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# A New Dimension in Movable Conveyors for Bulk Solids Handling

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## Summary

While a variety of movable conveyor systems has been in use for many years, the introduction of the totally mobile conveyor occurred only recently. The development and application of automatic guidance control technology has made total conveyor mobility possible.

Experience with existing totally mobile conveyors in bulk material handling has established their practical and economic viability. Studies show that the system offers great potential in adding substantial flexibility in the design of a variety of bulk materials handling projects in several industries.

Totally mobile conveyors offer particular promise in working large areas, reduction of system capital cost, operation with soft or unstable materials, and reduction of stockpile dust emissions. With operational and economic advantage proven, the door is open to general application.


## 1. Introduction

Over the years, many belt conveyors have been designed for some degree of mobility. The requirement of transporting material to or from a moving face, to or from a fixed conveyor system gives rise to the need for mobility. This is a basic material handling problem which is most simply solved with mobile haul units such as trucks or scrapers. However, the economics of belt conveying make movable conveyor systems attractive and many types of movable conveyors have been used.

Perhaps the most common movable conveyor system consists to two movable conveyors — a shiftable conveyor, and a bandwagon. A two-part system is used to reduce the production lost in moving the shiftable conveyor. The mobile bandwagon provides a flexible link between the shiftable conveyor and the working face allowing a greater range of face advance before movement of the shiftable conveyor is required.

Rigid frame movable conveyors mounted on tires are also in use. They generally require a well graded surface to operate on and are restricted in length by the size and weight of structure required to resist bending and twisting forces.

The "link" type movable conveyor is another concept which has been used. This type consists of frame sections pinned at the ends and mounted on tires or crawlers. The movement of link type conveyors usually requires multiple tractors to achieve the speed of movement desired and considerable alignment adjustment is needed. These problems have limited them to relatively short lengths.

Cascading of short conveyors is yet another method of achieving a degree of conveyor mobility.

Many variations or combinations of these systems have also been used. Recently a new type of movable conveyor has been placed in operation which is totally mobile and can be moved in a very short time. This totally mobile conveyor (TMC) makes extensive use of proven automatic control technology.

## 2. Developments in Automatic Controls for Mobile Equipment

Since the 1950s, construction machines for grading and paving irrigation canals have employed guide lines and automatic guidance controls to maintain alignment and elevation. These machines are crawler track-mounted with hydraulic jacking cylinders rather than the earlier system of running on preset steel rails. Some also utilize highly accurate mercury switches for controlling side-to-side (cross) level. From these early control applications has evolved a technology of highly accurate, yet simple and reliable, control systems for machine guidance. More recently, the development of laser controls and electronic microcircuitry have added additional capabilities and reliability (Fig. 1).

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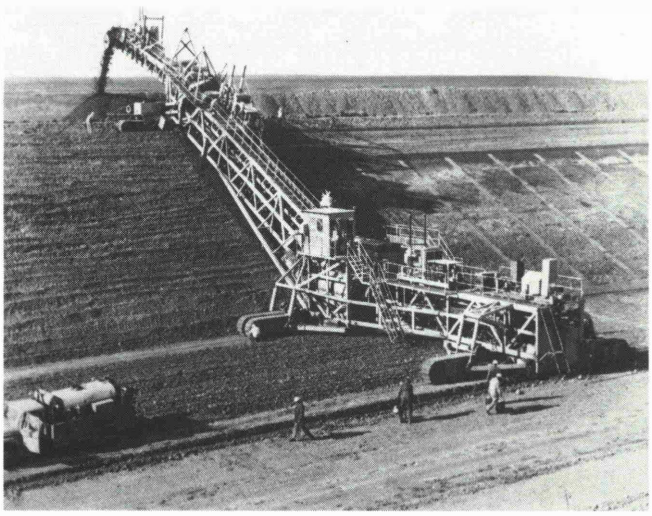

Fig. 1: 330 ton RAHCO canal excavation and finish grading machine. This 2,000 $y^3/h$ unit follows guide lines. Tracing error is on the order of 1.0 cm

Today, this technology is being applied in various ways to many types of equipment to reduce labor and machinery cost as well as adding new dimensions to the mobility of large machines. A significant application of this new controls technology involves the link-type movable conveyor and has resulted in a unit with capabilities of operation in applications previously impractical.

This conveyor automatically maintains section (link) alignment and belt levelness while moving in a direction perpendicular to the belt travel, pivots about either end or the center, and guides itself (Fig. 2).

