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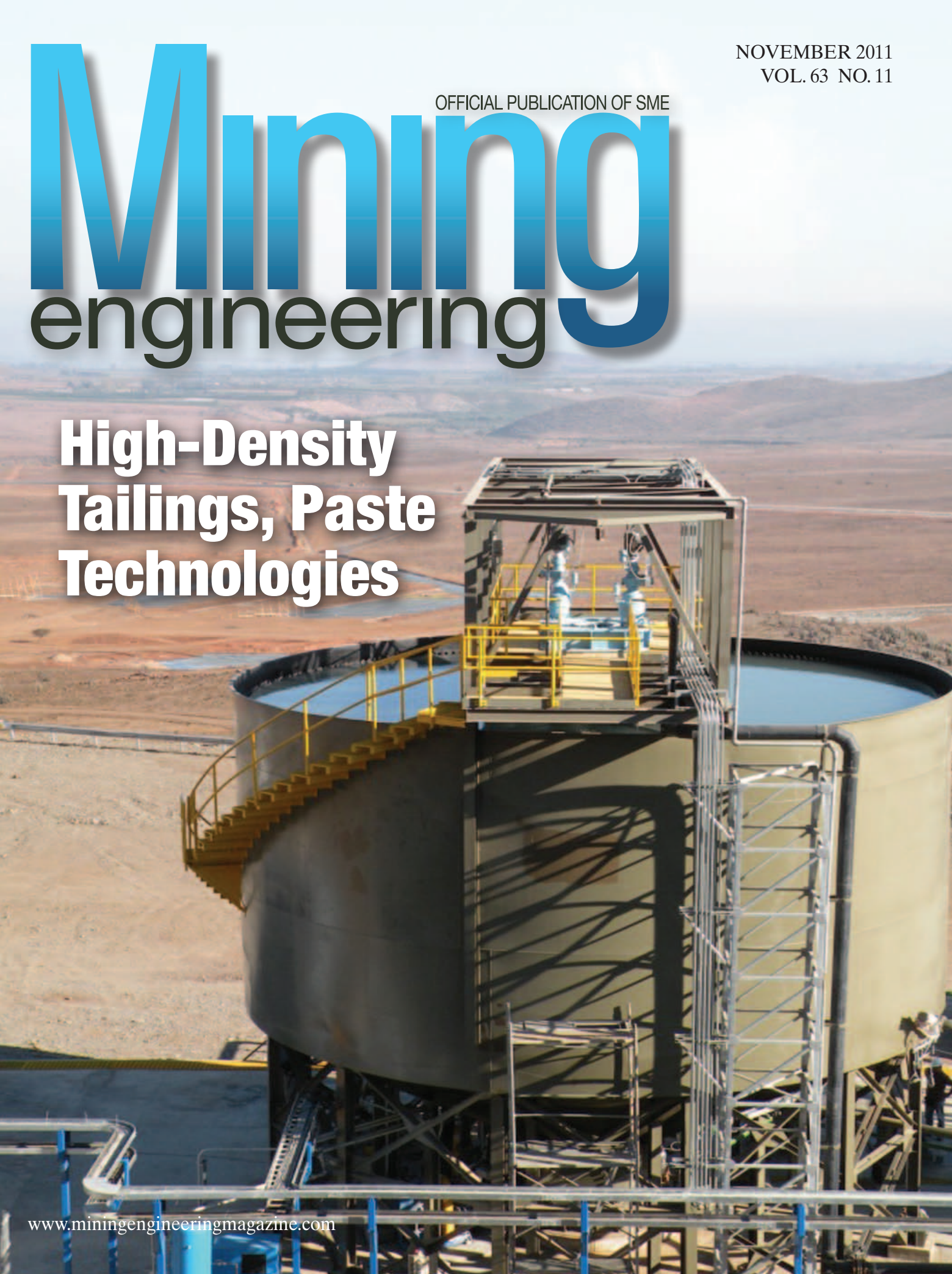
High-Density Tailings, Paste Technologies



