Shaft Sinking Investigation

Harold Foss

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A Thesis
Submitted To
Professor E. S. Stout

SHAFT SINKING INVESTIGATION

by
Harold Foss

May 27, 1954
Montana School of Mines
A Thesis
Submitted To
Professor K. S. Stout

SHAFT SINKING INVESTIGATION

25520

by

Harold Foss

May 27, 1954

Montana School of Mines
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Residence Hall
Montana School of Mines
Butte, Montana
May 27, 1954

Professor K. S. Stout
Mining Department
Montana School of Mines
Butte, Montana

Dear Professor Stout:

I am submitting my thesis on a Shaft Mucking Investigation according to your instructions given to me during this semester.

The thesis covers current mechanical shaft mucking methods with a comparison chart to better evaluate the different methods. As a conclusion I have brought in a possible future idea and discussed its mechanism and possible advantages.

I hope that this paper contains the information that you desire.

Respectfully submitted,

Harold Foss
Shaft Mucking Investigation

INTRODUCTION

This paper, investigating shaft mucking, has been prepared as a partial requirement for the degree of Bachelor of Science in Mining Engineering. In the following material I have attempted to collect and compile all available information on mechanical shaft mucking, to compare and contrast the different methods, and to trace their development through to the latest innovation. This development of the investigation is purposely being used to lead to a new method which will be discussed hypothetically as a conclusion to the paper.

Hand mucking in shaft sinking is no longer necessary because several efficient methods and machines have been devised for this purpose for use in both vertical and inclined shafts. For years shaft sinking was considered the hardest and most dangerous job in mining and, consequently, the turnover in shaft crews was high. This high turnover slows the operation because new men must be adjusted to the routine and peculiarities of the crew; accidents are more likely; and the costs of sinking increases. Mechanical shaft mucking has eliminated or alleviated the most disagreeable features of shaft mucking.

The most important advantage of mechanized shaft
mucking is the easing of the miner's toil. This single thing has made the entire sinking operation more efficient.

Although, it must be admitted that tremendous strides have been made by mechanizing shaft mucking, I think that the critical point in the shaft sinking cycle is still within the mucking phase. The record of the passed improvements in mechanized shaft mucking has been the most contributing factor in speeding shaft sinking and it would only seem reasonable to presume that future improvements will result in further ease and speed of this arduous and expensive task.

Published data has been utilized to describe and to discuss current mechanized shaft mucking methods. From this material a chart is devised for effective comparison and contrast in the respective performances. A bibliography will be found at the end to guide the inquisitive to additional data. As a further requisit to the writing of this paper worthy mention should be made of Professor K. S. Stout whose indispensable help and suggestions contributed most to make this paper possible. Of the others, who will remain anonymous in name only, I should like to thank also for the great help they have contributed of a more informal nature. With these thoughts in mind I would like to get started directly into the body of the report.
PRESENT MECHANICAL MUCKING METHODS

**Scraper and Slide**

In deepening its Fisher Hill shaft in the Adirondacks, the Republic Steel Corp. mucked the broken rock by slushing with a scraper and slide. Three tracks and a manway ran the entire length of the shaft. The center and north tracks were used for hoisting ore in 20-ton skips in balance. The south track was used as a man-and-material way, and also for handling some development muck. The center track was used for handling the shaft muck and was continually extended with temporary rails laid on the inclined rock floor of the shaft, so that it was kept within about 50 ft of the face. The scraper weighed 2500 lb, and the digging angle was 55 deg to the direction of the pull. A Fisher Hill innovation involved use of a longer scraper slide, so that the inclined approach from the shaft bottom to the skip did not exceed 40 deg. Scraping time was speeded 25 per cent by the use of the longer slide. Three shifts worked with this scheme -- one drilled the rounds and fired it, one scaled the roof, wet down, and moved the slide into position. The third removed the broken rock with the scraper and slide. The application of this longer slide and the sequence of operations made it possible to average a distance of 33.6 ft per week, or
about 7 ft per round. It would seem that this system would not interfere with the normal ore hoisting in the mine to a very large extent.

