Alternatives to Coal Mine Tailings Impoundment - Evaluation of Three Dewatering Methods at Rockspring Coal Mine

Charles Murphy, Alpha Natural Resources, Logan County, West Virginia, USA
Christopher Bennett, Alpha Natural Resources, Logan County, West Virginia, USA
Greg Olinger, Ashland Water Technologies, Wilmington, Delaware, USA
Bret Cousins, Ashland Water Technologies, Wilmington, Delaware, USA

ABSTRACT

In 2008, Alpha Natural Resources initiated investigations to determine the most desirable technology to facilitate the continuation of fine tailings disposal and water management at the Trace Branch tailings impoundment site during the capping stage at the Rockspring coal preparation plant. This 1800 ton per hour thermal coal facility was nearing capacity of its existing tailings impoundment and needed to determine and evaluate alternative methods to increase impoundment capacity and improve water management. This paper discusses the findings of various assessments and trade off studies that resulted in a decision to install eight three-meter belt presses capable of dewatering 180 tons per hour of tailings solids in a slurry so they could be mixed with coarse material and used as capping material.

INTRODUCTION

The Rockspring coal preparation plant has a throughput of 1800 tons of coal per hour and in the process, produces approximately 180 dry tons of fine tailings material each hour as 30% solids slurry. The slurry is pumped to the tailings impoundment area where the solids settle and then the water is recycled back to the plant. In 2008, the impoundment area was reaching capacity. If nothing changed, a new impoundment area would need to be built and there was not enough time to get a new impoundment area built and commissioned before the plant would need to be shut down. The operator of Rockspring, Foundation Coal (merged with Alpha Natural Resources in July 2009) undertook an extensive study of dewatering solutions, including geotextile tubes, deep cone paste thickening and filter belt presses, to decrease the volume sent to tailings to significantly lengthen the life span of the current impoundment area. Investigators concluded the filter belt presses provided the most practical and economical solution. Water management at the plant also became more efficient since much of the slurry water no longer left the plant, creating a reduction of water loss due to evaporation out at the impoundment site.

THE TAILINGS IMPOUNDMENT

Figure 1 is an aerial photo of the Trace Branch tailings impoundment. When regulators moved the area into closure, which involved the placement of capping material, the Rockspring plant, to continue operating, set up a mini impoundment area with a life span of 18 months. While regulatory processes were underway to establish a new full scale tailings impoundment area for the plant, it became apparent that 18 months would not be enough time to get a new impoundment area established and in operation.

Figure 1. Trace Branch tailings impoundment, Logan County, West Virginia

The capping process for impoundment areas includes placing coarse material over the surface of the pond to protect the fines in the area from wind, rain and other meteorological events after all the water drains away. The process creates a stable system that can then be reclaimed back to its original environment.

With the capping process underway, investigators studied how much fine material could be added to the capping material without significantly undermining the capping stability. Since the coarse material contained 5% to 6% moisture and the finished cap could contain up to 16% to 18% moisture and still maintain stability, there was opportunity for the fine material to be added. To reach the 16-18% total moisture target for the cap while handling the total 180 tons per hour of dry fines being produced by the plant (estimated to be approximately 1/3 of the capping material mixture), the fines slurry would need to be dewatered from its current 30% solids to approximately 60% solids.

If the tailings could be dewatered to 60% solids and mixed with the coarse material to cap the Trace Branch tailings impoundment, then the life span for the existing impoundment area combined with the mini impoundment area would allow ample time, approximately four and a half years, to permit and build a new, permanent impoundment area. The higher percent solids also would extend the life of the new impoundment area and significantly improve water management at the Rockspring plant.

THE TAILINGS SLURRY

The fines in the tailings slurry sent to the impoundment area consist of coal and rock material that has been consolidated to 30% of the slurry weight. The slurry contains fairly high clay content and approximately 80% of the solids are smaller than 40 microns in size, which creates problems when trying to increase solids content.