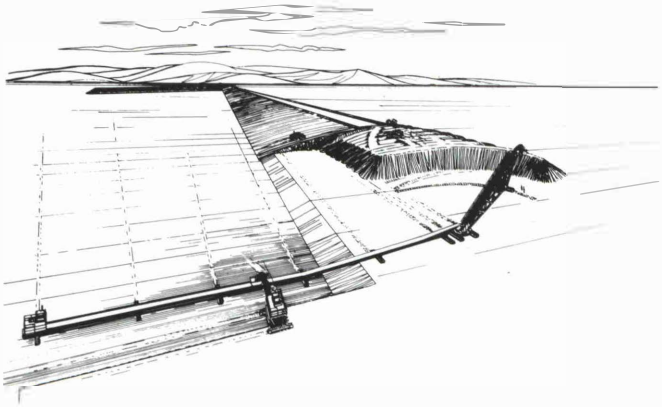

Fig. 2: Dike construction system with mobile bucket wheel excavator, TMC, and radial spreader. Shiftable conveyors used to extend the system to 500 m are not shown

## 3. Why a Totally Mobile Conveyor?

The potential of totally mobile conveyors (TMCs) is great. They have the ability to cover large areas with minimal time loss for repositioning. Because they operate immediately adjacent to the working face, compact, low cost reclaimers, excavators, or stackers can be teamed with them. The intermediate unit (bandwagon) is eliminated. Pilings, foundations, rails, and auxiliary moving systems are not required. Neither is a large maintenance facility.

Given the abilities of the TMC sections to hinge in the vertical plane and a wide range of leveling adjustment, the unit has the ability to conform to surface contours and travel up and down slopes. With these capabilities the TMC can operate on uneven terrain as might be found when following an ore body or on the surface of a stockpile.

The combination of automatic alignment, guidance, leveling, and contour conformation provides a long, continuous belt haulage system which can be "driven" to where it is needed much as other mobile equipment.

## 4. History of TMC Systems

In 1977, two TMC systems were placed in operation. The first was an excavation and earthmoving system used to construct the containment dikes of large (100 hectare) settling ponds. The second, a retrofit coal stockpiling/reclaiming system for a two million ton stockpile at a powerplant.

### 4.1 Excavation and Earthmoving System

The excavation system operates in the saturated clay soils of the Mississippi river delta, presenting a difficult challenge to any type of material handling and excavation system. This system consists of a mobile bucket wheel excavator, a TMC 100 m long, a cascading series of shiftable conveyors with a total length of some 500 m, and a radial spreader. All units except the shiftable conveyors are mounted on crawler tracks.

Use of the TMC simplifies the functions of the excavator. The mobile bucket wheel excavator in this system is unlike conventional bucket wheel excavators in that the wheel is fixed, since no slewing capability is necessary. Deletion of the slewing function eliminates cantilevering and counterweighting the bucket wheel, resulting in large weight savings (Fig. 3).

Fig. 3: RAHCO mobile bucket wheel excavator. This unit excavates in both the forward and reverse directions. TMC at left receives and conveys the wet clay

The wheel is wide (3.75 m) and is advanced into the cut perpendicular to the axis of rotation. To excavate, the mobile bucket wheel excavator (MBWE), propelled by its crawlers, takes a pass along the TMC discharging the material over a short conveyor directly onto the TMC belt. The MBWE has the capability to excavate in both directions of travel and makes succeeding passes along the TMC. After a pass in one direction the MBWE is repositioned for the next pass while the TMC is simultaneously advanced. This indexing process requires only two to three minutes.

The combination of the MBWE and the TMC excavation and haulage system techniques result in machines which are very compact for their capacities and reach and operate at low ground pressures (700 and 280 kg/m²).

Automatic control systems are used extensively in this system. A laser device is utilized to automatically maintain the excavator elevation to that required at the pond bottom. The MBWE automatically guides itself along a line mounted on the TMC and the TMC guides off the shiftable conveyors. Automatic controls on the TMC also maintain frame section alignment and level. An important benefit of automatic control is the elimination of the requirement for a high level of manual skill to maintain production. Except when indexing, the operators simply monitor operation.

