# ESCAVAÇÃO CONTÍNUA

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Mr. Moderator,

Ladies and Gentlemen I have been asked to speak to you today on bucket wheels, also known as continuous excavators. However, I believe this group will have more interest in learning something of how to select a BWE. This includes a discussion of suitable BWE material, output capacity, and design considerations. An unfamiliarity with these factors as applied to wheels in probably a major reason for their limited use throughout the world. The operator is more used to working with shovels, drag lines or other more conventional excavators. However, the modern high speed bucket wheel excavators frequently digs material which other excavators cannot handle without blasting. Given the proper conditions, the bucket wheel is capable of excavating at a lower unit cost than any other excavator. Cost performance will become increasingly important as more and more low-grade, high overburden cover property must be developed.

Bucket wheels, at present, are handling some very hard materials formerly drilled, blasted and dug with power shovels. Some of these materials are shale and slate overburden of the mid-west coal fields. A few years ago a wheel excavator was digging a hard interbedded quartzite and earthy formation in California. The shaving or milling effect of wheel buckets at the mining face permits them to dig materials too hard for conventional excavators.

A few years ago, two large wheels were purchased for the Great Canadian Oil Sands project in Alberta, Canada. This material has been classed by some as equivalent to a hard sandstone. These two wheels are now successfully excavating the tar sands at a combined rate exceeding 100,000 tons per day. In addition to digging this hard material, the mining is further complicated by the frozen conditions of the ground in the wintertime. Temperatures frequently drop do 50° below zero and even more. Early experience in the frozen tar sands gave mining considerable difficulties. This was particularly true in the lower grade materials which contained a higher percentage of water. To help this problem, Great Canadian Oil Sands spent considerable time and money in field research.

The result of this work was a successful program of drilling and blasting ahead of the excavator. Drilling and blasting involved the placing of wide spaced, large diameter, drill holes. The holes, 18 inches in diameter carried a low load of powder. This was just enough to shake up the frozen ground permitting the excavator to work more easily with less lost time. The ground also contained some very large, widely spaced, sandstone boulders. At first these were troublesome but with experience the operators have learned to work around them with a minimum of lost time.

Normally wheel excavators are not applied in material containing large amounts of coarse unsorted rock. It also used to be thought that wheel excavators leave off where drilling and blasting begin. This may not always be true as has been demonstrated by the tar sands operation in Canada. There is also an operation in

India, at Neyveli, where sandstone overburden is shot before excavating by a wheel. Approximately 15% of this material is broken, which allows them to maintain better performance and reduce wear when working the hardest overburden areas.

Actually the wheel could dig this material but only at a high cost and increased maintenance · downtime. Usually blasting produce a high percentage of large chunks which the wheel and ladder conveyor cannot handle. Most large wheels experience excessive slow downs and stoppages when rocks larger than 20 to 24 inches are encountered. These rocks plug chutes and damage transfer belts. Frequently, if the percentage of large rocks is not great, they can be disposed of economically by auxiliary means. Each operation and its material must be thoroughly investigated as was demonstrated by Great Canadian Oil Sands.

Due to the continuous digging cycle of a bucket excavator, it is physically smaller than conventional excavators of equivalent output.

Compared to a shovel or dragline, the bucket wheel excavator has:

(1) Lower instantaneous power demands
(2) Less weight for greater output
(3) No shock loading

Average power consumption for a BWE will be 0.30 to 0.50 Kwh per cubic meter compared to 0.50 to 0.71 Kwh per cubic meter for a power shovel. The BWE exerts different digging forces on the material than the forces required by a power shovel to pull the dipper through the bank. The milling or cutting of thin slices is the technique used in wheel mining for hard materials. On the other hand, the slow shovel bail speeds require high cutting and lifting forces to push the large heavy dipper through the weight of the bank material. Shaving or milling action of the wheel buckets work equally well in soft or hard materials with good indexing control. In some cases wheel power and maintenance costs can be decreased by inserting cutting teeth between the buckets. The ultimate speed of a wheel is only limited by the centrifugal force on the bucket load and the high mechanical wear. Developments since World War II in sophisticated steel alloys, solid state electrical controls, and steel cord conveyor belts plus improved hardware permit peripheral speeds of more than 1,000 feet per minute. High speeds have allowed expansion of the BWE into the digging of medium hard materials. The harder the material normally the faster the wheel must turn. In the last 20 years average wheel speeds have increased from 98 meters-per minute to close to 183 meters per minute.

