Conveying and stacking systems design for heap leach applications

Caleb Cook, Kappes, Cassiday & Associates, USA

Daniel Kappes, Kappes, Cassiday & Associates, USA

Abstract

Heap leach construction is an important component in the operation of a successful heap leach. Many methods are used, including direct truck stacking, on/off stacking in thin lifts, and conveyor stacking. Conveyor stacking is very common and uses a string of portable conveyors that feed a stacking conveyor where ore is then stacked onto the heap. While conveyor stacking is very practical and has many advantages, most of the industry has accepted using conveying and stacking systems that have not been engineered or designed with heap leaching in mind. These conveying and stacking systems tend to be overly heavy, which has led to many difficulties in proper heap construction and operation, especially for multi-lift heaps. Items that must be considered when designing these systems include the terrain, ore/material type, tonnage throughput, moisture content, cell width, lift height, as well as others. Engineering companies usually do not take these issues into consideration when conveyor systems are being specified, and suppliers tend to supply traditional off-the-shelf designs which are not well suited to the heap leach process.

As with any sophisticated processing system, the heap leach stacking system needs to be optimized. A look at several conveyor stacking systems being used in the field reveals many problems and pitfalls with the current approach and a need for a serious shift in how the industry thinks about conveyor stacking system design. Issues from poorly designed conveying and stacking systems range from minor problems, such as lost productivity and increased down time as a result of conveyors getting stuck or damaged while being moved, to severe problems, including potential permeability issues in the heap. While mining companies have dealt with these risks and difficulties by various operating methods, most could be avoided by making a purpose-built conveying and stacking system. This system would include lighter stacking conveyors, wide stance low ground pressure tires on portable conveyors, and the selection of the appropriate stacking method (top stack conveying system or retreat stacking).

Heap leaching: Permeability is key to success

Heap leaching has been used for the recovery of metals from ores for many centuries, but it was not until the advent of high-tonnage, high metal recovery operations in the 1970s, that it became necessary to optimize all aspects of the process. One of the major factors in heap leach performance is permeability, of which there are four aspects:

- permeability of the top working surface;
- uniform permeability of the heap;
- permeability of any intermediate layers between lifts;
- permeability of the drainage layer below the heap.

The first three of these are most directly affected by the method used to stack the heap. If the heap is stacked carefully so as to minimize compaction and maximize uniformity of material placement, then the heap should perform as predicted by laboratory tests.

Truck stacking of heaps

Heaps can be stacked by dumping the ore directly onto the heap from trucks. Truck stacking is used for the following reasons:

- Truck stacking offers operational flexibility: for example, it allows different ores to be sent to different areas of the heap.
- When the stacking rate exceeds 1,500 tonnes/hr (36,000 tonnes/day), conveyors begin to get large and difficult to maneuver.
- When run-of-mine (uncrushed) ore is stacked, conveyor stacking systems are not an option. However, run-of-mine heaps are very difficult to construct in a controlled manner, and recovery is difficult to predict. Run-of-mine heaps usually fall into the category of “dump leaches”, not heap leaches. In dump leaching, the object is to recover more value than it costs to do the processing. In heap leaching, the object is to recover a predictable amount which will show a predictable return on the investment.

Unfortunately, truck stacking compacts the top of the heap. Also, there is very little flexibility to add chemicals or moisture to the ore being stacked. Many precious metals heap leaches, and nearly all acid-based heap leaches such as copper heaps, are dealing with crushed ore which is high in clay. Truck stacking these types of ore almost always results in significant loss of values. Also, truck stacking is usually a higher cost method than conveyor stacking. For these reasons it should generally be avoided. Having said that, there are some very successful truck stacking operations such as the Cripple Creek operation of AngloGold Corporation. These heaps are built in 30 m high lifts, and the heaps are now over 200 m high.

Conveyor stacking of heaps

There are four basic configurations for conveyor stackers:

- Discharge from a tripper on a bridge conveyor which straddles the heap, normally applicable for on-off small tonnage heaps (such as the 1970s Rancher's operation at Ortiz, New Mexico).
- Discharge from a tripper on a long traveling belt which is supported on bulldozer tracks running on the heap (the Rahco stacker system, normally considered to be the best configuration for heap construction, but only applicable to large-tonnage heaps with regular geometry).
- Retreat stacking, using a radial stacker which operates from the base of the lift being stacked (this is the most common design).
- Top advance stacking, which uses a radial stacker operating on top of the fresh ore being stacked.

These four basic methods are discussed in more detail in the following sections.

Bridge conveyor stacking: Thin layer heap leaching

Thin layer on-off heap leaching (with heaps 1 to 4 m high) is sometimes practiced when the ores are not very permeable, or where high grade materials can be effectively pre-processed on their way to multi-lift heaps (where recovery would be slower and less effective). Examples are the above-mentioned Ortiz mine, or the classic Pudahuel, Chile, thin layer copper heap leach. These thin-layer heaps are especially useful for acid heap leaches of copper, zinc and rare earths. Often these ores are high in clay. They leach rapidly (in less than one week) but the acid solutions break down the ore and generate even more clay, so leaching for longer than one week does not work.