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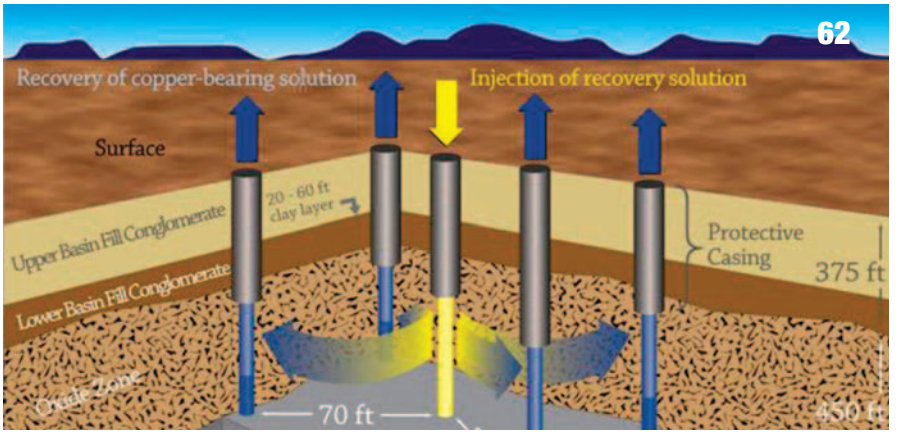

Feature Articles

Technical Papers (peer-reviewed and approved)

Elko Roundtable 2011:
high-density tailings, paste and filtered tailings

by Bryan Ulrich and Tom Kerr

FLSmidth 60 m high density thickeners at Esperanza, Chile (Photo courtesy of FLSmidth).

Knight Piésold and Co. hosted its annual roundtable discussion on March 17, 2011 at the Stockman Hotel and Casino in Elko, NV. The theme for Roundtable 2011 was, "High density tailings, paste, and filtered tailings," although the topic may well have been subtitled, "Don't prematurely rule out any technologies before they are given their day in court."

Bryan Ulrich, Knight Piésold's local representative, as well as Tom Kerr from Knight Piésold's office in Denver, CO, were on hand to help facilitate the discussion. Ulrich and Kerr are senior vice president and president of Knight Piésold's U.S. practice, respectively. The event played host to more than 30 attendees from several western states. Attendees included personnel from a dozen mining properties and various corporate offices. There were also attendees from manufacturing and specialist consulting firms who have been providing services to various high-density tailings, paste and filtered tailings operations worldwide. It may be noted that the term "filtered tailings" is used in this discussion. Alternative terms, such as "dry stack" or "dewatered tailings," should be avoided whenever possible, as such terms tend to give a false sense about the nature of the material since these materials typically still retain a significant amount of moisture.

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The purpose of the roundtable was to exchange ideas and information pertaining to high-density tailings, paste and filtered tailings. Compared with traditional conferences and symposia, this type of forum tends to provide a much less inhibited format for discussion. In the roundtable format, lively discussions and applicable tangential departures are encouraged.

This was the sixth in the series of Elko Roundtable events. Previous roundtables pertained to heap leach pad design, construction and operation; design, construction and operation of tailings storage facilities; site-wide water considerations; mine closure and cover design and strides toward sustainability in mining.

The initial subtopics for Roundtable 2011 included:

- Safety share.
- Introductions.
- Vender and supplier presentations.
- The thickened tailings continuum.
- Drivers for thickening.
- State of practice.
- Environmental and permitting considerations.
- Rheology, pumping and piping.
- Sedimentation.
- Filtering.
- Unique facilities.
- Surface paste storage strategies.
- Underground disposal.
- Practical experiences and lessons learned.
- Where to from here?

The roundtable created a good environment to discuss the current practice and challenges of tailings thickening and filtration challenges and accomplishments. Since there is considerable overlap between the roundtable's subtopics, the conversations frequently wandered from topic to topic and back again. In keeping with the spirit of an open roundtable discussion with unbridled conversation, the authors have chosen to create "sanitized minutes" of the meeting, wherein

WesTech deep bed paste thickeners in an alumina, red mud washing CCD circuit.

specific quotes are not attributed to their author, but rather the proceedings of the discussions are presented in a rather stripped down version in order to avoid stifling the exchange of ideas. Incidentally, the bulk of the conversation pertained specifically to above ground tailings storage, although underground disposal was also discussed. The following is partly a tangential discussion and partly the proceedings of the roundtable.

The day began with a tribute to safety. The U.S. mining industry has worked hard to achieve its significant and impressive safety record. This is especially true for western hard rock mines. Many of the major mining companies have started to make the idea and the actuality of safety a personal matter. The stories that follow are a brief reminder of an article authored by Jim Arnold (**ME**, May 2007, pg. 6) and a personal account of the tragic ending of another young life.

"I never met Cody. But I'll never forget his story." That is the brief story of his life as told by Arnold in the May, 2007 edition of *Mining Engineering* magazine. It was Arnold's first message as president of SME. I could not finish reading Cody's Story without getting a lump in my throat, and yes, a tear or two in my eyes. To this day the story still saddens me. As Arnold wrote, Cody was an amazing person and a two-time state champion wrestler. He was on top of the world, and at the beginning of what might have been an amazing life. In Arnold's article, there were two stories that were intertwined. The other story was how we can sometimes pay too little attention to the safety messages we hear such as "watch for deer on the highway" … "pay attention for icy roadway conditions." It seems like when we hear these messages over and over, we can almost go into autopilot just to get through these sometimes repetitive safety shares.