In spite of rain, floods, and the continuing problems inherent in excavating and conveying sticky clay, the initial pond was constructed at a cost 48% less than a pond constructed earlier with conventional equipment. A third pond was then constructed with a further 15% cost reduction.*

### 4.2 Coal Stockpiling and Reclaiming System

Although similar in handling capacity, the coal stockpiling and reclaiming system presents more problems than the excavation system. Again, the material is a problem in itself as the stockpiled coal contains 16 to 18% ash in the form of clay lumps which disperse through the pile after being soaked by the heavy rainfalls occuring in the region (1.3 m/year). The clay and rain make the pile soft and difficult to operate equipment on (Figs. 4 and 5).

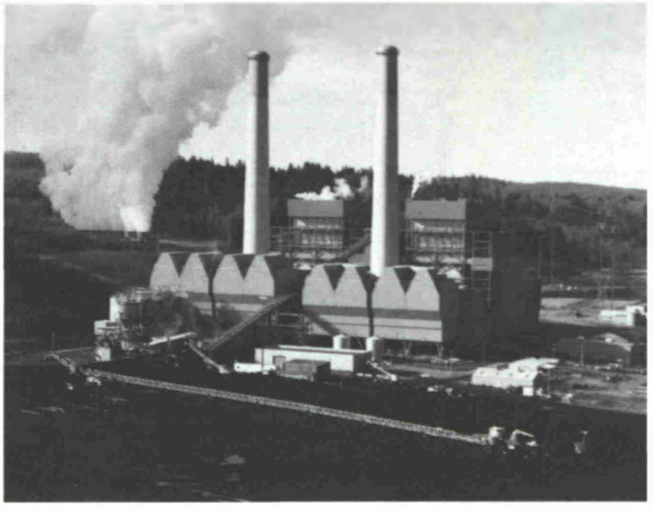

Fig. 4: 200 m RAHCO stockpiling and reclaiming system at Centralia Powerplant. The TMC support structure is constructed in segments, hinge-connected at each crawler

A portion of the stockpile is regularly worked with a bucket wheel stacker/reclaimer (BW-S/R) for short term surge requirements. Coal cycled through short term storage can be

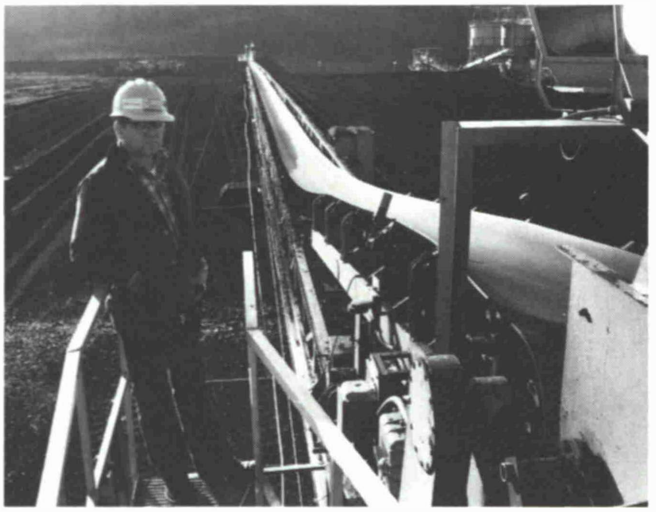

Fig. 5: View from tripper along RAHCO 200 m TMC showing precise support structure alignment and leveling achieved with automatic control systems

handled through the plant conveyor system with only occasional plugging problems.

The reclaim operation is much like the excavation system operation except the RDR is uni-directional and must be turned around at the end of each pass. In this system, however, the TMC is 200 m in length making the turn-around a small percentage of operating time. Although there is production loss in turning around, there are no continuous cyclical losses as experienced in the slewing of BS-S/Rs. Rate of reclaim (800 t/h nominal) is regulated by varying the advance speed of the RDR.

About two million tons of coal are maintained in long term storage. Because of the degradation of the clay, this coal causes serious plant system stoppages when reclaimed by

Fig. 6: Rotary drum reclaimer automatically following the guideline. The operator monitors the operation

bulldozers and pull-type scrapers (the self-loading scrapers first used could not negotiate the pile in wet weather).

Testing with a rotary drum type reclaimer showed the rotary action effectively fragmented the clay/coal lumps and mixed them with uncontaminated coal. This mixture would then flow through the plant system. As a result, a rotary drum reclaimer (RDR) and TMC were teamed to reclaim from the pile

* Cost comparisons were made on a unit cost ($/m³ of completed dike) basis-savings percentage on the excavation and haulage costs alone were actually higher.

and convey the coal to a stationary conveyor. The system was operational within nine months of order placement (Fig. 6).

