SOME INNOVATIONS IN EQUIPMENT FOR SCALING
HIGH ROOFS AND MINE WALLS

BY BRINTON C. BROWN, FRED D. WRIGHT, AND HOMER J. BALLINGER

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Brinton C. Brown, 1/ Fred D. Wright, 1/
and Homer J. Ballinger 1/

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1/ Mining engineer, U. S. Bureau of Mines, Rifle, Colo.

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SUMMARY

This paper describes the methods and equipment developed at the Bureau's Experimental Oil-Shale mine near Rifle, Colo., for placing men in position to scale loose rock from the walls, pillars, and roofs of high stopes or rooms. The equipment developed at Rifle has application not only in oil-shale mining but in most of the country's underground limestone mines and in the exploitation of other mineral deposits mined in high stopes by room-and-pillar methods. Equipment in use at Rifle includes:

1. A boom-type scaling rig with a self-leveling platform constructed on a small "cat"-mounted crane. Men working from the platform on this machine can efficiently scale mine walls and roofs 27 feet above the floor.

2. A conventional fork-lift truck modified to provide a remotely controlled working platform from which men can scale to heights 27 feet above the mine floor. The platform on this unit is larger than on the boom-type rig and allows the men to inspect larger areas of the mine wall from a single setting of the machine.

3. A third rig, consisting essentially of a platform mounted on a telescoping tower, designed and built to elevate men 65 feet above the mine floor. Versatility of this machine permits men to work from the platform at heights of 5 to 65 feet. In the operating position, the unit requires a minimum clearance of 25 feet. In the nonoperating position the tower of the machine folds to an over-all height of 15 feet 10 inches to permit travel through haulageways.

4. An industrial gun, lightweight scaling bars, and mechanical scalers, which have been tried for removing loose rock from the mine walls with varying degrees of success.

INTRODUCTION

Under the provisions of the Synthetic Liquid Fuels program, the Bureau of Mines is operating an oil-shale mine near Rifle, Colo. An important objective of the Oil-Shale Mining Division is to devise methods and procedures and develop equipment for mining oil shale on a commercial scale at the lowest feasible cost.

Study of the formation near Rifle indicated that a series of beds 73 feet thick presented conditions most favorable to commercial exploitation. A room-and-pillar variation of open-stope mining was the method selected with the aim to adapt as many surface-mining practices as possible to underground conditions, thus increasing output per man-shift and decreasing costs.
One of the many problems confronting the engineers developing the mine was the removal of loose rock from the roofstone and mine walls at various heights from 3 to 73 feet.

This paper describes the development of some new and unique scaling equipment in use at the experimental mine.

ACKNOWLEDGMENTS

All members of the Oil-Shale Mining Branch contributed ideas that aided in designing the scaling equipment. Fred D. Wright and other staff engineers prepared the specifications for the 27-foot lift platform and the 65-foot telescoping rig. Full credit must be given to W. H. Wagner, president of Mixermobile Distributors, Inc., for his cooperation in detail design and construction of both of these machines. Homer J. Ballanger, mining engineer, worked out the details for construction of the self-leveling platform on the boom-type scaling rig. Raymond Carlson, shop foreman, offered suggestions for fabricating scaling bars that reduced bar breakage by 50 percent. Lester Cargile and Charles Merrill, miners, noted the problems while they were scaling and testing the new equipment. E. D. Gardner, former chief of the Oil-Shale Mining Branch, was in close contact with the program and offered many valuable suggestions.

EXISTING CONDITIONS

Economic oil-shale beds of the Green River formation west of Rifle, Colo., outcrop 3,000 feet above the Colorado River and lie nearly horizontal, dipping less than 3 degrees to the west. The beds are not cut by faults and have relatively few jointing planes or vertical planes of weakness. Little local change in dip or strike of the beds has been noted.

The term "oil shale" is applied to a magnesium marlstone, a fine-grained sedimentary rock containing a solid organic material known as "kerogen," which yields shale oil upon heating. Oil shale, which occurs both thinly laminated and massive, is a tough rock with unusual resilience.

