EVOLUTION OF UNDERGROUND MINING EQUIPMENT

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INTRODUCTION

Equipment developed for open-pit mining adapted to large room and pillar underground work and new innovations in high speed drilling and blast hole loading is increasing production which in turn, under proper management and labor climate, will reduce mining costs.

An economical mining operation does not just happen any more than does success in any other business. Some basic criteria must be followed in making mining economic feasibility studies whether it is a study of a coal, zinc, iron ore, or an oil shale property. These studies often disclose conditions in extreme variance to initial published data on a mineralized area and its quoted reserves.

RESERVES

The United States Geological Survey, in the reserve publications, have used a minimum thickness of 5 feet for 45 gallon-per-ton and 15 feet for other grades of oil shale to arrive at an average 15 gpt production. For their purpose, which is to provide general information, the criteria is not questionable. However, in initial valuation of an ore body, or mineralized area, it must be reanalyzed by mining engineers to determine the practicability of mining and to arrive at an estimated cost, and by chemical engineers relative to usable grades and required refining processes consistent with today's technology. Any other basis used to arrive at a value for a mineral or an oil shale deposit is erroneous and without economic foundation.. For example:

A thickness of 15 feet of oil shale cannot be economically mined underground with today's tools and knowledge. It is doubtful that continuous beds less than 25 feet in thickness can be mined at prices compatible with the overall cost of producing synthetic crude from oil shale.

Also, until a great deal more is learned about retorting and associated processes, it appears uneconomical to mine, retort, and hydrogenate a product containing less than 25 gpt and very likely for the first few years the bottom grade will be in the vicinity of 30 gpt.

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In view of the foregoing, I would like to see some words of caution added to statements of reserves for the unenlightened. It is known by engineers that only a fraction of the huge tonnage of oil shale contained in the Green River Formation of Colorado, Utah. and Wyoming is exploitable on the basis of present or future projected technology.

MINE FEASIBILITY STUDIES

Typical room and pillar mining procedures have been worn out at these symposiums. Maybe you'll agree with me that we could have an oil shale industry in operation if all the words expended on the subject had been turned into useful energy. I'll try to refrain from repetition of details except that some points covered in mining studies must be repeated. We find that large rooms are essential to generate low mining costs. Large rooms permit the use of high capacity equipment. Often the same equipment is used in large volume open-pit mines except that it is modified to work under a roof and under adverse ventilation conditions.

Any consideration of mining must assess the thickness, extent, and quality of the product to be mined. Possibility of encountering any appreciable amount of water must be determined; haul grades to be negotiated, hardness of material to be mined, and the ability of the material to maintain a stable configuration during mining must be ascertained. Underground the stability of roof rock must be known. After all necessary physical knowledge is gained from a mineable property, it is assessed in conjunction with types of machinery most suitable for the type of mining required.

A revolutionary change in mining machinery has developed in the past decade with the most outstanding changes coming in the last half. In underground mining it might be more appropriate to say the application of machinery has been revolutionary.

DRILLING AND BLASTING

For many years underground mining tools were more or less standard "off-the shelf" items with little change in design from model to model. Operators were reluctant to risk down time and resultant loss of production often experienced with new tools. Manufacturers knowing the difficulty encountered selling an unknown model of drill or excavating machine did not push for changes which were expensive for them in retooling. A new educated breed of operator has come of age in recent years with demands for more sophisticated and better tools. Not long ago drills were so cumbersome both an operator and a steel and bit tender were required for each drill. Blast holes were hand loaded with expensive explosives and were usually fired with electric blasting caps. In addition to being expensive, often costing 12¢-15¢ and higher per ton blasted, the operation was hazardous through the use of the highly explosive blasting caps, electrically detonated, and the use of dynamite which in itself is not an entirely stable commodity. The use of fertilizer grade ammonium nitrate and oil with primacord has lessened the hazard to a great extent. Accidents from drilling a missed hole, an extreme hazard in past years, are almost non-existent.

BLAST DETONATOR

For those present who are unfamiliar with mining and its terms, primacord is a detonating fuse used primarily for initiating commercial explosives. It is a very strong, flexible cord with a core containing an explosive. When initiated with a blasting cap it detonates along its entire length at a velocity of nearly 21,000 feet per second and has the initiating energy of a blasting cap at all points, it will initiate branch lines, when used as a trunk and will detonate all cap-sensitive explosives with which it comes in contact. Thus the numerous loads of explosive in a mine face can be exploded with this product from a remote position with assurance that all loads will detonate if properly loaded and connected.