Riddell Mucker

Conceived and developed in 1942, and designed to speed the expensive and difficult task of shaft mucking, the Riddell mucker was by 1950 used in over twenty operations. In essence, it consists of a carriage, a frame, and a clamshell bucket. The steel carriage, on flanged wheels, moves horizontally along the long axis of the shaft, on a metal frame (see Fig. 1, page 5). Four hanging rods suspend the frame from the timbers overhead. Three air-driven motors are mounted on the the carriage, one serving the digging line, one the hoisting line, and the third the carriage movement. Two men originally rode the carriage, one handling horizontal movement, and the other operating the clamshell bucket suspended from it. The use of a double drum hoist has cut this to one operator. A light metal cover protects the men from falling water and particles. The clamshell loads directly into the buckets, and only the last 3 to 5 in. of muck left in the shaft bottom has to be hand-mucked. This material is picked and hand mucked into the clamshell while the bucket is being dumped. A 31-cu ft bucket can be loaded in 1 1/2 to 2 min. Pumping may be unnecessary, as the clamshell bails
FIG. 1. -- RIDDELL MUCKER
the bottom and drops both water and broken rock into the bucket. The single operator can achieve a high degree of control over the bucket, and can place it at any desired point in the shaft.

Boskovich Mucker

The Boskovich device, also constructed to operate inside timber, and easily placed in and removed from the shaft, was first developed and used at the New Park Mining Co's. May flower shaft in Keetley, Utah. This device features a power shovel dipper suspended beneath a mine cage. Four air hoists and an air piston provide swinging, crowding, and horizontal motion for the dipper. The cage to which the dipper is attached is constructed in accordance with the size of the shaft compartment, and its floor is mesh screen, enabling the operator to see the shaft bottom. An "A" frame is attached to the cage bottom, and to this a length of shafting is fixed at right angles to the long dimension of the shaft (see Fig. 2, page 7). A machine clamp and then an air piston, both attached to the shafting, terminate in a 5 1/2-cu ft bucket to form the dipper for digging. The bucket is moved by cables, the cables passing through traveling sheaves anchored to extension booms which extend horizontally from the cage in the direction of the long dimension of the shaft. The booms are adjustable, consisting of 2 1/2-in. pipe inserted
FIG. 2. -- BOSKOVICH MUCKER

A air hoist
horizontal dipper motion

B air hoist
vertical motion of mucker

air hoist
backward dipper motion

20 ft extension
crosshead

air hoist forward
dipper motion

screen floor

extension
booms

horizontal
motion
in 3-in. pipe. They can be quickly dropped below the cage when the mucker is hoisted for blasting. A man seated in the cage operates the dipper back and forth through the rock, using lever controls from two HU IR single drum hoists, and providing crowding action with a foot-operated valve controlling the aforementioned piston. In addition, three men work on the shaft bottom, leveling the muck pile, spotting the buckets, and operating a sponge pump. Only one or two buckets had to be hand mucked per round, as the dipper proved highly efficient in the final cleanup.

At New Park, use of the machine doubled the speed of mucking shaft rounds, shortened the time required to timber, and eliminated the need for staging in drilling station cutouts. It was noted there that use of the Boskovich machine had a favorable psychological effect on the crew and also saved physical effort for other phases of the shaft sinking cycle. When used as constructed namely, inside timber, the hazard of falling slabs resulting from too much open ground is reduced. **Inclined Shaft Mucking Device**

A self-loading skip good for 400-ft hauls has been developed at Bunker Hill for sinking an auxiliary shaft. Two machines are used, operating in balance in the shaft, which was sunk at a 50 deg angle. The frame is mounted on tracks. A steel section telescopes inside
this frame, and the digging bucket is mounted at its lower end. When the machine is lowered, a miner at the shaft bottom turns on an air motor, which actuates a screw mechanism and retracts the extended telescope section, to which the digging bucket is attached. The machine is then hoisted, the 1/2-cu yd bucket dumps into a small pocket in the footwall of the shaft. The rock is then transferred by slushing to a waste pocket in the main shaft. One machine is being loaded while the other dumps. A Pacific digging blade on the main frame serves as a butt plate, and as a means of cleaning down the footwall of the shaft. An illustration of this device will be seen on page 10, Fig. 3.