Cody's life was tragically shortened in a single car rollover accident. Cody was not wearing a seat belt. The story really struck me somewhere deep inside, and I can recall the details of the article to this day. The story is a testimony to the young man who lost his life and also a sobering reminder that we all need to wear our seatbelts, even if we're just driving next door, to the grocery store or golf course.

I didn't need the article to remind me to wear a seatbelt. In 1981, my wife-to-be and I were returning to Socorro from a day trip to Albuquerque. We'd just left the highway, passed a car, and came straight into the path of an oncoming car that was traveling the wrong way. Thankfully, we suffered relatively minor injuries, which we overcame pretty quickly partially because we were young. Our car was another story. It was a 1971 Pontiac Lemans Sport convertible. It was our pride and joy even though it constantly needed tender loving care, and I frequently had to crawl under the cursed thing to line up the shifter linkage just so it would shift. It was amazing how often this "repair" had to be done during a snow or rain storm. Our beloved car was totaled. Neither of us had been wearing a seatbelt. Since then we have worn seatbelts religiously. We were really fortunate to escape without significant injuries. Better not to tempt fate. The event left that kind of impact. We now jokingly say that we only buckle in those we love. The car never moves an inch until all of its passengers are securely buckled no matter how far (or near) we are traveling.

We hear similar messages at our MSHA new miner training, at our annual safety refreshers, and at weekly tailgate meetings. Always wear your seatbelt.

Recently, a young man with his life in front of him parked a truck that held all of his life's possessions. He had just resigned from his job so that he and his wife could spend some time traveling. He hopped out of the truck, maybe his mind elsewhere. He looked back and saw the truck rolling away. In desperation, he tried to stop the truck by running to hold it back. He was crushed to death by the truck at the very moment that his young life's most amazing experience was supposed to be beginning.

If somebody had asked him the day before (or the minute before) what he would do to stop a rolling truck, I'd imagine that he would have quickly said that he would have looked for something to throw under a tire. If you'd pressed him, he may have suggested that he might try to

hop in the cab as a last ditch effort. Climb in and hit the brakes. You'd have to tell him, no, that's unsafe. Do not attempt to do this. I'd imagine that you could have asked him about running to the truck to try to stop it with your own pure might. I am convinced that he would have looked at you like you were crazy. Stopping a 2-4 ton truck by holding it back, and trying to stop it with pure brute force. Preposterous, he would have said, don't be ridiculous. And yet that is what he did. In my mind, on any other day of the year, he would have never done such a thing. It defies logic. And yet it was a very human reaction to a very real event with very little time to decide.

Like Arnold, I believe that we cannot repeat ourselves too many times when it comes to delivering such important messages. Maybe it's the latest message that will finally sink in – maybe the latest reminder will save a life.

We all make mistakes. In Arnold's article, he quoted former SME President Bob Shoemaker who used to say, "there are no new mistakes." Arnold said, "He's right; we just keep making the same ones over and over." Every year at the mine where Arnold worked someone would plow into a deer and someone else would slide off an icy road. Like Arnold, I believe that we cannot repeat ourselves too many times when it comes to delivering such important messages. Maybe it's the latest message that will finally sink in – maybe the latest reminder will save a life. There must be people who are walking around today who wouldn't be if someone hadn't put one of those repetitious safety messages in their mind just before they did a job.

If this article can take the possibility of stopping a moving truck by running to hold it back with your own pure might, or can get just one more person to buckle up it will be a testimony to these two young men, two young men at the very beginning of their lives.

Presentations

Following the safety share, the discussions began with brief presentations from the various specialty manufacturers and consultants who were invited to the roundtable. These presentations were aimed at providing the attendees with some general background information, but also to help the attendees know whom they may need to contact when they are at certain points in their tailings thickening and filtration projects. Presenters provided information regarding various topics related to filtering, thickening, pumping and piping of thickened, paste and filtered tailings.