Very recently non-electric millisecond delays have come on the market for use with primacord. These delays are small interrupters varying in time of interruption. The explosive engineer can blast one load or string of loads according to his requirements by placing these delays in branch lines to fire in the desired sequence. If this were not done and all holes exploded simultaneously, extensive damage by fracturing could be done to roof and side walls. The damage could have the unhappy effect of requiring an excessive amount of time to scale the walls and roof; that is, remove loose pieces that could fall and damage equipment or injure men. Another result could be the fracturing of the face ahead to a point where drilling would be slow and would promote sticking of steel and bit breakage, or progressive damage could be so great that the mine would have to be closed for safety reasons.

By one of several ways' holes are drilled in such a manner as to force the center section of a face out into the mined area to leave a void into which successive blasted material can fall; then holes surrounding this so-called relief cut are blasted in a predetermined sequence to shape the advance heading. Complete explanation of the many systems of relief cuts and direction and spacing of perimeter blast holes could take up another symposium session. Every miner has his own pet scheme for drilling and blasting. Oil shale is uniform enough in density so that a pattern can be devised and programmed into a drill that will make the same cut day after day. Sounds monotonous but again it must be remembered that machines and not men will do oil shale mining. Of course, when large nacolite pockets are encountered an operator with experience must take over from the machine and use his judgment on procedure. The few operators required will need skills in electronics and associated subjects never dreamed of by miners 20 years ago.

Ammonium nitrate with about 5 percent diesel fuel was pioneered as a blasting agent in open-pit mines in 6-inch to 12-inch diameter blastholes. In the beginning a large charge of dynamite was placed in the bottom of the hole with its blasting cap and the ammonium nitrate was poured in rather haphazardly. Continued use, experimenting with the oil mix, amount of explosive required to detonate the ammonium nitrate, and assessment of results led to today's refinement. Today, trucks equipped with mixers, scales, and conveyors load a precise predetermined amount of explosive in each hole.

It was thought that ammonium nitrate would not propagate in small 1-1/2-inch to 2-3/4-inch blast holes used in underground work. However, it was learned by trial and error that the AN/FO would propagate and break the rock in a commendable manner in 2-1/2-inch holes provided the AN/FO could be well compacted into the blast hole. This was done by the simple expedient of building a typical sand blasting nozzle and blowing the AN/FO and stemming through a hose inserted into the hole. These early experiments were carried on while still using electric blasting caps and dynamite as an initiating agent for the ammonium nitrate and oil mix. One day someone detected a blue static spark generated by blowing the material through the hose . . . needless to say, further experiments were suspended pending investigation into grounding blow hoses and other components. As stated electric blasting is no longer necessary or desirable underground and hole-loading tools have become quite sophisticated.

It is expected that a fully automated blast hole loading machine will be designed and used in oil shale; a machine with components to mix, weigh both explosive and stemming and load the holes by push button and requiring only a minimum of operator guidance.

SCALING

After blasting, loose rock must be pried down from walls, roof, and face to make a safe mine in which to operate and to prepare as smooth a face as possible for the next round of drilling. Until recently this was a hand job with bars used to pry the loose pieces down. Men worked from the top of a drill jumbo or other platform. With the increases in labor cost, an effort has been made to adapt machines to the work. One machine which does a satisfactory job is the Gradall: another is the adaption of a backhoe to the work by removing the bucket and substituting a tooth. Both of these machines have well articulated booms attached to heavy bases. The booms can be manuevered by a skilled operator to pry the loose rock down using power from the engine and do so much faster than men with bars.

ROOF BOLTING

In haulways particularly, and any other obvious danger spots, scaling is followed by roof bolting as an extra safety measure. A good description of roof bolting is in an advertisement by Republic Steel which says: "Mine roofs can be compared to a triple decker sandwich in many ways with materials of different kinds laying one on top of the other and nothing to hold them in place"—so long as there is bottom support everything stays in place—but remove the plate, so to speak, and the bottom layer will deform. If fracturing occurs in the right zone, the bottom layer will fall thus exposing the next layer with no support—and so on. Roof bolts then function like the fancy toothpicks stuck through the triple decker holding the layers in position thus keeping the bottom layer from deforming or fracturing and finally falling.

Roof bolting until recently was a two-man job. One man drilled the hole then two men pushed the bolt into place, one holding while the other turned the bolt into its anchor. With new tools this has become a one-man job and is accomplished a great deal faster. A drill is fastened to the man platform, usually on a boom of the type used by power people to change bulbs on high poles. The operator turns a handle to activate the drill after manual positioning. When the hole is drilled the machine is retracted and bolt with anchor and nut is placed in an air powered wrench arranged alongside of the drill. The operator then activates the machine to push the bolt into the hole and tighten the nut with a pre-selected amount of torque. One man can drill and install more than double the number of bolts installed in a shift by the old two-man method.