Before the new dewatering plant was commissioned, all of the plant's refuse streams were allowed to settle in conventional thickeners to approximately 30% solids and then were pumped to the tailings impoundment. The settling time was slow (30 plus days) with the tailings liquid effluent recycled back to the plant. To speed up water turn around and keep the impoundment in compliance with state and federal regulations, the slurry was treated with polymer before injection into impoundment improving turn-around to two to five days.

Regardless of settling time, approximately 100,780 gallons of water per hour were sent to the impoundment area when the tailings slurry was at 30% solids. Increasing the slurry to the 60% solids so that it could be used during the capping process would reduce the water flow to the impoundment to approximately 28,800 gallons per hour further improving the plant water balance. This increases the water re-circulated within the plant by 71,980 gallons per hour and places much more control of the water balance in the hands of operations.

Because of the difficulty in dewatering these solids, pressure would need to be applied to obtain at least a 60% solids level. Thus, as mentioned previously, investigators studied three dewatering methods: geotextile tubes, deep cone paste thickener and filter belt presses. Figure 2 illustrates each of the three methods that were evaluated at Rockspring.

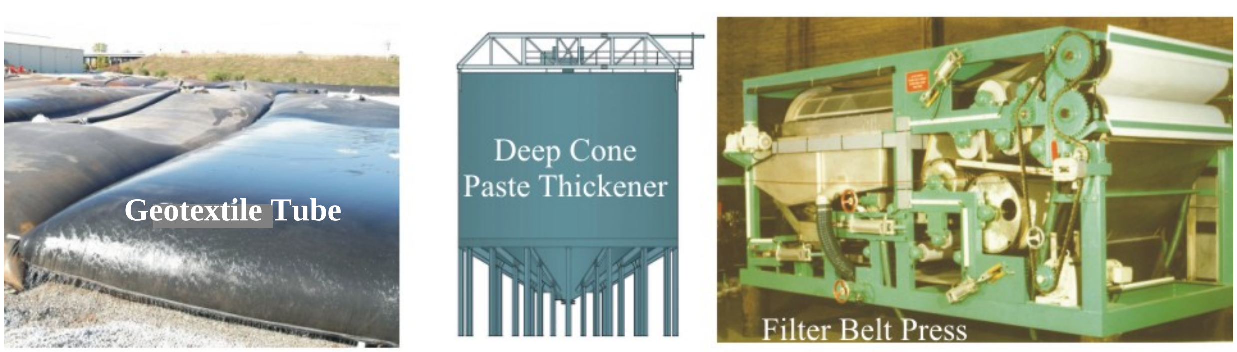

Figure 2. Dewatering methods that were evaluated at Rockspring

DEWATERING METHODS

All three dewatering methods were evaluated and the results are shown in Table 1. Comparisons were made on performance, size of area needed for operation (footprint) and capital and operating costs extrapolated over the four and a half year extended life span of the Trace Branch impoundment area and the mini impoundment. Operational drivers were determined through lab and small pilot testing. The economic drivers considered both capital and operational costs.

Table 1. Operational and economic drivers for dewatering Rockspring plant tailings

			Costs		
Method	Footprint (m^2)	Best % Solids	Capital	Operating (yr)	Over 4.5 Years
Geotubes	184000	85%+	-	$10.5M	$47.3M
Deep Cone Paste	400 (20 m diameter)	48-50%	$5.5M-6.0M	$2.5M-3.0M	$16.8M-19.5M
Filter Belt Press	930 (Building + belt)	65-70%	$4.5M	$3.5M	$20.3M

Geotextile tubes

The geotextile tube technology involves flowing slurry through a filter tube where the water passes through and the solids get compacted with the help of a flocculating chemical. Pressure is applied as water is forced through the membrane by the flow of slurry into the tube. Once the tube is filled, the geotextile tube is left in the impoundment area and a new geotextile tube is set up to continue the process. The technology is relatively inexpensive and very effective in many applications.