The idea of thin-layer heap leaching is a variation along the continuum of leaching (on the fast end of the scale) in vats or on belt filters, to (on the slow end of the scale) heap leaching. (Incidentally, the term "vat leaching" is often misused. It does not refer to agitated tank leaching. It refers or shallow tanks in which coarse ore is bedded, with leach solution percolating through the ore in either upflow or downflow mode.)

For alkaline heap leaches, such ores can be agglomerated and stacked in high lifts. But for acid heap leaches, there are no agglomerating agents that can maintain permeability of stacked materials in high lifts.

Racetrack design

A very productive but more capital intensive alternative to the bridge conveyor layout consists of an oval "racetrack" leach pad constructed of asphalt or other traffic-stable material. The heap occupies the oval, except for a "slot" in which the ore is removed. A front end loader or bucket wheel excavator removes the ore in the slot and advances the slot around the oval. A stacker runs on top of the advancing heap and dumps fresh ore on the leading edge. A photo of the system in operation at Round Mountain, Nevada, is shown in Figure 1.

Figure 1: Round mountain "racetrack" for on-off heap leaching
The tracked stacker shown on the left of the field of view is stacking ore over the edge, advancing into the slot. The front end loader and trucks on the right of the field of view are removing spent ore, which is sent to permanent heaps (seen in the far background) for additional leaching. Ore is brought to the stacker via a conveyor which lies in the center of the oval (it can be seen in the near background). Equipment moves continuously around the oval, and the ore is leached for approximately one month before it is removed

Rahco-type stacker for permanent heaps

A photo of a Rahco stacker stacking a permanent heap is shown in Figure 2. The stacker in Figure 1 is the same type of stacker – these are versatile machines. However, they are large machines that turn gradually, so the leach site must be large, or of regular geometry. Because this type of stacker can climb slopes, it can be used to construct multi-lift heaps.

Figure 2: Rahco stacker at the Chuquicamata, Chile, copper heap leach
The tripper can be seen in the background, dumping ore over the edge. These stackers can climb moderate grades, and make broad turns, while building a flat heap

Retreat stacking

The retreat stacker is the most common type of conveyor stacking system. It is easy to operate when the heap has a single lift. Because of limitations on the stacker weight, this single lift is limited to about 8 m. There are many cases where a single lift heap is better than a multiple lift heap – for example when the ore is very high grade (heaps at Sterling, Nevada and Hassai, Sudan, each averaged over 10 grams gold per tonne), when the ore cannot remain permeable in very high lifts, or where excessive rainfall must be managed. The cost of extra leach pad is usually not prohibitive, so single lift heaps are sometimes the best design choice.

When multiple lifts are utilized, the retreat stacking system has severe drawbacks related to trying to move heavy equipment around on the previously leached surface, which is often water-saturated and clay-rich. Therefore, the retreat stacking system should be used for multiple lifts only when the ore is hard and clay free.

Figure 3: Retreat conveyor stacking system at Yatela, Mali
Elements of the stacker system include: the radial stacker; the follower conveyor; the cross conveyor; and the grasshopper conveyors. The stacker builds the heap by swinging from side to side (the shadow of the heap can be seen in the foreground). As the stacker retreats up-pad, grasshoppers are sequentially removed. The light gray material is a 0.5 m cover of crushed rock situated above the plastic liner

Top advance stacking

Top advance stacking involves a flat radial stacker. The wheels operate on the top surface of the heap. The stacker swings from side to side and dumps ore over the leading edge of the heap, which is at the same level as the wheels. A top stacking system is shown in Figure 4.

Figure 4: Top advance stacking of a 12,000 tonne/day heap
This heap at Ocampo, Mexico, is climbing up a steep ravine. It is constructed as a spiral heap. Ore comes in on grasshopper conveyors at the lowest corner of the heap (these can be seen in the right side of the photo). The stacker is shown placing ore in a 10 m high lift which is being advanced over an existing, previously-leached, lift

The ore that the stacker is operating on is the newly placed ore, and so it is generally dry and can support the load of the stacker. However, since it is freshly stacked, it is in a highly uncompacted state so it is important to make the stacker as light weight as possible. Fortunately, since the stacker works at and discharges at "ground" level, there is no need for a truss lifting mechanism, or for the extra structural strength needed to support the elevated truss. This is a critical design area which the process engineer needs to give attention to: conveyor manufacturers usually build elevating radial stackers, and so a non-elevating stacker tends to inherit the more complex and overweight structure of its cousins.