Many of the attendees of the roundtable had attended (or indeed have been significant drivers of) one or more of the International Seminars on Paste and Thickened Tailings, while other attendees were fairly new to the topic. The discussions commenced with defining some of the basic concepts revolving around the practice of high-density tailings, paste and filtered tailings. The conversation began with the concept of the thickened tailings continuum and by defining "yield stress" and the importance of considering yield stress for materials that have been fully shear thinned. Rob Cooke (Paterson & Cooke) said that a yield stress can simply be thought of as the "thing" that keeps catsup from flowing from the back of its bottle when we hold the bottle upside down (adding jokingly that future generations will not understand why it took so long to invent the "upside down" catsup bottle). We have to shake the catsup bottle in order to overcome the catsup's yield stress. If it is shaken enough it becomes fully shear thinned.

Not all materials are prone to shear thinning, but for materials that are, this concept is important. Why? Because it is the behavior of the material that comes out of a delivery pipe that we are really interested in. That material has been shear thinned (if it is prone to such behavior). Material exiting a thickener may not be shear thinned. It may only become shear thinned after it has been agitated significantly, such as by a pump, for example. Since we are interested in how the tailings deposition is formed, or how the underground backfill behaves, it is the shear thinned rheology that should interest us.

Cooke provided additional insight regarding this topic because the term "shear thinning" is not quite an accurate term to describe the behaviors being observed. In shear thinning fluids, the apparent viscosity decreases with increasing shear rate (e.g., a Bingham Plastic) and that this effect is not time dependent. In thixotropic fluids, the apparent viscosity decreases over time when exposed to constant shear and this effect is reversible. For mineral slurries, the effects generally are nonreversible. The more correct term for that case is rheomalaxis. Cooke has started using the term "energy induced rheology reduction" to avoid the less correct terminology (shear thinned). The less correct term, "shear thinning" will likely persist, but we can assume the term is actually meant to be consistent with Cooke's term, but hereinafter, I will simply adopt the simpler term "thinned" for the sake of simplicity.

To summarize, yield stress should only be measured on a fully thinned sample, and yield stress is the force that is required to just initiate movement of the material.

The concept of thickened tailings continuum was discussed. The thickened tailings continuum has been presented numerous times elsewhere. It simply represents the nature and behavior of tailings at various degrees of thickening, as follows:

- Conventional slurry tailings.
- Conventionally thickened tailings.
- High density tailings.
- Paste tailings.
- Filtered tailings.

Yield stress is often employed as a distinct boundary to help define these brackets within the continuum. According to attendees of the roundtable, the yield stress separating conventional slurry tailings and thickened tailings tend to range between 5 and 20 pascals (pa) [1 lb/sqft is approximately 48 pa]. The boundary between thickened and paste tailings is approximately 100 pa, and 800 pa is the boundary between paste tailings and filtered tailings.

Some practitioners prefer to think of the thickened tailings continuum in terms of solids content rather than using yield stress as the reference condition. Sometimes this is convenient but it is not entirely meaningful. For example, consider two tailings slurry samples. One has a high magnetite content. The other sample is exactly the same, but without the magnetite component (the magnetite is "replaced" instead with the ordinary host rock, thus the volume of solids is identical for both samples, as is the volume of water). The difference in average particle specific gravity between the two samples is the only difference, but the two samples would have different solids contents. It isn't altogether satisfying to place these two materials at different positions on the thickened tailings continuum based simply on their different magnetite content (or specific gravity). A similar comparison could be made for otherwise identical samples containing different amounts of clay minerals. In this case, they may indeed have quite different yield stresses, but identical solids content.

So, although conceptually less intuitive for many people, yield stress is the preferred reference for the thickened tailings continuum rather than solids content.

With the background information presented, the conversation turned toward the main drivers that determine whether thickened, paste or filtered tailings should be considered rather than, or in addition to, conventional slurry tailings. At the 11th International Seminar on Paste and Thickened Tailings (Paste 2008), the lead author delivered a presentation on the "State of Practice of Tailings Thickening in the State of Nevada, USA." To write that paper, various operators across Nevada were interviewed and it was found that the solids content of Nevada tailings tend to range between 35 and 50 percent, with or without the use of thickeners and, when thickened, only conventional thickeners were used. This was something of a surprise to that audience, but given Nevada's expansive land and ample water supply, it was not altogether surprising to me. The drivers have not yet been determined for use of thickened, paste or filtered tailings in Nevada so this was a lively topic of discussion by the roundtable group. However, it appears that those drivers are now beginning to influence tailings management decision making in Nevada.

Presently, some of the key drivers for selecting thickened, paste or filtered tailings pertain to social acceptance, ease of permitting and water savings. Especially water savings. In very arid regions, water can come at a considerable cost and even more so if population centers are situated near the mining area. Accordingly, finding a means of reducing water consumption can come to the forefront in tailings management planning. Social acceptance and ease of permitting fall right in line with the water savings considerations. Other drivers include:

- Water recovery.
- Avoidance of evaporative losses.
- Topographic constraints.
- Land constraints.
- Regulatory restrictions.
- Closure implications.
- Draindown considerations.
- Corporate decision making.