Testing showed that geotextile tubes effectively improved the solids level in the tailings slurry. The clay content restricted the level of compaction the geotextile tube technology achieved, limiting the maximum percent solids to approximately 85%, which was well over the required 60% solids target range. However, at 85%, the number of geotextile tubes required for the four and a half year period exceeded the amount of available land space in which to operate them. Although all the costs can be posted as operational (geotextile tubes are consumables), the cost per year of $10.5 million made the geotextile tube option the most expensive. In addition, the effluent discharged during dewatering would still have to be pumped back to the coal plant for reuse, incorporating variability in the water balance. Therefore, the investigators’ conclusions were that the geotextile tubes were neither practical nor economical for treating the Rockspring tailings.

Deep Cone Paste Thickening

The technology of deep cone paste thickening is based on a steep-angled cone and a relatively deep thickener bed to enhance underflow density. The increased bed depth gives greater compaction, and thus applies pressure to push more of the water out of the slurry. This dewatering method incorporates modern thickener technology such as flocculants, feed well dilution systems for best flocculation, more effective raking mechanism designs, and high torque drives. Deep cone paste thickening has shown significant effectiveness in dealing with high clay tailings in the phosphate industry (Tao et al. 2008). These clays tend to be under 30 microns in size and colloidal in nature, much like what is found with the Rockspring tailings slurry.

Testing was designed to determine if deep cone paste thickening was capable of obtaining 60% solids for the tailings slurry at Rockspring. Investigators, testing with a series of flocculants and operational parameters, determined the best results achieved only 50% solids at an operational cost of $2.5M to $3M. Economically, over the four and a half year period, deep cone paste thickening is the best option, but since the nature of the Rockspring tailings does not allow dewatering to the 60% solids target level, the technology is not a suitable choice.

Filter Belt Presses

Water content in most slurries can be reduced to very low levels by applying mechanical pressure, depending on the solids ability to hold onto water. Belt filter presses are fed slurry that passes through a series of drum and roller systems, each series producing lower water content. As shown in figure 3, most belt filter press operations can be divided into three general stages: initial de-watering, which makes the sludge pulp; pressing or medium pressure filtration, which conditions the sludge for high pressure filtration quality; and high pressure filtration. The process begins as the sludge enters the press. It is mixed with a dewatering chemical either in the press or in a conditioning tank prior to the press. The sludge then enters the gravity drainage zone where a large rotating drum drains a majority of the free water. Pressure is first applied in a low pressure wedge zone, which begins squeezing the remaining water out of the sludge. Further de-watering occurs in the medium pressure zone, where two large, perforated drums of decreasing size apply pressure. Rollers perform the final de-watering in the high pressure zone (Jellesma 1978).

