IN-PIT CRUSHING AND CONVEYING
MINE PLANNING AND OPERATIONS

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by: Independent Mining Consultants, Inc.

Introduction

The rising operating costs and declining commodity prices at most properties have forced them to look at various alternatives to cut costs to stay competitive. Haulage costs have been an area that have risen significantly with the increase of diesel prices. One alternative to reduce haulage costs is to shorten the truck haul distance by bringing the truck dump point into the pit. Using an in-pit movable crusher or crushers, and conveying the ore and/or waste out of the pit can reduce the haul costs.

The potential effects of installing in-pit crushing and conveyor haulage on open pit operations and on mine planning requirements can be significant. This article will discuss the effects on pit geometry, operating strip ratio, and mine access requirements when movable crushers and conveyors are brought into the pit. Most of the examples and experiences are drawn from large base metal pits. The concepts discussed here also apply to coal, precious metals, and industrial minerals. Details of mechanical installations including belt widths, tensions, and crusher sizes will not be discussed because that equipment will vary with production requirements and many technical papers have recently discussed mechanical installations.

General thoughts regarding the method of evaluation of potential in-pit crushing and conveying installations will also be offered. As a general rule, it should be remembered that conveyor installations work especially well when large volumes of material have to be moved from one single source to a single destination, particularly when the destination is quite a bit higher than the source. Continually moving or multiple sources coupled with continually moving or multiple destinations are not necessarily the most natural or optimal situation for conveyor haulage.

The flow of material utilizing an in-pit movable crusher and conveyor system starts with the trucked material being dumped into the feeder pocket. The material is crushed and fed onto horizontal transfer belts in the pit or directly onto a major upslope belt taking the material out of the pit. There may be more than one of either belt type with transfers at each belt junction depending on the pit geometry and depth. Once the material exits the pit, it must be conveyed to the plant facilities or dumps. Figure 1 shows a simplified movable crusher and conveyor system in plan view.

Crusher and Conveyor Geometrics and Specifications

The first step when evaluating the potential installation of movable conveyors and crushers is to establish the geometric requirements of the installation being considered. Simple as it sounds, establishing how big, how long, how high, and how wide, will take at least a half a day to work out with a materials handling engineer, providing he has been briefed on the anticipated hourly tonnage rate and expected belt profiles. The mine planner with little background in conveyors will be surprised just how much room the crushers, conveyors and transfers occupy. Access to the belts and transfers must be assured for maintenance as well as for removal of the drive stations when the system is moved. Often a series of low tension belts will be used with minimal lift to deliver material from the in-pit crushers to high tension-slope belts for the lift out of the pit. The limitations of both types of installations must be well understood.

Movable crushers and feeder installations are offered by a wide range of manufacturers and engineering houses. Each has their strengths and weaknesses from a materials handling stand point. The mine planning engineer must understand the geometry of the system and consider the flexibility of the installations for modification. Some installations require that the feeder be placed within the bench above the crusher; the crusher product is delivered to the conveyor one bench below the dumping elevation. Other crusher-feeder systems are flexible in the feeding geometry such that the dumping elevation and the conveyor elevation can be the same, or separated by a bench. In either system, it is critical to know the range of horizontal angles that the feeder can deliver to the crusher and the range of angles that the conveyor can receive material from the crusher. Rotations as small as 10 to 30 degrees can often greatly simplify installation geometries and the material movement required for installation. The truck maneuvering area at the dump pocket will depend on the dumping geometry of the specific feeder, the truck size, and manufacturer. For haul trucks up to 170 tons an area 200 ft by 200 ft must generally be maintained for turn, spot, and dump.