**The Benching Method**

Another method of eliminating hand mucking was used at the Quemont Mining Corp's. No. 2 (vertical) shaft at Noranda, Quebec. This idea involved the use of a Model 21 Elmaco rocker shovel, and a benching method. Each half of the bottom of the long axis of the shaft was drilled, blasted, and mucked out alternately. The bench at one end was kept 2 to 3 ft below the previous bench, thus piling in one end the rock blasted at the other end. Benches were blasted out at an average depth of 5.5 ft, thus giving an average advance of 2.75 ft per bench. After blasting, some hand mucking is necessary to make room for the loader at the toe of the
FIG. 3. -- INKLINED SHAFT MUCKING DEVICE

A -- truck
B -- main frame
C -- boom
muck pile. A section of tracks with extension side rails is lowered onto the long axis of the shaft bottom, and the loader placed on the track. Six or seven men place two 40-cu ft buckets into position behind the loader. These buckets are hoisted in balance. When the rocker has completed its work, hand mucking is again required to clean off the bench. While the loader is working, four to six men are completing the blocking of the shaft sets, lining hoisting compartments, and placing guides and pipe. On page 12, Fig. 4 an illustration of this method may be seen.

**Hydro-mucker**

Manufactured by the Hydrocrane Division of the Bucyrus-Erie Co., and used successfully at the Mather-"B" shaft of the Cleveland-Cliffs Iron Co., the Hydro-mucker is a 2/8 yd clamshell-type bucket weighing 1400 lb. A vertically mounted hydraulic ram actuated by 5000 psi oil pressure opens and closes the bucket. An IR-type hoist raises the bucket, it is swung manually over the muck pile, and lowered on the broken rock. When it descends, the ram closes the bucket, and it digs into the rock, coming up to fill a 2-yd tray which is then dumped into a mine car lowered into the shaft on a cage. The speed of mucking is dependent on the time required to dump the rock. Cleanup time at Cleveland-Cliffs was reduced 35 to 40 per cent through
FIG. 4. -- BENCHING METHOD

broken rock

loader

40 cu ft capacity
use of the Hydro-mucker. Two Hydro-mucker types are shown on pages 14 and 15, Fig. 5 and 6 respectively. Both types have the same source and type of power used to close the clam. They differ in the position of the piston and the attended center of gravity.

Dragline Bucket Principle for Inclined Shafts

The northward extension in depth of the Sterling Orebody of the New Jersey Zinc Co. required the driving of an auxiliary underground shaft. Sinking of the lower portion of this inclined shaft led to the development of a mechanical mucking method that proved itself beyond expectations.

The 8 by 18-ft cross section and the 52 deg pitch of the shaft ruled out any application of scraper and slide loading directly into the skip, while the limited shaft dimensions made difficult the use of scraper and loading pan or bucket.

The mucking method that was used was one of a dragline principle. A toothed lip bucket was designed and constructed, open at the front only, with pull and tail ropes hooked at either end. When a counterweight was added to the rear to prevent overturning, one or two passes would sufficiently fill the 13-cu ft bucket. The pull and tail ropes are then disconnected by means of open hook attachments, and an upper single drum hoist raises the bucket to a dumping position through a stationary sheave located at the front of the bucket.
FIG. 5. -- HI-HEAD HYDRO-MUCKER

- hydraulic hose
- pistons
FIG. 6.—LOWHEAD HYDRO-MUCKER

Open position

Closed position
The pull connection is then tied to a hook hanging over the center of the skip and the bucket is dumped by the lower hoist with a rope through a sheave in the hanging and fastened to the tail connection of the bucket.

A 20-ft-long sinking cage consists of a wheel chassis containing three built-in steel platforms; a single drum at the upper and lower platforms and the double drum which fills the bucket at the center.

Though an inexperienced crew was used, an average advance per shift was 1.97 ft. In one 7-hr shift a record of 2200 cu ft of rock was mucked or one skip every 9 min. Four men were sufficient to handle this mucking arrangement.

**Dual Mucking Machines in Inclined Shaft**

Successful use of dual mucking machines in sinking its 12 by 8-ft 26-deg incline shaft below the 1400 level of its Ophir mine showed United States Smelting & Refining Co. that the key to advance was an efficient mucking system.

Changes made to convert the loaders to shaft mucking were:

1. Making a steeper discharge angle on the bucket and adding 4 in. to the discharge lip.

2. Extending the rocker arms an inch from the frame to permit the bucket to swing freely to both sides on a wider-than-average arc. There was no trouble
keeping the sides cleaned down, though the rib was 2 1/2 ft from the track.

3. A 200-lb counterweight was attached to the rear of the machine. Its chief function was to increase the machine's stability for digging in the muck pile. On an angle of 26 deg the tendency is for the machine to nose over when digging in somewhat coarse muck and thus derail the mucker.