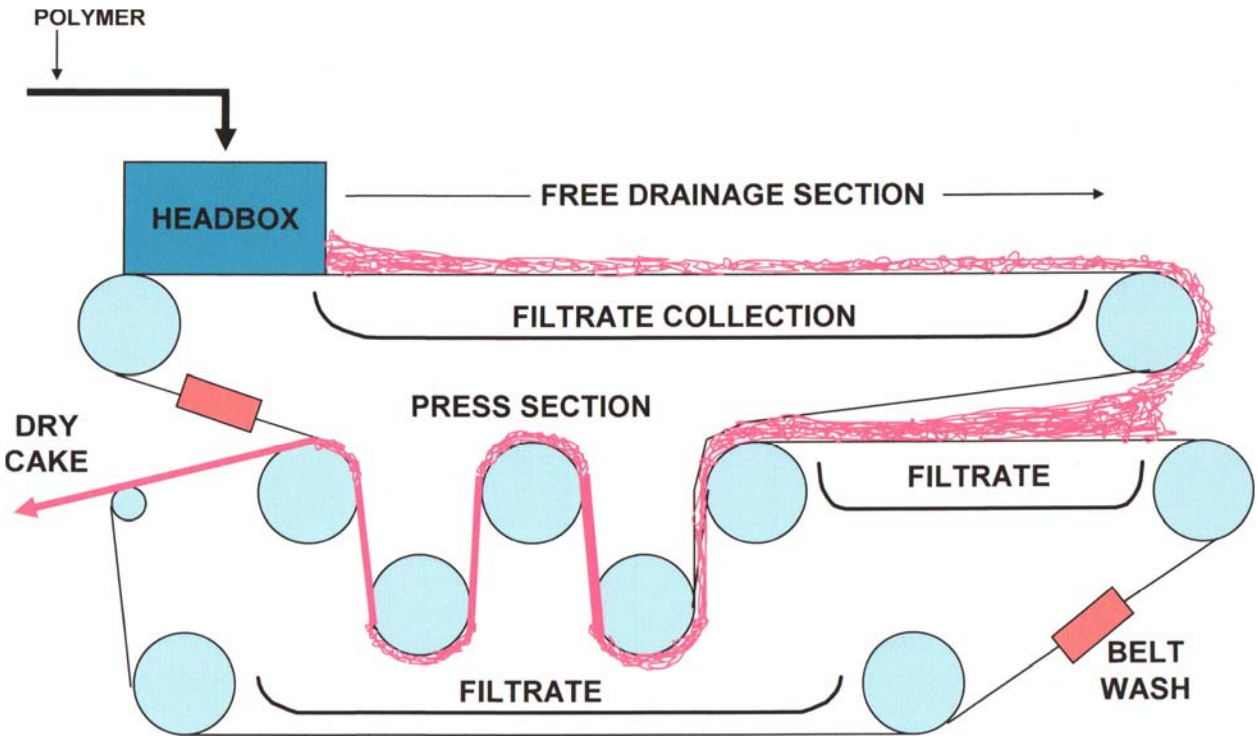

Figure 3. Illustration of filter belt press operations

Testing the Rockspring tailings slurry on a filter belt press indicated that a higher than 60% solids target was achievable. Operational costs were higher than the deep cone paste method, but were not prohibitive.

As a result of the evaluations, the investigators determined that filter belt presses were the best option for the Rockspring coal plant to help them achieve their goal of economically lengthening the lifespan of their impoundment area and improve water balance.

PLANT DESIGN

Having chosen filter belt presses as the dewatering method, designing the entire system involved determining how many presses would be required and how they would operate. Given the current 180 dry tons per hour of tailings, six presses would be needed to handle the flow rate. The design team added two extra presses to allow for maintenance without reducing production. This also easily accommodates increased production.

Figure 4 is a flowsheet of the Rockspring dewatering plant as designed and commissioned. Design began in April of 2009 with construction initiated in April of 2010. Commissioning of the plant began in July of 2010.