Initial system layouts had the TMC discharging directly onto the stationary conveyor. This would have restricted BW-S/R operation. The choice was then made to discharge the reclaimed coal onto the short term stockpile and rehandle it with the BW-S/R. This decision dictated receiving coal for stack-out from the BW-S/R (Fig. 7).

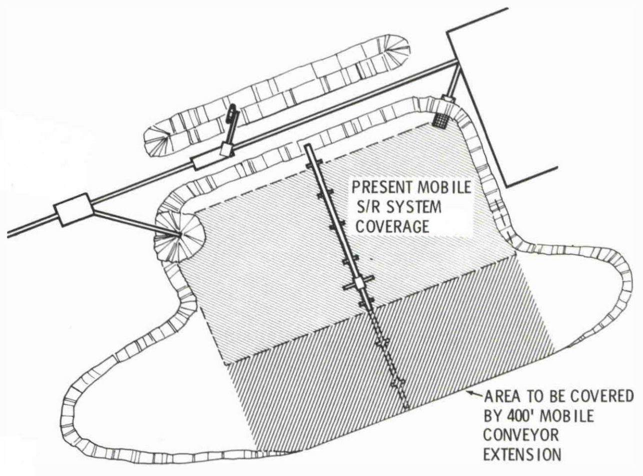


Fig. 7: Layout of power plant system — 2 million ton stockpile

To implement stack-out a variable speed tripper with a short stack-out belt travels the length of the TMC. With the main belt reversed (from the reclaim direction of travel) coal received from the BW-S/R is conveyed over the traveling tripper and is discharged by the stack-out belt into a windrow along the TMC. When the tripper reaches its limit of travel, the TMC is indexed and another windrow is placed in the reverse direction. The windrows are leveled by a bulldozer which simultaneously compacts the coal to prevent burning. The maximum rate of stack-out is 1,200 t/h (Fig. 8).

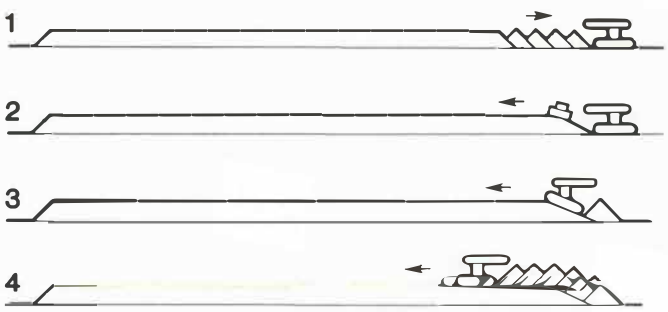


Fig. 8: Stockpile building sequence with TMC system

When a layer of coal has been put down over the entire area, the short stack-out belt is reversed, placing the windrow on the opposite side of the TMC. The travel of the TMC is also reversed and a new layer is put down as the machine moves back across the stockpile. The tripper travel speed is variable so the windrow height can be changed to alter the surface contour of the stockpile or the thickness of the layer. During reclaim, the tripper is parked at the outboard end of the TMC (Fig. 9).

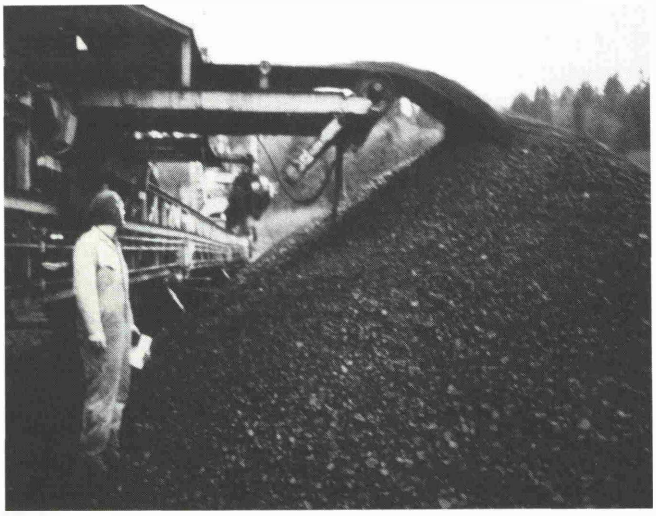

Fig. 9: RAHCO TMC traveling belt tripper and stack-out conveyor. Windrow can be made on either side of the TMC at 1,200 t/h

Automatic controls used in the coal stockpiling and reclaiming system functions are similar to those used on the excavating equipment except the laser elevation control is not used. Instead, the reclaimer cutter elevation is referenced to the RDR guideline mounted on the TMC (Fig. 10).