To anchor the loaders when in use, a double wrap of 3/8-in. cable was made around two adjacent track ties so that the end loops fell inside the rails (two clamps kept the cable from slipping). Two snatch blocks for each loader were hooked in the end loops and a 5/8-in. equalizing cable was run through the blocks. These cables were 48 ft long, although shorter lengths were available. The anchor cables were spaced at 40-ft intervals. The 60-ft drum cables of the loader were fastened to the equalizing cables by means of safety hooks. Fig. 7, page 18 will show a schematic arrangement of the cable anchorage for mucking.

Loading speed was determined largely by the fragmentation. In moderately fine muck, a skip could be loaded in as little as 1 1/2 min. During a mucking cycle, an average of 10 to 12 skips were loaded each hour. After sinking was put on an incentive basis, the average advance was doubled to 120 ft per month.
FIG. 7.-- DUAL MUCKING MACHINES IN INCLINED SHAFT

Section of Incline

3/8" anchor cable

5/8" 40 to 50' equatizing cable

Plan View

safety hooks

60'-3/8" drum cables

26 deg

cable overwinds on drum to hold mucker down
"Grab" Speeds Shaft Mucking

Perhaps the major drawback of shaft-mucking grabs has been lack of a power system for closing the jaws. From South Africa came a new design which opens and closes the jaws by air power, exerts full downward pressure on broken rock as the jaws close, and yet has the lower center of gravity necessary for stability. The grab (see Fig. 8, page 20) was developed by C. McLauchlan, E. A. Jahns, and H. Carlstein, all of Anglo American Corp. The unit was first used in sinking Free State Geduld No. 1 shaft in 1950, and has been used in successive Free State shafts. In previous shafts, boys hand-lashed (shoveled) broken rock into kibbles (sinking buckets).

The major units of the grab system are similar to those used in the Riddell system:

1. An operating platform is suspended below the bottom set. At Geduld No. 1, it consisted of a 10 by 46-ft framework upon which a traversing carriage moved to position the grab in the shaft bottom.

2. The operator rides on a traversing carriage which propels itself along the operating platform and which mounts the hoist from which the grab is suspended.

3. At Geduld No. 1 two grab-and-carriage units were mounted on the same operating platform. (When mucking
FIG. 8. -- AIR-POWERED GRAB

lifting eye

guides

pin

piston rod

side pivots

pivot bearing (fixed to cylinder)

cylinder

jaw
was completed, the grab and traversing carriages were hoisted to the surface).

The grab is suspended from a lifting eye which is immovably connected by the guides to the head of a two-way air cylinder.

The two grab jaws rotate on pivot bearings fixed to the cylinder wall. A pin inserted in the upper end of the piston rod is housed on each end by G. M. shoes which ride up and down on the guides. The pin, in turn, transmits force to link arms which actuate the jaws.

Important design features:

1. Because the link arms are almost horizontal as the jaws close, maximum closing force is transmitted to the jaws at the instant of closing.

2. Use of the two fixed pivots on each side (instead of a common pivot) allows for wide opening of the jaws and for full loading with only a shallow bite.

In Geduld No. 1, two grabs operated simultaneously, dumping into 4 kibbles (two 2 1/2-ton for one hoist and two 4-ton for the other). At designed speed, an operator dumps a grab-load every 30 sec. Two grabs excavate a 5-ft round (275 tons) in just under four hours.

"Cactus"-type Mechanical Grab

A new world shaft-sinking record was set in May, 1953, at No. 2 shaft, Vlakfontein Gold Mining Co. on
the Far East Rand, South Africa, when a total of 585 ft was advanced. The previous record, held by Virginia G. M. in the Orange Free State was 504 ft advanced in April, 1951. Vlakfontein's advance included concrete lining of the 24-ft diameter shaft at a depth between 3,700 and 4,000 ft.

Record speed is attributed in part to the "cactus"-type mechanical grab (mucking device) used to remove broken rock (see Fig. 9, page 23). This grab doubled the speed of mucking time and required only half the number of lashing boys (muckers) to complete the job.

The air operated cactus grab is based on the Priestman design modified and adapted by New Consolidated Gold Fields engineers. Vlakfontein workshops constructed the unit. The multi-point grab penetrates and gathers fine or coarse rock equally as well.