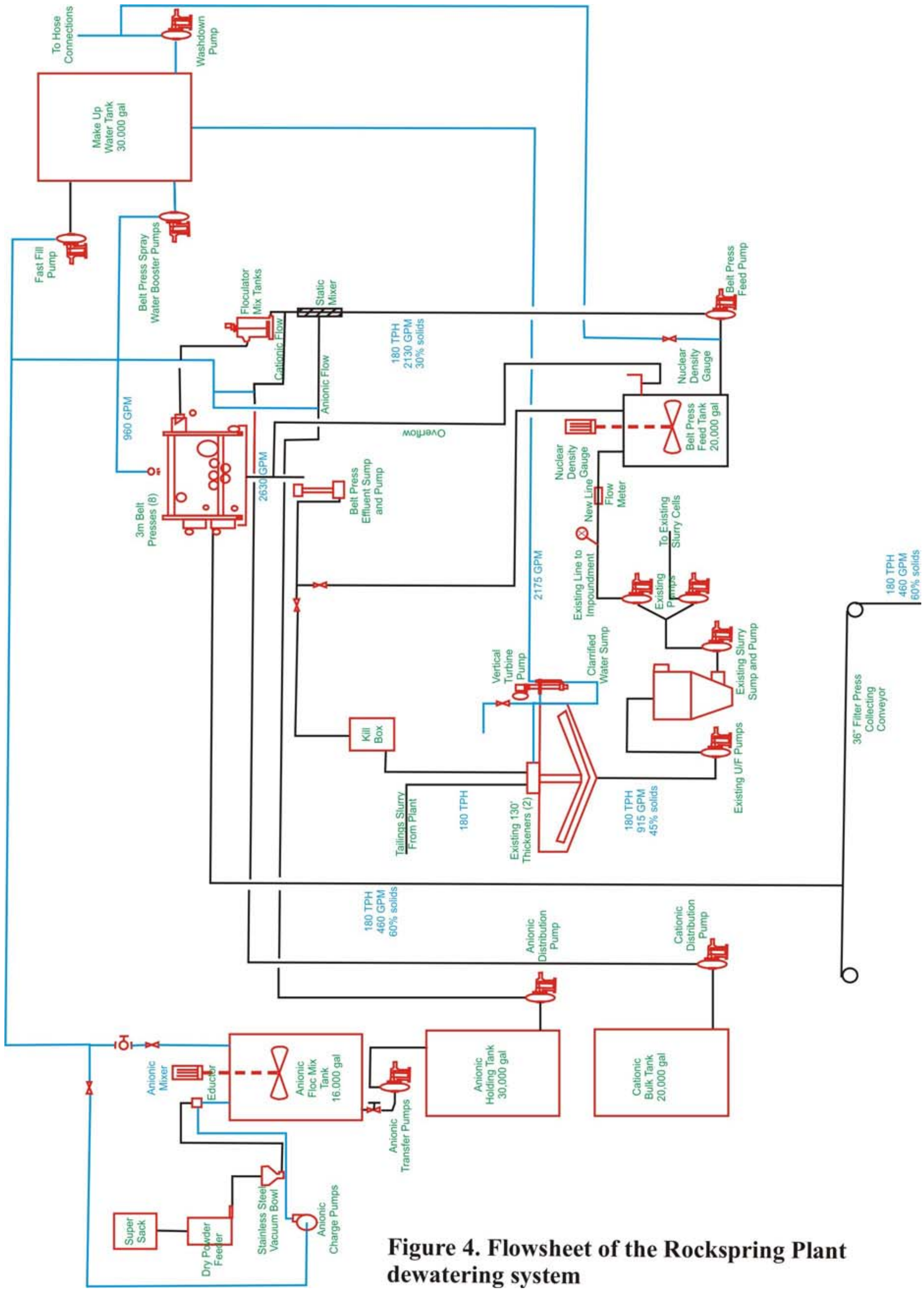

Figure 4. Flowsheet of the Rockspring Plant dewatering system

The slurry line that originally flowed to the impoundment area from the existing thickener plant was tapped into for the new dewatering system and re-routed through a flow meter. Now the slurry flows into a 20,000 gallon stirred feed tank for the six operational filter belt presses (eight in total). This tank can also be fed extra water from the belt press sump for better control. The tank has an overflow system that sends slurry directly to the belt press sump as a bypass.

From the belt press feed tank, the slurry passes through a static mixer where anionic flocculant is added to begin the dewatering process. Once through the static mixer, cationic coagulant is added to further enhance dewatering in the press. A small floculator mix tank is a pre-feed tank for the belt presses, allowing for better control of press operations. Originally, two static mixers were considered; however, due to concern that the second static mixer might cause flocculant breakdown, it was decided to utilize the floculator tank. .

The slurry then enters the press, where it is dewatered to approximately 60% solids. From the press, the filter cake is discharged onto a 36 inch collecting conveyor belt that moves it to a place where it can be mixed with coarse material to make the final capping material. That material is then transferred to the Trace Branch impoundment area. The collecting belt was chosen over a radial stacker because the cake had transfer difficulties due to sticking in the radial stacker and the conveyor system required a much smaller containment area.

Flocculant System

Fully automated, the flocculant system was designed and constructed by Ashland Water Technologies. The nature of the Rockspring tailings requires a two stage flocculation process to manage the clays. The first polymer added is a very high molecular weight, anionic flocculant which adsorbs onto the surface of the particles thereby making them net negatively charged. The second polymer added is a low-medium molecular weight, cationic coagulant which interacts with both the clay particles and anionic flocculant.