Overlying the 73-foot measure of mineable oil shale is a solid bed of barren marlstone ranging in thickness from 6 to 8 feet. This marlstone is the mine roofstone. It stands unsupported over spans of 60 feet or more.

The experimental mine has been developed by extending headings 60 feet wide and 27 feet high into the 73-foot series of beds under the uncemented bedding plane of the roofstone (fig. 1). Pillars 60 feet square, spaced 60 feet apart and staggered in one direction, support the roof. Two benches, each 25 feet high, follow as the heading is advanced. In a three-level operation there are working areas 27, 50, and 73 feet high. Haulage adits entering the working areas are 18 feet high.

Blasting in underground openings loosens rocks on the walls, pillars, and roofstone of the mine. These loose rocks present a condition that is hazardous and a menace to the safety of men and equipment and introduces the problem of raising men and light tools into position for removing the loose rocks.
Figure 1. - Lay-out of Underground Experimental mine.
Figure 2. - Traveling crane with self-leveling platform.
Figure 3. - Vertical profile of boom-type scaling rig.
"Scaling," often referred to as "barring," is the removal of loose rock from mine roofs and walls. Because each rock to be scaled presents an individual problem, it is difficult to design a mechanical scaler; therefore, at present scaling is done manually with lightweight bars.

Cost of scaling during periods of full production represents a substantial percentage of the direct mining cost.

The aim of scaling research is to devise more efficient means of scaling and, if possible, to completely mechanize the operation.

OUTLINE OF THE PROBLEM

Conventional scaling in drifts and stopes in metal mines is done at the beginning of operations by miners and their helpers. In immediate working areas, loose rocks in the back are removed with solid-steel bars before drilling and/or loading machines are set up. These areas are generally small, and the height from footing to back is relatively low. Scaling usually requires only a fraction of an hour.

In mines where open-stope methods of mining are employed, the height of roof above the floor is often more than 90 feet. In some districts, men employed as roof trimmers work a full 8-hour shift devoted to scaling from 100-foot ladders held in position by guy wires. The hazardous and arduous nature of the work led to higher wages for scalers or roof trimmers.

During the period of development of the Bureau's experimental mine, scaling was done by miners standing on truck beds and using steel-tipped bars with aluminum handles. Men worked from ladders to scale portions of the mine that could not be reached from truck beds. Manual scaling, makeshift scaling platforms, and ladders were time-consuming and inefficient. This led to the investigation of a lift machine for rapidly placing workers in position to scale. When the rooms were later developed to heights of 50 and 73 feet, a thorough job of scaling was essential to insure the safety of men and equipment, and development of such equipment was mandatory. The remaining portion of this report is devoted to a description and discussion of the Bureau's experience in the development of scaling equipment.

BOOM-TYPE SCALING PLATFORM

It was generally considered by the engineering staff that a platform mounted on the end of a boom would provide the best means of elevating men to a position for scaling, because (1) the machine controlling the boom would be out of the way of falling rocks, and (2) it would furnish a stable platform for the men working at various heights.

A Superior revolving crane mounted on an International TD-9 tractor was selected (fig. 2). Working on the pantograph principle, a self-leveling platform and a ladder were constructed on the crane boom. The boom connects to the tractor about 5 feet above the ground. As expanded metal platform 33 inches wide by 48 inches long, with a 42-inch-high guardrail, is pin-connected at the end of the boom in a position that does not interfere with the hoist cable (fig. 3). A ladder and handrail provide access to the platform and act as the upper arm of the self-leveling pantograph.
The revolving boom-swing angle on this unit is 275 degrees. It is readily seen that scalers are able to reach a wide area in the back without moving the tractor. The crane is provided with a positive locking device for holding the boom at any desired vertical angle both with and without the engine in operation.

When the boom is horizontal, the clearance height is 12 feet. With the boom fully elevated, a drill can be mounted on the pipe guardrail to drill plug holes into the roofstone for eye pins to support electrical cables, etc. At a slightly lower platform position, the roofstone can be inspected thoroughly by the miners, and loose rock can be removed when necessary.