Capacity of the grab is one ton. It will load a 90-cu ft, 5-ton bucket in about 3 min, and clean and hoist more than 100 tons per hr. Leaves of the grab are tipped with tungsten carbide. The grab is mounted so that it traverses the shaft on a radial arm riding on a monorail attached to the main or lowest deck of the sinking stage.

Sinking and lining operations are run on a three shift basis. Two, 1-yd Blaw-Knox concrete mixers, mounted in the headframe, discharge into a common launder
FIG. 9. -- A THREE-DECK SHAFT SINKING STAGE

Blaw-Knox concrete bucket
concrete chute
8" dia rubber pipe for concrete
winch
center deck
concrete forms
blasting cable drum
scribe board
slewing wheel
slewing gear box
slewing motor
grab winch unit

20-cu ft cactus grab
drivers cab
90-cu ft bucket
fleeting wheel for cross traversing grab
rough diameter

top deck
finished diameter
operating platform
octopus
television cable drum
lighting cable drum
bell cable drum
main deck
curb rings
monorail
outer and inner roller tracks

28'-5"
feeding into a Blaw-Knox concrete bucket on shaft doors. The bucket is lowered and discharged into an "octopus" which feeds into the space between walls and shuttering (forms).

Concrete forms 11 ft high ride on a steel curb ring. Concrete is poured during the drilling shift. The lining is broken on 12 ft 6-in. centers with 18-in. spacings which will carry the permanent steel work of the shaft.

A three-deck sinking stage is used as shown in the following diagram. The monorail and grab assembly are attached to the lowest or main deck which also carries drum cables. The second deck carries the winch which lowers the shuttering. The top deck is used to extend pipes and control distribution of concrete. The cage is hoisted by a four-drum Fulton hoist.

The average sinking cycle is as follows: Re-entry period, 15 min; cleaning, 4 hr; blowing, 45 min; drilling, 1 hr and 15 min; loading and blasting, 1 hr and 25 min; average delay, 25 min; total, 8 hr.

The 5-ton sinking buckets are carried on rope guides. This shaft was therefore the deepest in Africa using rope guides. Vibration and resonance on the ropes present a problem requiring further improvements in design. One solution may be the use of different suspension weights on each of the pairs of ropes. Loaded
buckets are tipped by means of a chain hook hanging from the headframe in a 300-ton waste bin.

Discussion

In looking over the performance charts (see Tables 1, 2, 3; pages 26, 27, 28 respectively) care should be exercised in comparing data of one method with another because of such variables as character of broken rock, speed of hoisting, difference of cross section dimensions of shaft, shape of cross section (rectangular or circular), difference in number of men in mucking crew for a balanced cycle of operations.

All the vertical shaft methods use the same procedure as for handling the loaded rock to be removed from the shaft. That is, the rock is either loaded directly into buckets for hoisting or, as in the case of the Hydro-mucker, onto a tray which is dumped into a mine car on the cage. This means, of course, that an empty bucket must always be available to keep the loader busy and that the speed of cleanup is dependent on how fast the sinking hoist can empty the full buckets. Those operations which indicate that double-drum hoisting was used were able to keep the loading machines busy most continuously.

In the average cubic yardage mucked per man-hr, the figure varies in American methods from a low of 1.8 to a high of 3.7 for vertical shafts and as high as 7.5
TABLE 1. -- Performance Chart of Various Types of Mechanical Shaft Muckers