Certain clay particles have both anionic faces and cationic edges. The primary anionic flocculant not only neutralizes those cationic edges, but it also provides anionic loops of polymer that extend far from the surface of the particles to make the attachment of the secondary polymeric coagulant more efficient. The second cationic polymer interacts with the anionic loops and tails of the first polymer. This process tightens the flocculated tailings and squeezes excess water from between the clay particles. The result is a much faster release of water in the free drainage section of the press and better compressibility of the sludge cake in the press section. This combination of polymers acts to increase the solids throughput of the press while, at the same time, increasing the final cake solids (alternately lowering the cake moisture).

The anionic flocculant is supplied as a dry powder in supersacs. Using four dry powder feeders, the flocculant is mixed with water to a 0.25% concentration in a 16,000 gallon mixing tank. This process is fully automated, adding the right amount of water for four supersacs to make a consistent concentration. From the mixing tank, the anionic flocculant is pumped to a 30,000 gallon holding tank for distribution to the static mixer at each belt press. The flocculant flow at each belt press is also monitored and controllable.

The cationic coagulant is in the form of a liquid polymer, ready to be added directly just before the floculator tank for each belt press. Stored in a 20,000 gallon tank, it uses the same type of pumping systems as the anionic flocculant.

Water Management

With less water being retained in the impoundment area and/or being evaporated during this process, the water management processes were more manageable. The extra water now comes off the belt presses and rather than building a catch basin for this water flow, it was found to be much more effective to let the water flow onto the plant floor and collect it with a sump system. Averaging 2630 GPM, the sump sends most of the water back to the existing thickener. Some of the water can be re-routed to the belt press feed tank if necessary. Two nuclear density gauges are used to keep the feed to the belt presses consistent.

The existing thickener overflow is pumped to a 30,000 gallon make-up tank to feed all the other water uses in the plant. A thickener was considered rather than a make-up tank to produce a better quality of clarified water for chemical mixing and other sources, but the main consumer of the water is the existing thickener where higher quality water is not necessary. Upon determining the effects of lower quality water in other areas as being minimal, the 30,000 gallon tank and its smaller footprint was selected.

The 30,000 gallon tank is now the center of the water management system that reduces water loss. Averaging 2175 GPM of flow throughput water is distributed for anionic flocculant preparation, spray systems of the belt presses, and washdown water for the belt press feed line and hose connections throughout the plant.

PLANT COMMISSIONING

Late in July of 2010, the new Rockspring dewatering plant underwent commissioning. Slurry flow was slowly turned over to the presses to allow each press to be fully commissioned one at a time.

During the commissioning period, maximum dewatering was determined for the belt presses and produced cakes with percent solids in the 70% range, confirming pilot test investigations. The overall commissioning went smoothly with six presses converting approximately 30 tons of dry solids as a 30% solids slurry into 60% solids per hour. .

Flocculant and coagulant dosages were also optimized during commissioning. Figure 5 is a graph of the press performance over the first six months of 2011. The pound per ton dosage varied as conditions in the presses and slurry characteristics varied. Cake moistures averaged in the low 40% range (high 50% solids), which is sufficient for the capping operations. Excess capacity is built into the system such that, when needed, press conditions can be modified to lower the target moisture levels.