The mining engineer who is unfamiliar with the wheel excavator will find it difficult to select the correct wheel design for his particular job. This situation comes about through a lack of published design controls. A number of years ago, I was in this situation and had to develop much of this information for my own use. The engineer must consider all of the operating elements and work conditions before choosing a wheel of specific size and design. He must evaluate in his own job the type of materials to be handled, the mining plan he will use, the BWE output capacity, and the method of material transport away from the excavator.

The mining plan must be reflected in the final selection of the BWE design. In a sophisticated operation, the wheel is designed to fit a specific plan to product the lowest ownership and operating costs. Frequently, the design of the wheel will require specific design changes to meet the job conditions. The extent of these changes will determine the final price of the machine. One can pay, for wheels of equivalent rated output, up to $1,000,000 difference in cost. This difference in cost is a measure of the changes required to the basic wheel design.

A formula frequently used to compare BWE of equal sizes is:

> The BWE service weight less ballast divided by true hourly capacity and multiplied by the digging height.

The most efficient BWE should have the lowest guide number. However, this cannot be the only criterion used in final selection.

When installing a wheel keep moving and maneuvering of the machine to a minimum.

The most favorable operating costs are obtained using long mining faces and the maximum reach of the BWE boom in each of the mining cuts. However, multiple benches may be required in thick ore overburden. But, it is more desirable and cheaper to maintain the fewest working levels possible. To do this may require high face mining or subgrade digging, which both require an increase in the design boom lenght. Again a rule-of-thumb here is that for each 1/3 meter increase in digging depth, 1 meter must be added to the digging ladder lenght. Axiomatically, when boom lenght is increased, service weight and cost go up. A short boom, close coupled design, machine will have the lowest capital cost. In some cases, it can be less expensive to buy two short boom machines instead of one high face digger. This decision will require a detailed economic analysis of both capital and operation cost. Usually any reduction chion can be made in the weight of the front and digging wheel will produce 5 to 10 times as much reduction in the overall machine weight.

Mining slopes in the pit plan design should be 5 to 10 degrees. This is the normal range of permissible operationg slopes for a bucket wheel excavator, and imposes restrictions as to the shape and condition of the deposit that can be worked. Straight travel of the machine can be on slopes up to 20 degrees. In addition, the mining plan must consider wheel diameter and the auxiliary equipment required for the operation. Mining slopes must be related to the position of the leading crawler relative to the toe of the digging face. This position afeects design wheel diameter and boom lenght. The interaction of these factors require selection of the optimum method for wheel cutting at the face.

One of the major factors the mining engineer must consider in selecting a bucket wheel excavator is its sizing in relation to the output required Ratings are readily available for the entire range of power shovels versus type of material to be dug. In the case of a bucket wheel excavator, the buyer most often must develop his own criteria for operating factors, Bucket wheels are rated according to their bucket capacity. For example, a 700 liter machine means that each bucket has a capacity of 700 liters. Within the basic size range of machine very often profile dimensions, weight, and horsepower will vary considerably. A large mining wheel excavator is not a standard model item as are power shovels and other conventional excavators. For this reason, no standards are available for these large special machines as to digging rates, bucket factors, or performance to be expected. However, once a machine has been agreed upon with the vendor, it is normal to negotiate performance guarantees. Some typical applications of bucket wheel excavators can be found in the American Institute of mining Engineers book "Surface Mining". BWE's have been made in rater output from midgets of 100 tons per hour to giants producing more than 200,000 tons per day. Bucket wheel excavator capacity must be based on a specific machine, the job and estimated cost but these are often complex to derive. The entire procedure, in a sophisticated operation, to determine wheel capacity is beyond the scope of todays talk, and frequently it is necessary, when considering large wheel excavators, to engage a consultant to assist in selecting the proper machine.

The theoretical capacity of a bucket wheel is easily determined. However, the theoretical and true design capacity are never the same quantity. You can calculate theoretical output by the product of three factors:*

(1) Number of buckets on the wheel
(2) Struck bucket capacity
(3) Wheel FPM at the mid-speed point

In operation, you control wheel output by:

(1) Its speed
(2) The depth of its cut
(3) Slewing speed

Slewing refers to the revolving speed of the entire machine as it swings across the face. Attempts have been made to automate wheel slewing. However, these have proved unsuccessful due to variations in bank material.