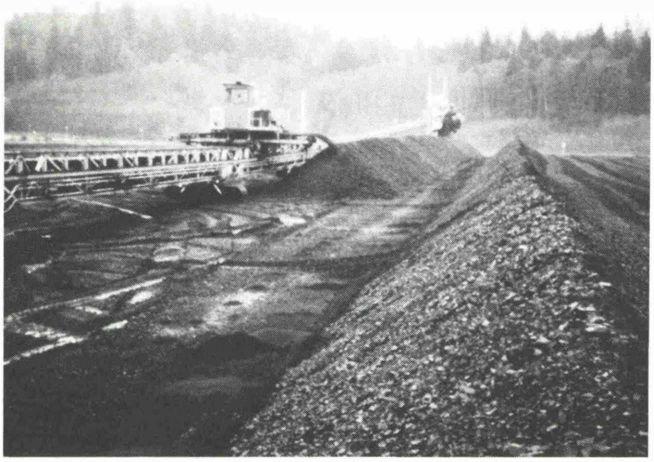

Fig. 10: 200 m RAHCO TMC in stack-out sequence

In the five years of operation of the coal stockpiling and reclaiming system, it has handled about five million tons of coal in all types of weather (including periods when the surface was frozen to a depth of over 0.5 m). Since the TMC system has operated simultaneously with pull-type scrapers, the owners have cost records on the two methods which are directly comparable. These records show that, on a cost per ton-km basis, the operation and maintenance costs of the TMC system are 49 % less than the scraper/bulldozer system. Even with no depreciation or insurance charges against the scraper/bulldozer system the total operating, maintenance and ownership costs are 25 % less for the TMC system. Coal from a maximum distance of 200m is being stacked and reclaimed for an average of US $ 0.12 per ton.

Because the coal stockpile is located on a mud flat with low loading capacity it covers a large area and is constructed with gently tapered edges. As presently configured, the TMC system works about 75% of the pile volume, but only 60% of its area. The contemplated addition of 120m to the TMC length (as provided for in the original design) will allow for working about 90% of the volume adding little to unit costs. Minor pile reconfiguration will then raise the pile coverage to 100%.

As in the excavation system the compactness of the machines allows low ground bearing pressures (below 420 kg/m²).

## 5. TMC Design

The TMC is comprised of a single belt conveyor of conventional design in an open top structural framework. The framework is constructed in sections approximately 23m long and connected by ball joints. The terminals can be designed in any number of ways depending on the system application. The coal stockpiling and reclaiming system described above has a reversable tail pulley drive and adjustable boom at the head end while the excavation system TMS is equipped with a head pulley drive which is also on an adjustable boom.

TMC systems can be electric or diesel engine powered or can be a combination of diesel and electric as a given situation dictates.

Because of its capabilities for precise control, hydrostatic power is employed in many of the auxiliary systems with low power requirements.

Each structural frame section is mounted on one or more crawler tracks through a pivoting mechanism which is controlled by the automatic leveling system. The crawlers utilize standard, high quality crawler tractor components for maximum service life. The operational service level of the crawlers is quite low as they operate only when indexing. This relates to a small percentage of total system operating time. Crawler power requirements are normally low as high movement speeds for the TMC are not usually required.

Maximum TMC length is governed by essentially the same limitations as conventional shiftable conveyors.

Structural frame alignment is maintained by controls which instruct the crawlers to eliminate any angle error between adjacent sections. These controls are accurate to an alignment error of 1.0cm in 10 meters. For this reason, no extraordinary belt training equipment is required.

A master control station is located on the TMC structure. Where a traveling tripper is required a second control station is located on the tripper. Normally, two operators are used but, depending on local work rules, remote controls allow the system to be operated by one person in both the stack-out and reclaim modes.

## 6. Potential Applications

From the systems described above it is apparent that totally mobile conveyor systems have promise for bulk material movement in applications presently utilizing bulldozers and scrapers or where BW-S/Rs are used with very large stockpiles. In particular, the mobile conveyor system is a candidate for replacing construction type machines where fugitive dust is a problem.