Several advantages of the boom-type scaling platform are:

1. It enables men to work above obstacles on the floor.
2. There is no damage to the equipment due to falling scaled rock.
3. Men are moved to any desired position easily and rapidly.
4. The machine may be used as a portable crane without interference from the platform.
5. It is very handy for mounting percussion drills or stoper machines for drilling plug holes into the roofstone and ribs.

Some disadvantages of the machine which led to the development of a new type of scaling platform are:

1. A remote-control device on the platform to maneuver the boom up and down and laterally was impractical to incorporate in this type of machine.
2. The tractor must be moved to and from the face as the boom travels in an arc when moved up and down.
3. On uneven floors, the weight of the men on the end of the boom sometimes causes the machine to tilt - in effect, a seesaw motion - even though the boom is designed to carry 1 ton at all platform heights.

FORK LIFT-TYPE SCALING PLATFORM

A special piece of equipment was designed and constructed primarily for charging blast holes, some of which are 25 feet above the floor of the mine (fig. 4). This unit is also used as a scaling platform. No similar equipment designed specifically for this purpose is in use elsewhere, to the authors' knowledge.

This unit is a modified Wagnermobile Duo-Way lift machine adapted to elevate men and explosives to various heights above the mine floor. It consists of a three-wheeled fork-lift truck with 23-foot vertical tracks (fig. 5). A 5- by 10-foot wooden platform encircled by a 42-inch guardrail is mounted on the fork tines of the truck. The truck is powered by a Diesel engine.
Figure 4. - Mobile blaster's platform used for scaling.
Figure 5. - Vertical profile of fork lift-type scaling platform.
The tower on this unit can be tilted forward about 8 degrees and tilted back 12 degrees from vertical by a hydraulic control. The tracks are hinged at a point 12 feet above the floor, and folding is controlled hydraulically. With the track tilted back and the top section folded back, the traveling height is 12 feet 6 inches.

The carriage can be operated with the track in any position. A remote-control device was installed between the tracks to lower the men and supplies after the platform is raised. It consists of a fixed cable that can release the mechanical brakes. When the engine is not running, this permits lowering of the platform. Because there is no practical remote hoist control available, one man must operate the hoist from the truck cab to raise the platform. A sectional ladder (fig. 4) was welded to the side of the tracks for access to the raised platform.

Over-all width of dual wheels is 96 inches, which provides enough lateral stability to prevent falling over when tilted sideways at a 10-degree angle to the horizontal with a load of 1,000 pounds on the platform in its top position, i.e., 19 feet 6 inches above the floor.

The unit has several advantages over the boom-type scaler:

1. The remote control brake release enables the scalers to start scaling at the top of the face and work down to the floor without leaving the platform to operate the controls.

2. The greater length of platform eliminates congestion and allows the scalers to bar a greater area for each movement of the truck.

3. Stability of the machine both laterally and axially is greater, which eliminates seesaw motion on uneven floors.

4. Tilting the tracks forward makes it easy to work above and over any loose rock on the floor at the face. Also, tilting enables the men to work with ease around any irregularities that may occur in the face and walls without moving the truck.

There are some disadvantages of this type of machine:

1. The height of room that can be scaled is limited, as the truck is capable of supporting only a slightly higher track.

2. The front of the truck and tracks are vulnerable to falling rocks because of close working conditions.

3. Chassis clearance above the floor is low, and often it is necessary to remove scattered rock to avoid damage to the underside of the truck.

4. Loose rocks become wedged between the dual tires.
65-FOOT SCALING RIG

As the middle bench advanced in accordance with the proposed mining method, loose rocks on 50-foot-high pillars and walls presented a problem. A new scaling unit with a higher lift was required. Relative advantages of the boom-type scaler and lift-truck scaler were considered before specifications for the new machine were prepared.