One final item should be settled with the materials handling specialist before starting planning. The operating schedule of crushers and belts and the peak or surge capacity versus average capacity will be of necessity to him when detailing the system. Materials handling equipment by nature are most efficient with a constant material movement rate, consequently, design specifications are generally given in tons/hour. Mining equipment capacity is generally discussed in tons/day or tons/shift. For example, substantial variations in shovel tonnage may occur on an hourly basis, yet the end of shift average can be very consistent from shift to shift. These fluctuations do occur with a mill site crusher, however, there is generally a course ore stockpile immediately downstream to smooth fluctuations in crusher output. The short exit belt from a permanent crusher can be over designed to handle the surges from the crusher without much additional capital expense. Movable in-pit crushing systems generally deliver directly to a complete belt system and surges in crusher feed are transferred directly as surges in the entire conveyor system. A trade off of design capacity in the conveyor system must be worked out between the miner and the materials handling engineer. As a starter, the mining engineer should estimate how many pieces of loading equipment will deliver to a given crusher followed by a calculation of maximum hourly production as if the shovels are truck covered. It may not be cost effective to build the conveyor system to handle the extreme peak, but knowing the fluctuations in mine throughput will help in setting the required operating range of the materials handling system.

Advanced Planning Requirements

Conveyor and crusher installations should be designed in advance and planned for in the same manner as mine haul roads. As a general rule, it is wise to plan on establishing conveyor beltways and crusher installations as part of the normal course of mining instead of requiring custom excavation or placement of material to establish conveyor routes and crusher stations. This is dictated by simple economics that a specific earth moving construction project is a costly capital item and an additional expense outside of mining. The ideal situation is to establish the necessary access geometries (haul roads, crusher sites, beltways etc.) while mining at the planned rate. Other than grading, no additional material movement is required to establish beltways and crusher pads.

In practice, this generally cannot be perfectly accomplished because waste stripping must generally be accelerated to install the alternative materials handling system. The reasons for this occurrence will be discussed later, but for now it should be noted that slight accelerations to the waste mining rate utilizing the existing mining fleet are cheaper on a per ton or per yard basis than mobilizing a contractor fleet for specialty construction. One ramification of this approach is often a delay in the in-pit crusher-conveyor installation. For example, a new property would not usually utilize an in-pit crusher-conveyor installation until after preproduction. This is because the beltways and crusher pads are not established until there is an initial pit opening. At least one pushback must be mined prior to belt installation to establish a new pit wall with the additional beltways established on that wall for use during the next stage of mining. In certain applications, a pit rim crusher with belts going to a distance destination might be installed for use during preproduction. The crusher could then be moved into the pit later and the belts extended.

Time Sequenced Mine Plans

When evaluating or planning for a potential new system of this type, a series of phase or pushback drawings which include beltways and crusher pads are generally the first step. These drawings should include truck access to every bench, ample mining room, and the geometrically correct beltways, transfer stations, crusher pads, and transfer access roads, as outlined earlier.

When designing a pit layout including crushers and conveyors, it is often convenient to make templates or cutouts of crusher and conveyor installations at the planning scale. The cutouts can be moved and rotated rapidly to visualize alternative layouts without time consuming rescaling of the drawing. Similar templates or rulers with bench spacings and haul road grades marked out can speed any pit planning effort.

The pushback drawings are digitized and preliminary tabular production schedules can be run (by hand or by computer, preferably both) to make a preliminary evaluation of the effects of the crusher-conveyor installation. Because of the complex interaction of geometric requirements, this process will probably have to be repeated until a workable solution is defined. Anywhere from two to six sets of trial phase drawings are not uncommon to determine an appropriate working geometry.

The results of phase drawings and production scheduling can be used to set production targets and cutoff grade strategies. The resulting production schedules for a crush-convey installation should not be considered more than order of magnitude estimates. More than any other type of haulage system, time sequenced mine plans are imperative for the evaluation of movable crusher and conveyor systems. The timing of crusher moves, belt moves, assurance of truck access, and verification of the proper interaction of mining and materials handling equipment cannot be done without stepping through the mine geometries in appropriate time increments. Maps of annual time periods, illustrating the mine geometry at each year end, are generally sufficient for long range planning. Near term or short range operational planning requires shorter time increments.

The annual mine plans or composites should be digitized and the contained tonnage of ore and waste calculated to assure meeting of production targets. Conflicts of crush-convey installations with normal mining procedures can be worked out on paper and the operating and capital cost of installation estimated from realistic drawings. Truck haulage profiles can be measured and costs estimated for material delivery to the crushers or appropriate destinations. All costs and benefits of mining are tied to time for input into financial analysis. Trade off studies between various mining and materials handling plans can be evaluated.