While conventional BW-S/Rs are best suited to long narrow areas requiring a minimum reach, the mobile conveyor system is better suited to wider, more square areas and is most applicable to sites of that general configuration.

Both of the systems described above are "linear", that is, the mobile conveyor works along a fixed conveyor, thus covering a rectangular area. The mobile conveyor can also operate in a radial mode, pivoting about a fixed point at one end. This results in a "pie" shaped area of coverage. The radial mode requires a somewhat greater number of moves for handling a given tonnage over a given area. This, however, is not a major factor and the use of a moving tripper (or hopper) on a fixed conveyor, as generally required in a linear system, is not necessary (Fig. 11).

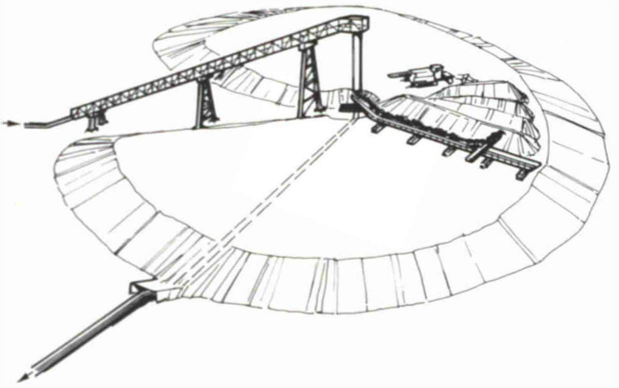

Fig. 11: Radial configuration of TMC system

Where the area to be worked is irregular, it is possible to use two mobile conveyors in tandem and in combinations of linear and radial modes (Fig. 12).

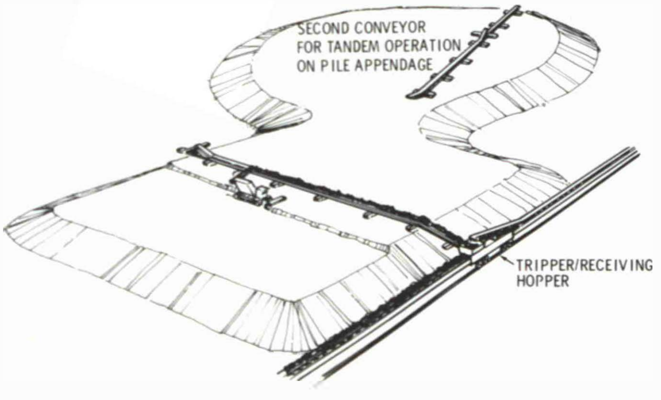


Fig. 12: Tandem TMCs in a combined linear and radial system

Mobile conveyor systems can operate on slopes or hillsides. In stacking operations, the system generates its own operating pad and can be set up in rough terrain for disposal of material such as mine tailings or spent oil shale. The system is well suited to operations where thin lifts of material must be laid down for compaction over large areas.

The spreading of unstable mine waste on slopes is another potential mining application. With the mobile conveyor running up or down the slope of the waste dump the material can be stacked out at a low angle without the danger of slope failure (Fig. 13).

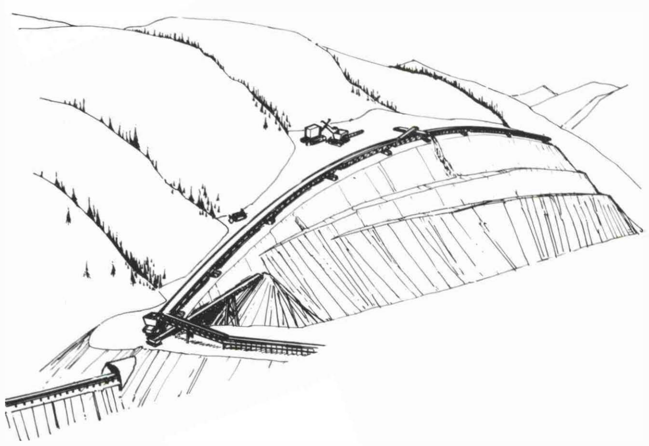

Fig. 13: Radial TMC system in rough terrain

A "cross-pit" mobile conveyor system for an open-cast mine has also been studied. In this application, a 'V' shaped pit cross-section is used with a mobile conveyor running down one slope and up the other. An excavator on the advancing face makes passes up and down the slope loading the mobile conveyor while a tripper/stacker makes passes up and down the waste pile face dumping the excavated material on the slope. The entire system moves back and forth along the length of the pit. To remove ore from the bottom of the pit, a second conveyor is mounted under the waste conveyor and is loaded by another excavator. Ore conveyed out of the pit is then transferred to a surface conveyor or loaded into trucks (Fig. 14).