Most of the leading manufacturers of lift machines were contacted. Mixermobile Distributors, Inc., offered to work with the Bureau on the design and construction of a unit that would operate in any room 25 to 73 feet high. This unit (fig. 6) was called a Wagnermobile telescopic lift truck.

The telescopic lift truck (fig. 7) consists of a three-wheeled truck 22 feet 10 inches long by 11 feet wide supporting a sectional tower. Minimum operating height of the tower is 21 feet (fig. 8). The working platform travels along vertical tracks on the outside section of the tower from the lowest position (56 inches above the floor) to the maximum height of the base section of the tower (21 feet). Upon reaching the upper limit of the base section of the tower the platform is automatically locked to the innermost section of the telescoping tower. With the carriage locked on the top section of the tower, the platform may be raised to a maximum of 65 feet (fig. 9) by extending the other three sections of the telescoping tower. Hoisting is accomplished through a cable and pulley arrangement, as shown in figure 7.

The truck and hoist controls are powered by a Hercules 6-cylinder Diesel engine.

The working platform is 14 feet long by 3 feet wide and is enclosed with a guardrail 42 inches high. The entire platform is made of steel and has an expanded metal floor. The top front member of the guardrail is made of 3-1/2-inch heavy-column pipe to provide a mount for percussion drilling machines.

The tower can be tilted forward 10 degrees and tilted back 5 degrees from vertical by hydraulic rams. When telescoped, the tower can be folded back by hydraulic rams to a position horizontally over the cab of the truck. Traveling height with the tower folded is 15 feet 10 inches (fig. 10).

Lateral stability is increased by two stabilizers 10 feet long, which can be extended when needed. Without these outriggers, the unit has enough lateral stability to operate on floors having a slope of 10 degrees with a 1-1/2-ton load at the top platform position.

A ladder is provided on each section of the tower for accessibility when the platform is raised. As shown in figure 7, a cable and reel are mounted on the platform guardrail. This is a remote control for releasing the mechanical brakes. A hydraulic device operated through a gear reduction retards the speed as the tower is lowered.

This unit has been useful for numerous jobs inside and outside of the mine in addition to scaling. These include maintenance of electrical equipment suspended from the back, elevating men for pillar research measurements, and for a variety of tasks requiring the elevation of men and equipment to high positions.
Figure 6. - Sixty-five-foot scaling rig in rooms 50 feet high.
Figure 7. - Vertical profile of telescopic lift machine.
Figure 8. - Using telescopic lift scaler in rooms 27 feet high.

Figure 9. - Example of versatility of the 65-foot rig; use in the mine yard.
Figure 10. - Sixty-five-foot scaler folded for traveling through 18-foot haulageway.
Figure II. - Light-weight scaling bars in use at the oil-shale mine.
Advantages of a unit of this type are:

1. There is a large saving in the capital investment when using one machine versatile enough to operate on any level of the mine.

2. Providing an elevator at any desired place quickly and easily is a great advantage.

3. Mounting tools, drills, etc., reduces the amount of labor required to do odd jobs at elevated heights and results in big savings in time and money during a period of high wages.

Some disadvantages are:

1. The front end and base of the tower are vulnerable to falling rock. An armor plate about 8 feet high should be attached to the bottom of the unit to protect the base.

2. The chassis is too low, and clearance is not always enough to permit moving the machine over rough places in the mine floor.

3. A desirable feature on this scaler would be a hoisting control on the platform in addition to the brake release. Remote-controlled tilting from the platform also would be advantageous.

SCALING BARS

Common practice in many metal mines is the use of solid-steel bars for scaling. At the Sullivan mine in Canada, steel bars were replaced by aluminum tubing in 1927. Present trend of the industry is to adopt magnesium and aluminum alloy tubing for scaling bars.

Because our scalers use the bars for an entire 8-hour shift, light weight is of primary importance. As shown in figure 11, the design of bars in use at the experimental mine is simple. The steel tip is made of 1-1/8-inch high-carbon tool steel fabricated in our shop, as follows:

1. The shank end of the steel tip is turned and threaded on a lathe.

2. The tip is forged and then air-cooled.

3. About 2-1/2 inches of the forged tip is reheated to a temperature just below dull-red heat and quenched in water to harden.