Siting and Access Requirements

The requirements to know the precise working geometry and to do detailed time sequenced planning are necessitated by the fact that installations of movable crushers and conveyors can be inflexible and unwieldy. Materials handling engineers and salesmen will take exception with that statement, but compared to the total flexibility common with truck haulage, in-pit conveyors can restrict mining in large sections of the pit. The individual crushers and conveyors may be fairly portable, but developing the geometries for connecting the conveyors and transfers requires some time. The goal is to have the new conveyor installation prepared, by having the tables in place before moving the drives, transfers, and belts. This effectively ties up two pit wall areas with conveyor belts or proposed conveyor belts for some period of time. Truck access roads cannot use those two pit wall areas because conveyor-truck crossings are expensive and time consuming to place. All truck access must consequently be routed around the crusher-conveyor installations, which is easier said than done. A dual system must actually be maintained, one conveyor system, and one truck system. It may not be cost effective to handle all material types to all destinations by conveyor, therefore, the truck haulage system may be just as heavily utilized as the conveyor system. For example, in an open pit with one open end, haulage will often take advantage of this lower natural pit exit. Material from mining areas higher than this exit will be trucked out of the pit and the in-pit crush-convey system will handle the material below the pit exit, replacing the uphill truck haul. In another situation, a particular material type may be of insufficient quantity or is scattered in several areas of the pit. This material would not warrant a separate crush-convey system and if it's destination is different than the primary conveyed material, sharing the system would not be possible. In most pits, there will always be some material which would be best trucked out of the pit.

In-pit crusher locations are generally selected with the primary goal in mind to shorten the truck haul profiles. Detailed calculations of optimal central locations for the crusher to minimize haul distances are of little value. Studying the bench maps will show where the ore, waste, and other products are located within the pit, and provide an idea as to general location for in-pit crushers.

The optimal location for an in-pit crusher is where it will be out of the way of mining for the longest period of time. The corners and flat areas of a pit that do not change over a long period of time can be utilized as crusher locations without generating a large quantity of additional stripping to establish the crusher pad.

The analysis of crusher-conveyor installations are geometric problems which must be worked out in time sequence with maps and drawings. Tabular or pure mathematical treatments which do not include the geometric constraints and orebody limitations will not provide workable mine plans, let alone optimal plans.

Advanced Stripping Requirements

One drawback to in-pit crush-convey systems is the additional or accelerated stripping required to install the system over what an all truck haulage pit would require. This fact is at first not readily apparent but a look at the mine geometries will illustrate the problem. Figure 2 shows two cross sections through a simplified pit with a clear boundary between ore and waste. The numbered slices represent phases or pushbacks to be mined in sequence. The first case illustrates approximate pit wall geometries utilizing truck access. Wide benches appear on sections where haul roads pass through the section. The second case illustrates approximate pit wall geometries utilizing in-pit crushers and conveyors. Additional wide areas on the pit wall are left for conveyor routes, crusher stations and the original haul roads. Both cases show the phases having the same crest location. The volume of ore in phase 1 of the truck option is greater than that of phase 1 of the crush-convey option because of the additional room required for the crushing and conveying equipment.

Let us assume that phase 1 of the truck case contains an 18 month supply of ore. Phase 1 in the crush-convey case might contain 14 months of ore supply. The all truck case could mine ore from phase 1 for 12 months while stripping waste from phase 2 to release additional ore. If the waste were removed in 12 months, a 6 month ore exposure cushion would be maintained at all times. To maintain the same 6 month cushion on the crush-convey option, the phase 2 stripping would have to be moved in 8 months. The phase 2 waste volume of both cases being roughly equal, the crush-convey option would have to accelerate the operating stripping capacity by 50%. From phase 2 on, the strip ratio for the two cases can be held roughly equal.