LOADING BLASTED MATERIAL

Loading of blasted material onto conveyances underground has been done with electric power shovels where the area was large enough for a shovel to turn and where the back was high enough to accommodate the boom and stick. In fact, this has been the prime way to excavate underground even though there were limitations. A shovel has the advantage of being able to tip and pry the blasted mass and come up with an almost full bucket without undue wear on the shovel. Also, in a limited way, scaling could be done with a shovel. But a shovel is a slow moving beast and is an almost stationary piece of equipment when loading. Hauling equipment must be brought to the shovel. Due to the fact that a shovel, after excavating blasted material from one room, moves on to another, and each time the hauling medium must be brought to the shovel, the use of conveyors and also stationary equipment is precluded.

Recently tractor manufacturers decided to try for some of the shovel business with their front-end loaders. They articulated rubber tired tractors to greatly reduce the turning radius thus reducing front wheel scrubbing and resultant tire wear. Turning time from excavation pile to conveyance and return was also greatly reduced. Heavier and more cut-resistant tires were obtained from manufacturers and buckets were shaped for rock loading. These innovations were first applied to medium sized tractors with such outstanding success that today many huge machines are appearing on the market. Recently a 20-cubic-yard bucket mounted on a large KW Dart tractor was used to load coal in a western mine. The machine idled one power shovel with an 11-cubic-yard bucket and a smaller front end loader used for cleanup and part-time loading. The big rig had sufficient time to clean up and prepare its own roads.

Implementation of these machines in oil shale, underground mining, should show beneficial effects on loading costs. In developing a mine, one machine can excavate and tram material from a face to a dump or stockpile up to 500 feet in distance at less cost than those required to operate a shovel and trucks. We have not made detail studies, but we believe favorable costs will result from the use of front-end loaders teamed with conveyors. The ability to tram material can revolutionize this operation. When material is loaded on a truck, the cost of hauling a mile or so is usually no more, and more likely less, than the cost of making a short haul and dumping onto a secondary hauling device. It can be seen that conveyors loaded with the front-end loader, in spite of their high capital cost, might haul at more attractive unit prices than those developed using trucks, provided an economical means is developed to move conveyors as mining progresses.

An 11-cubic-yard shovel costs 5 times as much as front-end loader of the same capacity and useful life is about 5 times that of the loader. But the difference in operating cost between the two will pay for a loader in 18 months to 2 years. There is also an appreciable saving in capital investment. An 11-cubic-yard shovel is too large to modify for underground work. Generally a shovel rated at 2-1/2-to 3-cubic yards is electrified and modified for this purpose. Such a shovel still carries a price tag substantially higher than the cost of a front-end loader and the operating cost also exceeds the cost of the loader.

HAULING

No conclusive assessment of hauling economics for an oil shale mine has been made by our people, therefore at this time all that can be said is that there are several methods with promise. Diesel-electric trucks operating in open-pit mines are showing excellent operating cost savings over all diesel models. All electric trucks receiving power from trolleys are operating in open-pit and underground mines and are receiving praise from operators for their efficiency. Conveyors show promise for developing reduced hauling costs. Generally hauling equipment is tailored to a particular mine to best serve the physical operating conditions.

CONCLUSION

When the need for a supplementary supply of fuel from oil shale becomes critical, the mentality of men, money, machinery, and methods will put an oil shale industry into operation.

It is entirely possible, using costs generated in similar work and knowledge of the product, to evaluate drilling, blasting, loading, hauling, crushing, storing, and reclaiming costs within plus or minus 5 percent of actual generated cost.

Of course, these efforts must be keyed to a property sufficiently explored by core drilling, geological analysis, and topographic configuration to reduce unknown physical hazards to a minimum.

With complete understanding and cooperation between government, business, management, and labor, using highly sophisticated machines, oil shale mining costs will be achieved that will be attractive to the petroleum industry in their oil shale development. If following processes can make the same strides in reduction of costs on a percentage basis as appears to be possible with advanced developments in tools for mining oil shale, then there should be no appreciable increase in cost to the public for fuels from this source. Salaries of machine operators will probably be relatively high but operators must have skill, knowledge of machinery, and the willingness to keep the mining machines producing at their highest possible potential.

So many new innovations are in the minds of men, on drafting tables, and in manufacturers proving grounds that it is presumptuous to try to outline the evolution of mining equipment as it will apply to large operations as far away as 5 years. Considerable effort is being directed toward lowering the cost of mining by the creative thinking of mechanical engineers and operators.