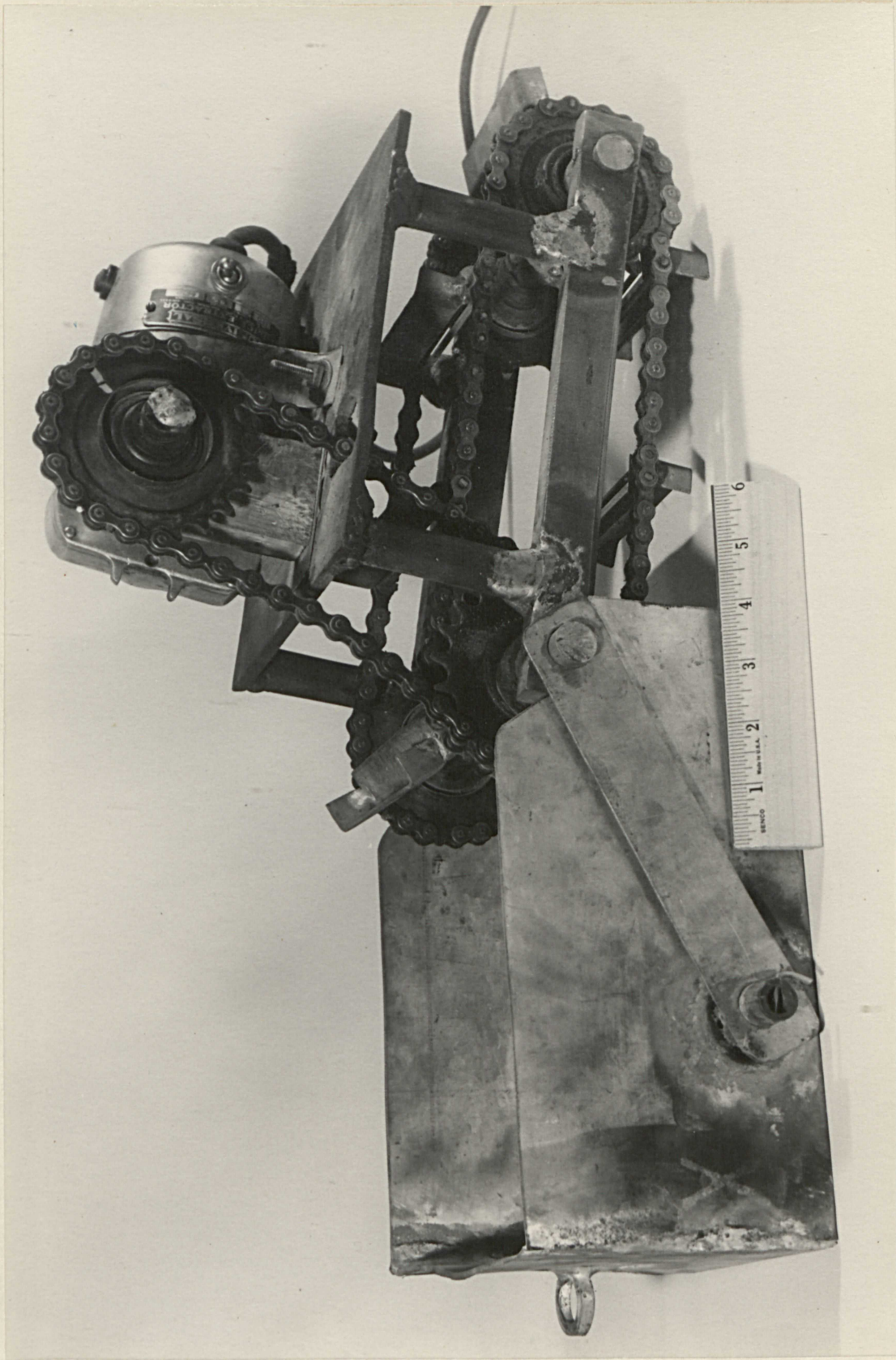