Often the accelerated waste movement will begin several years prior to crusher-conveyor installation to smooth the peak stripping requirement and to establish the initial installation geometries. The cost of this additional stripping must be included when making a financial analysis of crusher-conveyor installations. Comparing capital price of the crusher and conveyor hardware alone to the reduced operating cost will not provide an honest or accurate assessment of the true costs. To illustrate the potential magnitude of the costs involved, a detailed plan for an in-pit ore and waste crusher-conveyor was done recently by a large base metal producer. The plan indicated that 13 million more tons of waste per year for each of the next two years, would have to be moved in excess of the current truck plan. These additional stripping costs of $10 to 12 million per year would be incurred for two years prior to installation of the system if continuous feed to the mill was to be maintained. It should be noted that this was an established, mature property that required radical changes in plan of approach to accommodate a new haulage system. The point is that any system which occupies or ties up room in the pit greater than that required by haul trucks will require an acceleration of the waste movement somewhere in the mine life over the equivalent truck case. This acceleration generally must occur in the early years, which does not help the DCF or ROI situation particularly when coupled with today's commodity prices. A careful and accurate time sequenced mine plan is necessary to evaluate all costs incurred with any alternate haulage system.

Potential Benefits of In-Pit Crushing

At first glance, in-pit crushers and conveyors may seem to be more trouble than they are worth. However, very important points in their favor must be considered. Operating costs per ton of material conveyed, particularly on long uphill climbs, are cheaper. Shorter hauls in the pit can reduce the size of the required truck fleet thus lowering truck capital and replacement capital costs.

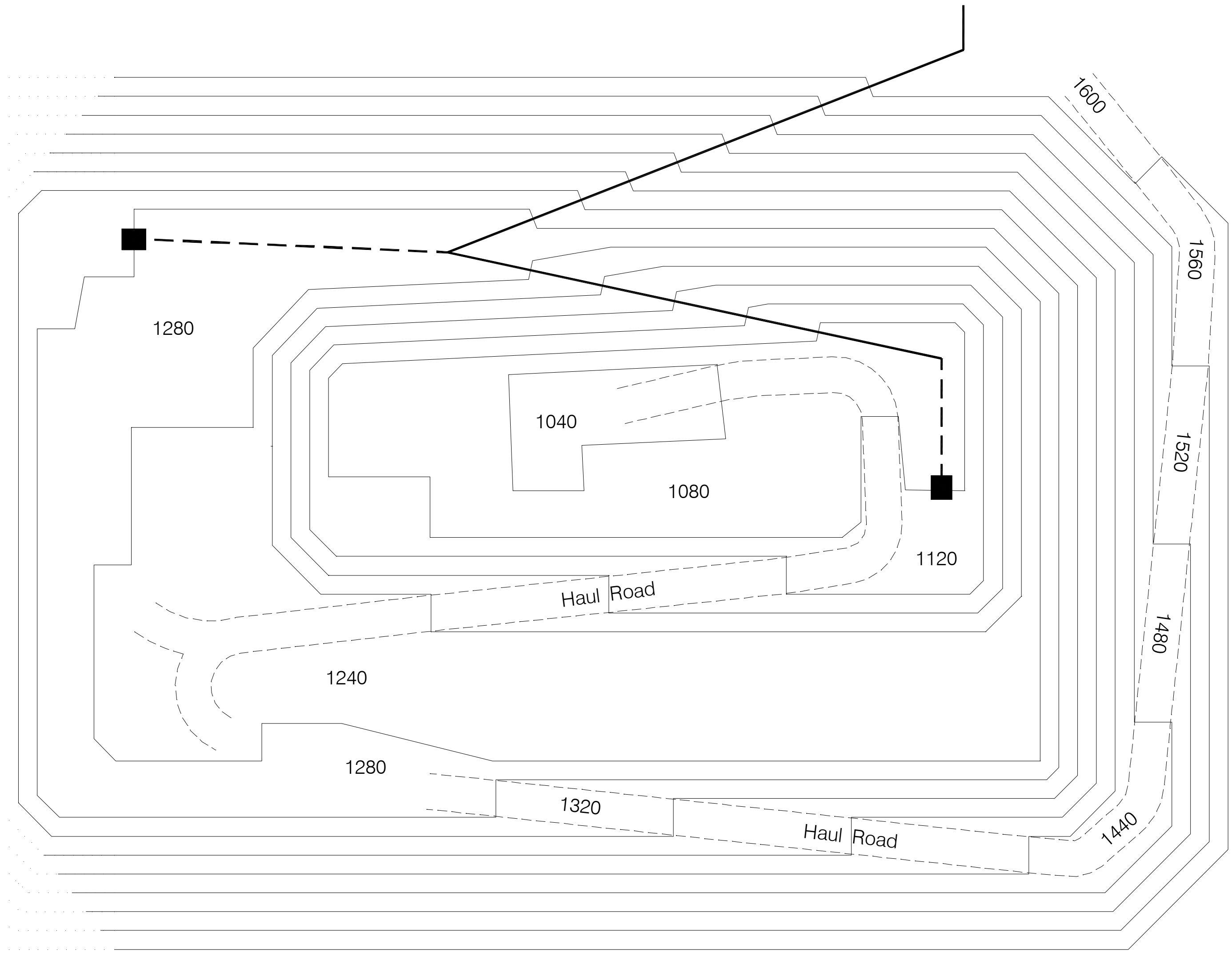
The operating cost per ton of material may be sufficiently low to effect a reduction in the ore cutoff grade strategy. There is consequently potential for extending the pit life with additional reserves.