When calculating true bucket wheel excavator output capacity, the theoretical output must be derated for the probable conditions. These will reflect items as maintenance outages, type of material, excavation plan and job management efficiency. The effective working hours per week are usually established by considering the maintenance and work schedule required. Common practice is to schedule four hours a day for wheel maintenance, six days per week, and 12 hours of maintenance every 7th day. Using this schedule, a large bucket wheel excavator has 132 hours for effective digging per week.

Because of the large capital expenditure for a bucket wheel excavator, operating must be scheduled for a 24-hours day. As indicated above, depending on the operating plan adopted, varying periods of no productivity will occur. A rule-of-thumb I frequently use to size a bucket wheel excavator as a mining machine is to take 50% of its theoretical output. However, this again must be adjusted in the final analysis depending upon conditions and method of transport. The calculation of wheel output capacity can be done in various ways depending upon the designer. Most wheels built today are of the cell-less type with an annular ring which holds a substantial quantity of excavated material. This ring may give the wheel an increase of up to as much as 50% over output. Depending on the manufacturer, his guarantee may exclude or partially include the material in the annular ring. When buying a machine you should ask the manufacturer to state the design method he is using. The cell type bucket wheel does not have the ring filling complication and true output is easier to calculate.

Often a poor operator can seriously affect production, particularly if he is inefficient in the reverse swing. The major cause of production outagers can be attributed to digging and maneuvering delays of the wheel. It has to cut ramps, make box cuts, and if working with a belt conveyor system, will be out of production for conveyor or rail shifting. By careful planning, major moves are kept to a minimum in good mining lay-outs. The digging maneuvers are an inescapable feature of the BWE and result in the biggest production outages other than maintenance.

Some correction can be made for maneuvering losses by buying a machine with a boom-crowd mechanism. The crowd mechanism operates similar to that on a power shovel, allowing the boom and wheel to be extended and or retracted. This can increase efficiency by:

(1) Minimizing excessive movement on unstable ground by making deep terrace cuts.

(2) Easier mining of interbedded waste bands.

Probably the major reason for a crowd type machine would be for interbedded selected mining. Normally less skilled operators and reliance on swing speed control are required. While some advantages do result from a crowd mechanism in the proper circumstances, its disadvantages are in the greater maintenance cost and a higher capital investment. In todays market, very few machines are being produced with a crowd mechanism. This is because the crowd results in a greater machine weight, height and higher cost; and therefore, can seldom be economically justified.

Bucket design can be either of the closed-back or the open chain-back. The closed-back bucket is generally used for free flowing non-sticky material and the chain-back bucket for sticky, hard-to-discharge, soft or wet material. Combined with the chain-back in sticky material the bucket can be flarred to give additional dumping ease.

It is not unusual to encounter cost of 2.5 to 4.0¢ U.S. per cubic meter for wheel excavated material. Some of the high strip ratios encountered in mid-western United States coal mining are only possible due to the use of bucket wheels. Throughout the mining industry wheels have established a name for low unit cost in earth moving and reclaiming operations. It is difficult to compare direct operating costs between operations. Each user generally reflects in his costs the elements required for his own purposes. But there are some accepted cost rules on excavators

(1) Costs of the digging wheel itself represent 80-95% of the total excavator maintenance.

(2) Repair parts for an excavator amount to about 6-8% of the total excavator cost per year.

The biggest single variation in cost is found in tooth wear. Likewise power costs will vary considerably from area to area.

Some representative BWE operating costs show a range of 2.0¢ U.S. to 10¢ U.S. per cubic meter. These costs do not include depreciation. The wide range of costs experienced can be attributed to the amount of auxiliary equipment required for each operation. This equipment might be tractors, a belt wagon, belt shifter, or a cable reel car. Most of the maintenance costs will occur for teeth, lips and liner plates. The other big item of expense on the excavator is the ladder belt. Outside of these items very little maintenance is required on a wheel since they do not experience the same impact and shock loads as power shovels. Most commonly direct operating costs fall in the range of 3 to 4¢ per cubic yard. Nearly all of these operations have wheels which are associated with auxiliary equipment. Generally speaking , capital cost on a wheel will amount to approximately $2 U.S. per pound of excavator weight.

The most common transport system for a wheel is a shiftable belt conveyor system. However, wheel excavators work well using trucks or rail haulage if designed for these initially. The continuous output of the BWE and the advances made in recent years make it potentially machine for high production and at even lower costs than those presently achieved.