The purpose of the slight bend in the tip is to provide a fulcrum near the working end.

At the present time, handles are made from a 1-inch standard 61ST aluminum tubing. The tubing is 1-inch I.D. and has a wall thickness of 0.133 inch. The point at which failure occurs most frequently is the base of the threads in the aluminum section. A possible way to overcome this trouble would be to use a shrink fit or a resin-type cement or rivets to hold the tip in place. Scaling bars are fabricated at an approximate cost of $3 a bar.
Future investigations will include testing various grades and shapes of extruded aluminum alloy tubing. One-inch-square aluminum tubing has been used successfully in one mine for a number of years. A magnesium alloy may lend itself to the best improvement in lightweight scaling bars because, with greater wall thickness to give equal stiffness, there is a greater saving in weight over aluminum tubing. In addition, the physical properties and weldability of magnesium may be amenable, so that steel tips can be replaced by the lighter magnesium alloy. This would make an ideal manual scaling bar.

INDUSTRIAL GUN

A number of mines and quarries in this country have used the Remington Industrial Gun with remarkable success in the removal of loose rock from mine walls.

The gun, weighing 92 pounds is approximately 8-gage. It is fired by a lanyard connected to a rotating sear, which releases a rotating hammer that strikes the firing pin. The gun is single-shot, requiring manual opening and closing of the mortise-type breech block.

Ammunition used has the appearance of an over-sized shot-gun shell. It is loaded with a three-ounce lead projectile that develops a muzzle velocity of more than 1,600 feet per second. Having a muzzle energy of 7,575 pounds, approximately 3-1/2 foot-tons, it delivers a powerful blow. The manufacturer reports the energy at various distances as follows:

<table>
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<th>Yards</th>
<th>Foot-pounds</th>
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<tr>
<td>50</td>
<td>5,684</td>
</tr>
<tr>
<td>100</td>
<td>4,387</td>
</tr>
<tr>
<td>150</td>
<td>3,584</td>
</tr>
<tr>
<td>200</td>
<td>2,987</td>
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</table>

As shown above, at 200 yards the blow struck by the slug is approximately 1-1/2 foot-tons. Some quarries report effectiveness at 1,000 feet.

Aiming is accomplished through open sights cut in the gun cradle or by bore sighting.

The gun in use at the oil-shale mine is mounted on a war surplus bomb trailer, as shown in figure 12. It is easily adjusted horizontally by means of a hand crank (traverse gear) and vertically by means of a hand wheel, so that it may be aimed quickly and accurately.

Tests include dislodging overhanging icicles on the cliffs, which menace the safety of men and equipment. Large icicles were removed very successfully at distances ranging from 50 to 200 yards. Protruding rocks on pillars at inaccessible places in rooms 50 feet high have been removed. Some rocks were not removed. This was due in part to the elastic qualities of the rock and shooting at points on the rocks not favoring their fractures. The effectiveness of the gun depends on the prowess of the operator who aims it.
Figure 12. - Industrial gun used for removal of loose rocks on mine walls.
The gun will be tested more thoroughly as the benches advance. Although use is limited, the gun has an application in scaling areas where broken rocks on the floor prohibit the use of lift machines.

COSTS

The Bureau's experience with various types of lift trucks and boom-mounted platforms clearly shows the economy of these machines in allowing efficient use of scaling labor in high stopes. The initial cost of such machines is relatively high, but the saving in labor resulting from their use outweighs the investment cost. The approximate cost of this equipment follows:

- Boom-type scaling platform.................. $7,500
- Fork lift-type scaling platform................ 8,500
- 65-foot telescoping scaling platform......... 12,500

The units provide safe access to elevated positions and eliminate the use of ladders or other more hazardous equipment. In addition, the mine walls and roof can be inspected regularly and efficiently to insure safe working areas throughout the mine.

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