Summary

The installation of the in-pit crush-convey system can have a dramatic impact on the pit geometry, operating strip ration, and mine access. The tradeoffs of lower operating costs versus the increased strip ratio, more complex mining geometries, less flexibility in mining, and the initial installation capital costs, must be evaluated. This requires detailed planning of conveyor routes, crusher locations and number of crusher moves, and ore availability. An all truck haulage plan with a conveyor route penciled up one side of the pit will not be sufficient.

To summarize, a few points should be emphasized when setting out to evaluate in-pit crushing and conveying with movable or even stationary equipment:

1) Thoroughly understand the working geometry of the equipment to be utilized or evaluated. Work closely with your materials handling specialist.
2) Establish the operating schedule and the surge capacity of the materials handling system.
3) Try to incorporate the crush-convey equipment into the mine geometries with minimal custom earthwork.
4) Use time sequenced mine plans in sufficient detail to quantify material movement and materials handling equipment moves.
5) Verify the proper interaction of all mining and materials handling equipment over the mine life. Assure proper access and operating room.
6) Be prepared for the additional stripping requirements to establish the system and consider all alternatives to maintain consistent material flow. (Changes to cutoff strategy or pre-scheduling of waste.)

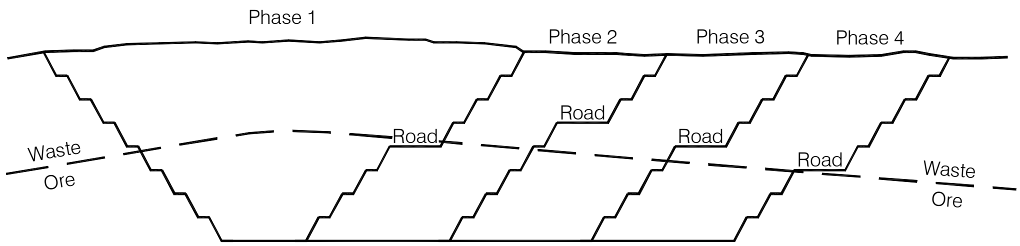


Crusher Location
Horizontal Transfer Belt
Upslope Belt

Figure 1
Example of an In-Pit Crusher-Conveyor System

Schematic Pit Cross Section

All Truck Haulage



Schematic Pit Cross Section

In-Pit Crush-Convey Haulage

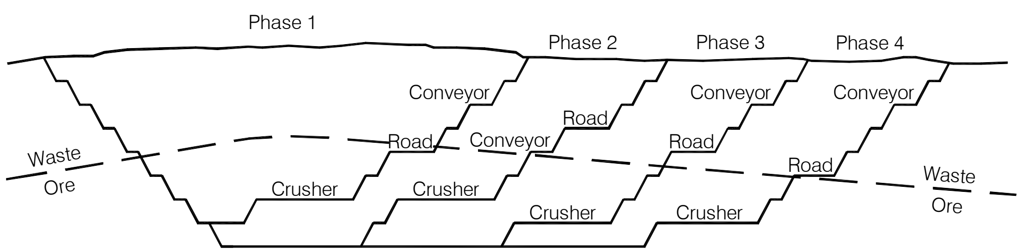


Figure 2