The benefits of adopting thickened, paste or filtered tailings as a tailings disposal strategy with respect to facility closure was discussed at some length. One advantage of reducing the moisture content of the tailings before sending it to the disposal area is that the amount of consolidation the tailings will experience (including postclosure consolidation) should be reduced in most cases. This is also an advantage of subaerial tailings, although this achievement is accomplished differently with the two methodologies. The first process recovers water in the mill and the latter process recovers water via an underdrain, but also water is lost to evaporation. Compared to conventional slurry, either process helps to reduce the magnitude of consolidation by removing water from the tailings. In this case, the possible disadvantage of subaerial tailings is that some of the moisture is lost to evaporation (although if water does not come at a premium price, this may not be a disadvantage).

Kerr gave a brief summary presentation of the La Quinua thickened tailings project in Peru that can be found at: http://www.convencionminera.

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Tailings disposal at Esperanza, Chile (Photo courtesy of FLSmidth).

com/perumin_cms/upload/archivos/TT-184%20Final.pdf. The Yanacocha Mine's La Quinua Mill has a thickened tailings storage facility that is contained within an active heap leach facility. It is a unique and unprecedented design that provides its operator with cost, land-use and closure efficiencies. This design requires that leach ore embankments retaining the tailings provide the same level of stability required of major tailings dams. As compared to conventional tailings dam construction, the leach ore in these embankments is consistent with normal heap leaching operations; that is, with thick uncompacted lifts to maintain adequate permeability for leaching. The resulting loose structure makes the proper assessment of static and dynamic liquefaction a critical issue. The key design principle for avoiding liquefaction is to maintain the phreatic surface well away from the outer faces of the embankments and within large unsaturated structural shells. The geotechnical design work that led up to this design was quite impressive. The facility was successfully commissioned in early 2008 and its performance to date has met or exceeded its design objectives.

In some aspects, this facility bears a resemblance to Barrick's pipeline tailings facility at the Cortez operation in Nevada, which also couples a tailings facility and a heap leach facility. At Cortez, the containment structures are composed of spent heap leach material, but these materials are placed in controlled, compacted engineered lifts to achieve stability requirements. At La Quinua, the containment structures are loosely placed and function as an active part of the heap leaching operation.

The roundtable's conversation then turned toward surface disposal facilities that combine tailings and waste rock in a more uniform manner, although not necessarily in homogeneous mixtures. Some of these methods have trademarked titles, which will not be repeated here. Mention was made of the work Ward Wilson and his colleagues completed at the University of British Columbia. One primary goal of the work by Wilson et al. was to study the benefit of a homogeneous tailings and waste rock mixture in creating a saturated cover layer for a waste rock pile that could ward off acid rock drainage (ARD) production. A similar strategy was mentioned that would not have to consist of a blend of materials (i.e., filtered tailings) that may also be capable of accomplishing the same net effect. Other methods of creating blended facilities were also discussed by the group, weighing their specific advantages and disadvantages.

With any developing technology, there is bound to be some degree of skepticism. However mention was made of a project where blended tailings and waste rock were successfully used to create a closure cover.

Some time was also spent discussing surface and underground disposal of high-density tailings, paste, and filtered tailings. Central thickened discharge (CTD) also known as the Robinsky method, was discussed, as were other methods. CTD is often used for high-density and paste tailings when large land areas are available and topography is relatively flat. In other terrains, the tailings facility may bear a similar resemblance to conventional tailings storage facilities.

The size of these operations continues to grow over time. Presently, high-density tailings, paste and filtered tailings are being considered for mines with very high production rates. La Coipa in Chile was said to be the largest presently operating filtered tailings facility with a production rate of around 20 to 30 kt/d (22,000 to 33,000 stpd). The Rosemont copper mine in Arizona plans to produce filtered tailings at the rate of 90 kt/d (99,000 stpd). Paste tailings are now being produced at the rate of 40 kt/d (40,000 stpd).

High-density tailings, paste, and filtered tailings producing equipment is keeping stride with the industry's pace. When the equipment manufacturers at the roundtable were asked about the latest innovations that are filling their whiteboards, they responded that the future lies in what the future mines will require – the manufacturers will respond the industry's needs, thus ending the day on a high note.

By all accounts, this year's roundtable was seen as being highly successful. Next year, Knight Piésold plans to once again host a roundtable discussion in Elko. ■