With top advance stacking, there is no limit to lift height. This is a significant advantage when compared to retreat stackers. Unlike the Rahco stacker, the top advance stacker can be maneuvered in tight and irregular areas.

By proper conditioning of the ore it is possible for almost any ore to be stacked in single lifts of 15 or 20 m, or even higher. This provides another challenge for the process engineer: what is the optimal lift height? Some truck-stacked heaps (for example, Anglogold's Cripple Creek operation) build individual lifts of 30 m.

But there can be a problem with high lifts: Do the ore fines segregate near the top of the heap? How long does it take the leach chemicals to stabilize throughout the ore? How long does it take the solution to saturate the lift and start exiting from the base of the lift? Conveyor-stacked heaps have excellent control over the ore quality: ore can be wetted on the conveyors, almost to the full operating moisture level. This accomplishes two things: fines stick to coarser particles, and end up uniformly distributed throughout the heap; and chemical solutions can be added on the belts so that the heap is uniformly under leach as soon as solutions are applied to the top surface. The only height restriction may be related to geometry of the heap.

Conveyor stacking equipment is not designed with the process in mind

Surprisingly, although the critical importance of permeability is recognized by almost all production personnel, stacking systems designers do not usually start with this concept when designing production equipment. Why? Stacking systems designers are usually the stacking systems suppliers. They are mostly concerned with how easy is it to fabricate, sell, and use the equipment, rather than how the design of the equipment affects overall recovery. The metallurgists in charge of process design should be actively involved in the equipment design process, but they usually give this a very cursory review. It is common to see operators struggling with stacking equipment which gets bogged down in water-saturated, soft material. Often mobile equipment such as front end loaders or even cranes are brought onto the heap surface, to help the process. All of this leads to the formation of an impermeable or variably permeable drainage surface, with resulting loss of metal recovery. Proper equipment design could eliminate this problem. The process design professionals need to spend more time with the equipment suppliers, making sure the equipment is optimized for the process.

Deficiencies of conveyor stacking systems

The lack of interaction between the process design engineers and the equipment manufacturers has resulted in the widespread application of conveyor stacking systems which have significant design imperfections. These can be characterized as follows:

- insufficient or overly-sufficient equipment structural strength;
- excessive equipment weight;
- excessive ground pressure of tires or tracks; and
- poor design of the systems which are used for equipment movement on the heap.

Insufficient or overly-sufficient equipment structural strength and excessive equipment weight

The conveyor manufacturer is naturally biased towards making equipment too heavy. Weight does add to costs, but a bit of extra weight will result in higher quality, which is good for product reputation. This serves the equipment manufacturer well for most applications where conveyors are used, since the equipment is running on a constructed surface such as a concrete slab, and weight is not an issue. The operating surface of a heap leaching poses unique challenges. The working surface is often irregular, and composed of soft or water-saturated material. This imposes severe stress on the equipment. This can cause collapse of the equipment. Unfortunately, the fear of collapse is often compensated for by over-design, which results in excessive equipment weight. Many existing stacking systems struggle with excessive weight, and resort to the excessive use of mobile equipment to aid in positioning conveyors. It is important that the conveyor designers should have to defend their design weights to the process engineers, and demonstrate structural calculations that yield a high strength to weight ratio.

Excessive ground pressure of tires and tracks

The ideal conveyor stacking package should be composed of equipment which travels over the heap without causing visible wheel or track ruts. The human foot exerts a pressure of about 5,000 kg/m^2. This pressure will not depress the top heap surface. A pickup truck tire exerts a ground load of about 18,000 kg/m^2. It is easy for a pickup truck to depress the top surface of a soft, wet heap to the point where the truck has trouble driving out of the depression. So, as an ideal goal for conveying equipment operating on top of a heap, designers should try to achieve a ground pressure of no more than 10,000 kg/m^2. Using this rule of thumb, large high-flotation tires can support a load of 2,000 kg. Larger or heavier loads should be supported on steel caterpillar-type tracks.

Poor design of systems for moving equipment

Stacking equipment must continually move on the heap, often several meters per day. This movement should be done by the equipment itself, using powered wheels or tracks. The goal should be to eliminate all auxiliary equipment such as bulldozers, front end loaders, or cranes from the top of the heap. The designer should remember that every time an endloader or a bulldozer moves on top of the heap, some recovery is lost. Equipment drives should be powerful enough so that the equipment can extract itself when it runs into depressions in the surface.

Conveyor stackers should be equipped with stinger conveyors and operator controls that allow continuous movement of the ore discharge stream. With good equipment and good training, the conveying system can be used to build a nearly flat heap surface with no assistance from mobile equipment such as bulldozers.

Summary

In summary, there are several different ways to place the ore onto heaps for leaching, and not all of these are optimal in all circumstances. Poor choices result in a small loss of recovery due to bad stacking equipment or methods. Such losses are often accepted in practice because they are not easily measurable, or because the equipment cannot be modified.