<table>
<thead>
<tr>
<th>Feet sunk/mucker:</th>
<th>Angle of shaft:</th>
<th>Type of rock:</th>
<th>Cross section dimensions</th>
<th>GPM water pumped:</th>
<th>How much left not timbered:</th>
<th>Type of Shaft Mucker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1562 ft</td>
<td>Vert.</td>
<td>St. Regis Quartzite</td>
<td>54 by 66&quot; I.D. 3 compart.</td>
<td>15 to 20 gpm</td>
<td>12 ft</td>
<td>Riddell</td>
</tr>
<tr>
<td>342 ft</td>
<td>Vert.</td>
<td>Quartz Diorite Porphyry</td>
<td>9 by 19 3 compart.</td>
<td>25 gpm</td>
<td>20 to 30 ft</td>
<td>Boskovitch</td>
</tr>
<tr>
<td>1463.5 ft</td>
<td>Vert.</td>
<td>Rhyolite Breccia-fractured</td>
<td>25 by 16 ft 5 compart.</td>
<td>2 1/2 Imp. gpm</td>
<td>20 to 30 ft</td>
<td>ETMCO (bench Method)</td>
</tr>
<tr>
<td>1820 ft (from 1273 to 3093)</td>
<td>Vert.</td>
<td>Jasper, Slate, &amp; Quartzite</td>
<td>13' 1&quot; by 18' 7 1/2&quot; 4 compart.</td>
<td>70 gpm</td>
<td>20 to 40 ft</td>
<td>Hydro-mucker (lowhead)</td>
</tr>
<tr>
<td>1100 ft</td>
<td>50° incl.</td>
<td>Quartzite</td>
<td>15' 2&quot; by 7' 6&quot; 3 compart.</td>
<td>20 gpm</td>
<td>5 to 15 ft</td>
<td>Bunker Hill design</td>
</tr>
<tr>
<td>1500 ft</td>
<td>33 1/2 deg incl.</td>
<td>Granitic Gneiss</td>
<td>10' by 30' 4 compart.</td>
<td>Minor flow</td>
<td>Generally no timbering</td>
<td>Scraper &amp; slide</td>
</tr>
<tr>
<td>1045 ft</td>
<td>52° incl.</td>
<td>Metamorphosed limestone</td>
<td>8 by 18' 3 compart.</td>
<td>Minor flow</td>
<td>No immediate timbering</td>
<td>Dragline Method</td>
</tr>
<tr>
<td>457 ft</td>
<td>26° incl.</td>
<td>Hard and siliceous</td>
<td>12 by 8' above track</td>
<td>No water</td>
<td>No timber</td>
<td>Dual Mucking Machines</td>
</tr>
<tr>
<td>548 ft below 3850 level</td>
<td>Vert.</td>
<td>Unobtainable</td>
<td>48 by 11' approx. rough dimensions</td>
<td>10,000 gph</td>
<td>Variable</td>
<td>&quot;Grab&quot; type Mucker</td>
</tr>
<tr>
<td>Unknown</td>
<td>Vert.</td>
<td>Unknown</td>
<td>24-ft diameter</td>
<td>Unknown</td>
<td>Approx. 20 ft</td>
<td>Captus Grab &amp; Staging</td>
</tr>
<tr>
<td>Initial cost of mucking machine</td>
<td>% of muck loaded</td>
<td>cu yd per man hour</td>
<td>average mucked per cycle</td>
<td>Average time to muck out</td>
<td>No. of men in mucking crew</td>
<td>Type of Shaft Mucker</td>
</tr>
<tr>
<td>--------------------------------</td>
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<td>-------------------</td>
<td>--------------------------</td>
<td>--------------------------</td>
<td>---------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>$6886.34</td>
<td>100%</td>
<td>3.7</td>
<td>55 cu yd</td>
<td>3 1/2 to 4 hr</td>
<td>4</td>
<td>Riddell</td>
</tr>
<tr>
<td>$1899.49</td>
<td>95% plus</td>
<td>2.75</td>
<td>55 cu yd</td>
<td>5 hr</td>
<td>4 per shift</td>
<td>Boskovich</td>
</tr>
<tr>
<td>$5402</td>
<td>70% per bench</td>
<td>1.08</td>
<td>81 cu yd</td>
<td>8.7 work hr per bench</td>
<td>8.6</td>
<td>ETMCO (bench Method)</td>
</tr>
<tr>
<td>$2000</td>
<td>99%</td>
<td>1.2</td>
<td>149.6 cu yd</td>
<td>13.4 hr</td>
<td>4</td>
<td>Hydro-mucker (lowhead)</td>
</tr>
<tr>
<td>$5000</td>
<td>98%</td>
<td>2.5 to 3</td>
<td>60 cu yd</td>
<td>5 to 6 hr</td>
<td>4</td>
<td>Bunker Hill design</td>
</tr>
<tr>
<td>$7500</td>
<td>100%</td>
<td>7.5</td>
<td>120 cu yd</td>
<td>8 hr</td>
<td>4 men-2 on each shift</td>
<td>Scraper &amp; slide</td>
</tr>
<tr>
<td>No record</td>
<td>95% plus</td>
<td>No record</td>
<td>1.97 ft advance per shift*</td>
<td>No record</td>
<td>5 men</td>
<td>Dragline Method</td>
</tr>
<tr>
<td>Cost of two Rocker Shovels+</td>
<td>95% plus</td>
<td>No record</td>
<td>2.50 ft advance per shift*</td>
<td>4 hr actual mucking</td>
<td>5 men</td>
<td>Dual Mucking Machines</td>
</tr>
<tr>
<td>No record</td>
<td>95% plus</td>
<td>1.07 tons per man hr</td>
<td>No record</td>
<td>No record</td>
<td>No record</td>
<td>&quot;Grab&quot; type Mucker</td>
</tr>
<tr>
<td>No record</td>
<td>95% plus</td>
<td>No record</td>
<td>585 ft advance **</td>
<td>4 hr actual mucking</td>
<td>No record</td>
<td>Captus Grab &amp; Staging</td>
</tr>
</tbody>
</table>