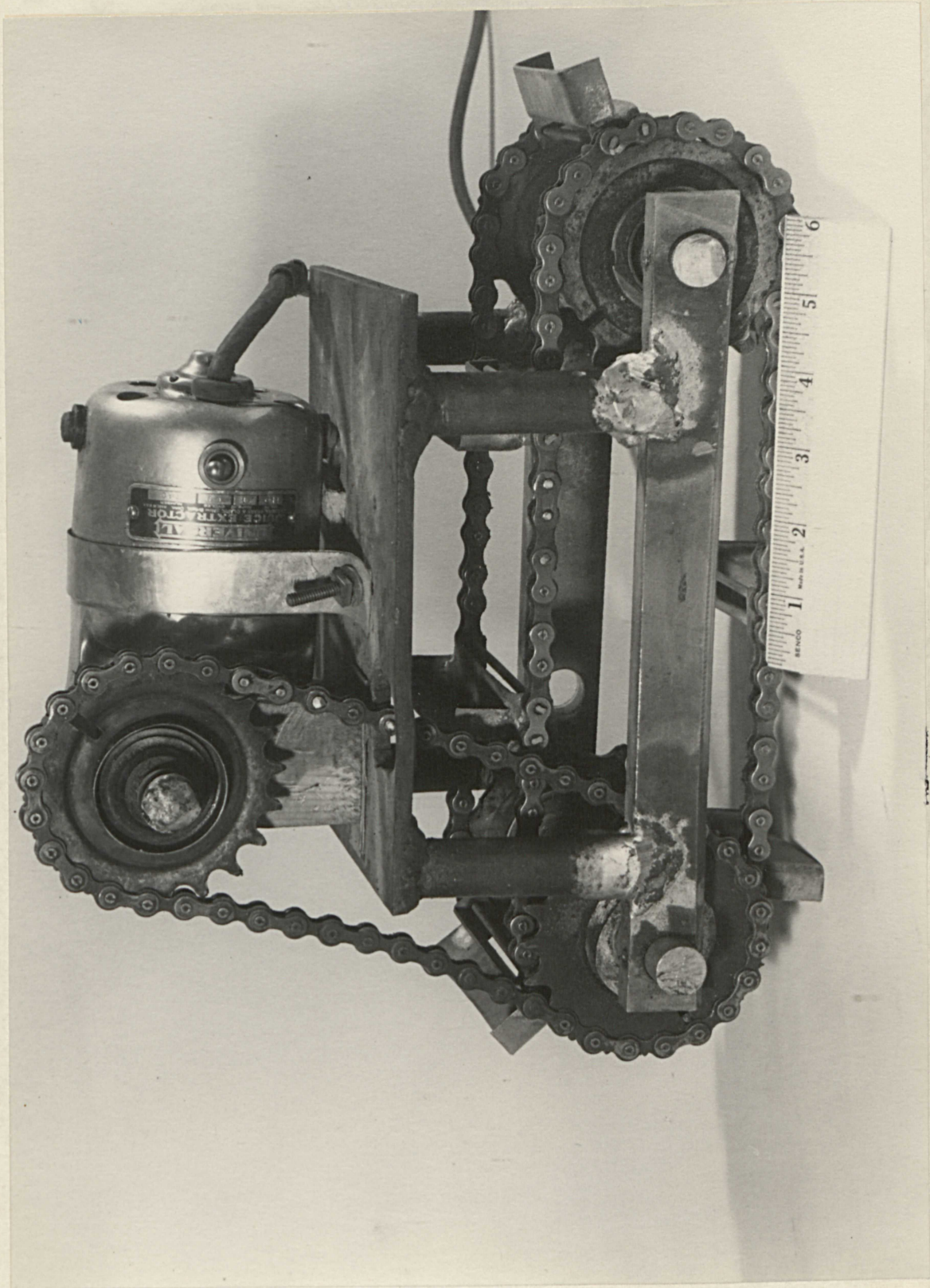but X x X x 3.3 = 3.3 X^2