The ability of the TMC to move readily opens a seemingly endless number of possible applications.

## 7. Features of the Mobile Conveyor System

Below are listed some of the basic advantages and features of totally mobile conveyor systems:

- Covers large areas.
- Eliminates much of the need for dust generating mobile construction equipment.
- Low ground pressure for operation on soft materials.
- No foundations or rail systems required.
- Low equipment cost.
- Minimum site and erection expenditures.
- Easily moved from site to site.
- No massive parts.
- Can be completely assembled and tested prior to delivery.
- All parts at or near ground level for ease of maintenance.
- Stockpiles can be located on soft soils and irregular areas.
- Low power consumption.
- System can be operational on short project schedules.

## 8. Costs

The above are the basic features of the mobile conveyor as revealed in projects and studies to date. No positive system aspects, however desirable, are of significance unless overall system economics are favorable. Experience indicates that life cycle costs for mobile conveyor systems compare very favorably with other systems.

Initial capital costs of TMC systems studied are about the same as for systems of construction equipment (trucks, front end loaders, scrapers, and bulldozers) with equal capacity. The construction equipment, however, must be replaced several times in the life of the project. Capital costs are much less than the installed cost of other continuous systems (BW-S/Rs, etc.) of similar life.

Operating and maintenance costs of TMC systems appear to be much lower than construction equipment systems and, although no direct comparison with other continuous type systems has yet been made, studies to date indicate operating and maintenance costs similar to those of other continuous type systems. The apparent reason is that repair parts and labor costs show a relatively direct relationship to initial capital cost and machine weight.

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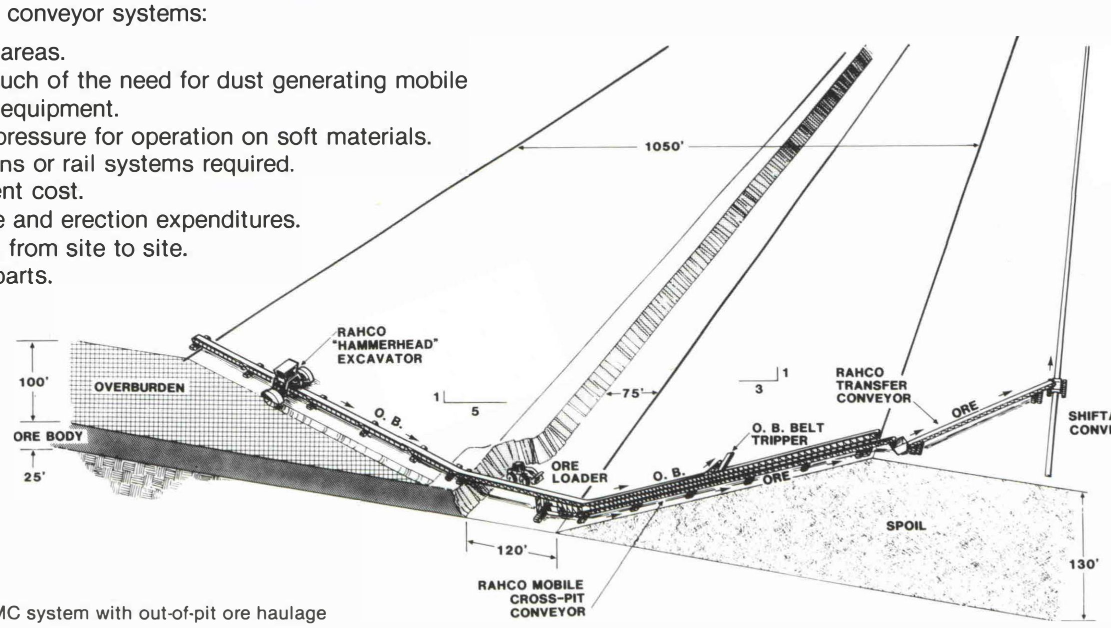


Fig. 14: Cross pit TMC system with out-of-pit ore haulage