* added innovation costs
### TABLE 3. -- Performance Chart of Various Types of Mechanical Shaft Muckers

<table>
<thead>
<tr>
<th>Was time lost due to hoist capacity</th>
<th>Hoisting cap. cu yd per shift and depth</th>
<th>Capacity of muck bucket</th>
<th>Hoisting cost per 1 or 2 drum</th>
<th>Mucking cost per foot</th>
<th>Nature of rock</th>
<th>Type of Shaft Mucker</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>At start 16 - 1530', at end 14 - 1592'</td>
<td>32 cu ft</td>
<td>2 drum $27.07</td>
<td>Medium</td>
<td>Riddell</td>
<td></td>
</tr>
<tr>
<td>Yes -- 25%</td>
<td>At start 15 - 100 ft, at end 12 - 400 ft</td>
<td>21 cu ft</td>
<td>1 drum $29.02 (supplies)</td>
<td>Medium some coarse</td>
<td>Boskovitch</td>
<td></td>
</tr>
<tr>
<td>Negligible</td>
<td>At start 14.1 - 100', at end 12.1 - 1400'</td>
<td>29 cu ft net average</td>
<td>2 drum $59.34 (total)</td>
<td>Medium EIMCO (bench method)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes -- 30%</td>
<td>At start 20 -- to 100', at end 14 -- 1000 to 3000'</td>
<td>54 cu ft</td>
<td>1 drum $54.96</td>
<td>Varied from fine to coarse Hydro-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>At start 10 -- 600', at end 10 -- 1100' (new dump)</td>
<td>9 cu ft plus</td>
<td>2 drum No record</td>
<td>Medium (some slabs)</td>
<td>Bunker Hill design</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>100</td>
<td>150 cu ft</td>
<td>3 drum 50 hp hoist</td>
<td>Medium to coarse</td>
<td>Scraper &amp; slide</td>
<td></td>
</tr>
<tr>
<td>Yes -- not excessive</td>
<td>220 cu ft (record)</td>
<td>48 cu ft</td>
<td>1 drum No record</td>
<td>Medium Dragline Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes -- amount not known</td>
<td>Not available</td>
<td>34-cu ft skips</td>
<td>2 drum No record</td>
<td>Medium Dual Mucking Machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes due to limited bucket size</td>
<td>Not available</td>
<td>3.75 ton capacity</td>
<td>2 drum No record</td>
<td>Medium and wet &quot;Grab&quot; type Mucker</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No record</td>
<td>Not available</td>
<td>90 cu ft*</td>
<td>2 drum No record</td>
<td>Medium and wet Cactus Grab &amp; Staging</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Loads 90 cu ft (5-ton) bucket in 3 min or cleans and hoists more than 100 tons per hr
for the 33 1/2 deg inclined Fisher Hill shaft. Taking into account that the Quemont low of 1.08 is attributable to 30 per cent of the clean-up being done by hand and the Cleveland-Cliffs only averaged 1.2 because of the large crew maintained for balance in the timbering and drilling cycle, it is evident that the machines are comparable and all speed up the cleanup operation.

The Riddell mucker is reported to be able to handle large fragments impossible to move with a hand shovel. The Hydro-mucker is reported to have excellent digging characteristics because of the positive closing action of the hydraulic pistons. It has sufficient force to break rocks that tend to prevent the bucket from completely closing. The "Grab", besides having a positive closing action, has a larger opening span of its jaws (7'ft 4 in.) and a variable speed and strength of the closing jaws. The jaws start their closing slowly to achieve maximum digging and as the jaws come together the speed of closing increases with much force so that even wet conditions proves no obstacle. Stability is ensued by the low center of gravity and the grab will close or open in any position taken during the loading operation. The Cactus grab has all the above advantages and even more. By its circular open position of its multi-point jaw, the Cactus grab has better loading and gathering ability in its action, further it has a
larger capacity. It must be kept in mind however, that the phenomenal record of 585 ft in one month attested to the Cactus mucker is due also to the sinking staging used as well as to this new type mucker.