$$= 1.125 \text{ in.}^3$$

$\therefore X = \sqrt{\dfrac{1.125}{3.3}}$
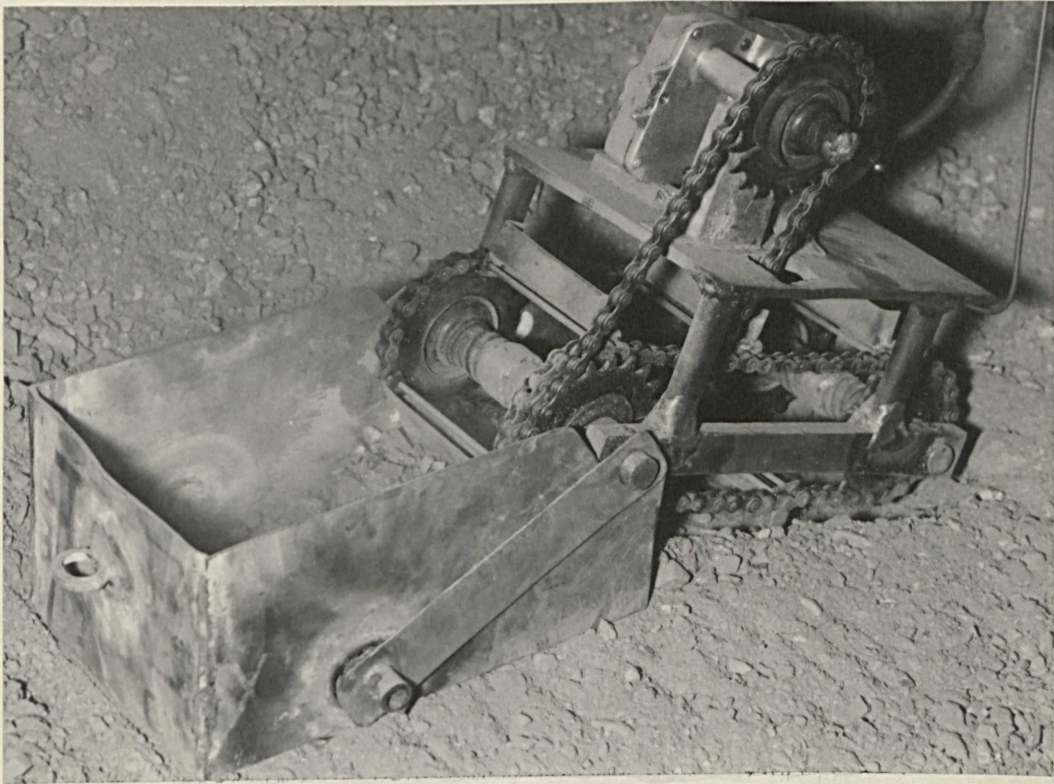
$$= \underline{0.533} \text{ in.}$$

The assumption on p. 7 of the shape of the body of material moved by a scraper (i.e. a triangular prism 5 x 5 x 21 in.) is a good assumption.

Mucker resting on loading pan in operating position.

Working model of mucker.

Model operating on crushed tungsten ore. (1/2000 sec.)

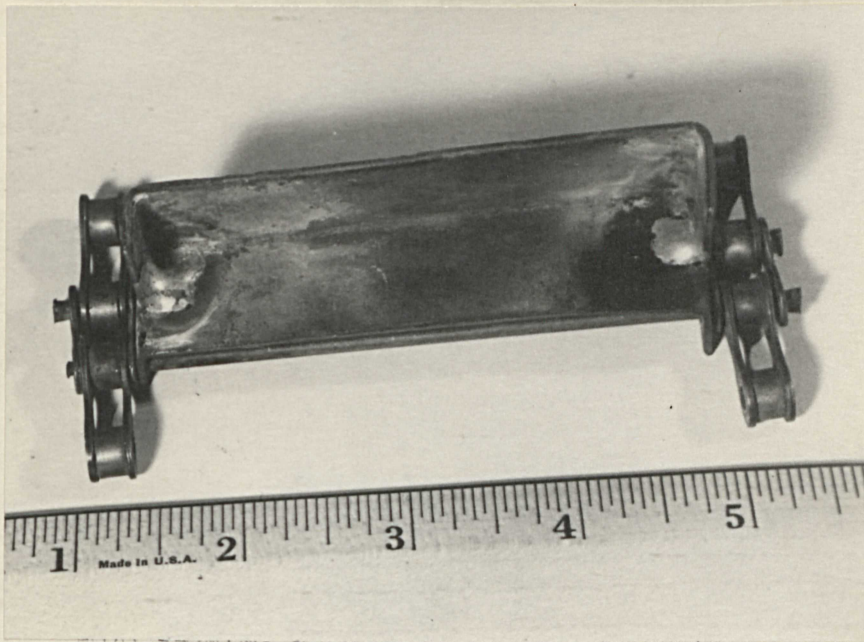Model operating on crushed ore. (1/100 sec.)

Photo showing scraper attachment to chain.

Photo showing scraper attachment to chain.

SUMMARY

The performance of the model was very satisfactory, as a matter of fact, the performance surpassed all expectations. It is amazing how much dust and dirt the little model could kick up out of the muckpile. The model filled up the loading pan in 28.6 sec. The approximate scale of the model is 1/4; because materials on hand were not exactly to scale.

No bearings were used in the model. The sprockets ran on brass shafts with heavy grease. Therefore, the friction in the model was very much more than it would be in a carefully-manufactured full-scale prototype.

The model is bulky but a full-scale mucker of this kind will not be as bulky. The motor will be inside the sprocket and frame assembly (see p. 10) and not on top of the frame work as the case is with the model.

CONCLUSION

The principle, employed in this mucker, has been proven, by
the trials with the model, to be suitable for mucking operations
in mine shafts, winzes and other similar mucking operations.

At this point I would like to express the wish that somebody
would be interested in financing the manufacturing of a full
scale prototype of the mucker and possibly the promoting if
the prototype proves to be worthy as a mucker. (The mucker
with no name - - yet.)