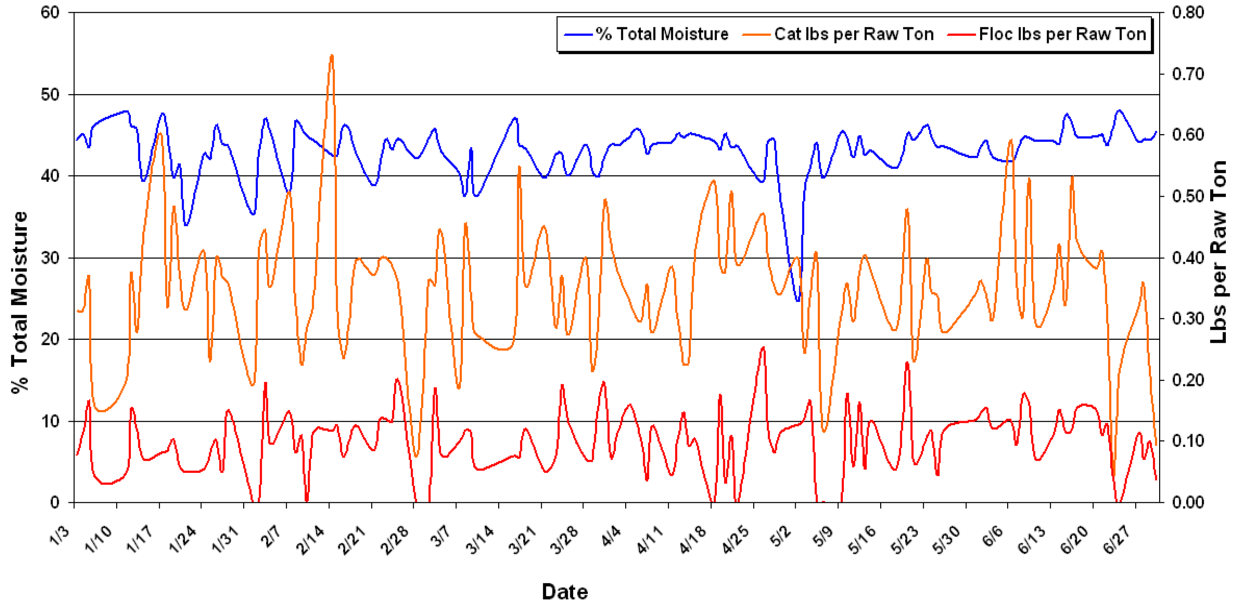

Figure 5. Cake moisture and chemical usage data

Dosage of the anionic flocculant and the cationic coagulant are controlled through DC pumps. There is no direct automation on the polymer feed system besides specific gravity for control of slurry gravity with water. The anionic flocculant is injected into water and diluted before entering the 2- inch static mixer. After dilution, the cationic flocculant is injected into the bottom of the flocculator. To allow proper conditioning time between the two flocculant additions, the static mixer is positioned eight to ten feet before the flocculator.

CONCLUSION

The evaluation of geotextile tubes, deep cone paste thickeners and filter belt presses allowed investigators to determine which technology provided the best solution and value to the Rockspring coal plant. Each dewatering method had advantages, but the tailings' characteristics showed that filter belt presses performed the best.

The installation of filter belt presses at Rockspring extended the life of the current Trace Branch impoundment area and the mini impoundment area combined by approximately four and a half years by making the tailings slurry usable as part of capping material and by reducing the volume per day pumped to the impoundment areas. The extra time now allows for permitting and construction of a new permanent impoundment area. The new area can be designed around the lower volume that will be sent to it per day, reducing capital costs in construction and land use.

Water management is much more efficient. Most of the water now re-circulates in the plant instead of going out to impoundment and then recycling back with all of that system's impoundment retention and evaporation losses. The new water balance contains considerably less water and the plant requires less fresh make-up water.

ACKNOWLEDGMENTS

The authors would like to thank the many people at Rockspring, Alpha Resources, and Ashland Water Technologies, who brought their expertise, hard work and dedication to the project, and in doing so, found and implemented the best solution to the Trace Branch impoundment's life span dilemma.

REFERENCES

1. Tao, D., Parekh, B.K., Honaker, R. 2008. *Development and Pilot Scale Demonstration of Deep Cone Paste Thickening Process for Phosphate Clay Disposal*. Final Report to Florida Institute of Phosphate Research. FIPR Publication No. 02-162-229. Lexington, KY: University of Kentucky.
2. Jellesma, A. 1978. *Belt Filter*. US Patent No. 4212745.