The inclined shafts show a marked increase in the rate of advance because of mechanical cleanup; this is less evident in the vertical shafts. In general, broken rock is easier to handle in inclined shafts, but in these cases faster hoisting, and the mucking machines and methods should be credited. The Bunker-Hill design is particularly ingenious.
POSSIBLE FUTURE SHAFT MUCKER

In describing a possible new type of shaft mucker, I should like to refer to a novel dredge pump described by George T. Bator in the September 1950 issue of Mining Engineering. The particular job demanded the pumping of a mixture of slime-free sand, gravel, and boulders up to 6 in. in diameter, at the rate of 175 tons per hr in one single-stage pump against a static head of 90 ft and a total head of 140 ft, of which 20 ft is on the suction side. Furthermore, the pump wearing parts must have a minimum hardness of 550 Brinell for the sake of abrasion resistance.

The most difficult demand to be met was a material which would stand up to the extreme hardness of the parts exposed to abrasion. The superior abrasion resistance of Ni-Hard is generally recognized but it is admittedly attained at the expense of decreased ductility so that the use of Ni-Hard had not been feasible in large dredge pumps of conventional design.

In the pump now to be described, this difficulty was circumvented by taking advantage of the incompressibility of water. A one-piece Ni-Hard casing liner of volute design is mounted in and surrounded by an outer casing of ordinary cast iron. The construction and the relation of the shell liner to the outer casing is such that there is a space of approximately 1 in. between
the two which is filled at all times with clear water, so that the shock and impact caused by the heavy boulders, rams, water hammer, or blow-backs, are cushioned by the confined body of water and thus transmitted to the heavy cast-iron outer shell. It is this feature of the design that enables the extremely hard and non-ductile Ni-Hard to withstand the heavy shock loads. This is one of the features most imperative for converting the novel dredge pump to a much more novel method of shaft mucking. At this point it must be kept in mind that this discussion is going to be largely of a hypothetical nature. What may look good on paper may give an altogether different impression when put to the actual test. Nevertheless, I shall make reasonable comparisons and assumptions and hope that the idea may seem feasible enough to stimulate a more worthwhile contribution to the shaft sinking problem.

First we see that in reviewing current shaft muckers, the critical point is in the initial grasp and lift of the broken rock from the muck pile. It would seem that a pressure differential could be used to lift muck in a shaft just as it is done in dredging operations. A total lift not exceeding 20 ft would be sufficient to remove the muck from the muck pile and discharge it into a container to be hoisted. Changes which I propose to make to convert the above described dredge pump of 140-ft
head to a muck pump of 20-ft head are the following:

1. Increase suction and discharge size to handle larger and courser material

2. Lay the pump on its side to reduce shock and impact caused by heavy boulders.

3. An open type of impeller with the bottom periphery removed so that the vanes hang down from the top periphery, thereby permitting passage of larger particles without increasing size and radius of the impeller.

4. Thicker vanes with reenforcement on the trailing edge would be necessary to make up for the lost support of removing the bottom periphery of the impeller.

5. A carriage, such as that used by the Riddell mucker arrangement, to either move the whole unit effectively around in the shaft bottom, considering the intake a rigid member, or, a carriage to move a flexible intake pipe while the pump itself remains stationary.

Advantages of this pump may be described as follows:

1. This device may be used in any type of shaft varying from vertical shafts to inclines and slopes

2. Fewer men will be required to operate this mucker

3. It could be used in the wettest or the driest conditions; with but the use of a sump pump to take
away excess water or in dry conditions water could be added to the muck pile.  

4. This device could be used for mucking out sumps.  

5. In some cases waste rock may be pumped directly from a development heading to a filling operation.  

Fragmentation is one catch to this type of mucker, but it is hoped that this system will prove of sufficient merit to warrant a study into obtaining better fragmentation.  

In conclusion, I can only say that at least my own interest in shaft mucking by this new method has reached the point where I would like to see it put to practical test. Perhaps a study of the comparison chart will give someone else in inspiration that will lead to some other new type of shaft mucker.
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