Feed Size Changes for Increased Throughput at Newmont Carlin's Dry Grinding Circuit

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FEED SIZE CHANGES FOR INCREASED THROUGHPUT AT NEWMONT CARLIN'S DRY GRINDING CIRCUIT

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ABSTRACT

Newmont Mining Corporation's Carlin ("Carlin") operation processes roaster feed through a double rotator, dry grinding mill following secondary crushing. Metso Process Technology & Innovation ("PTI") was involved in a review of crushing and dry grinding circuit operations in August 2009. A number of opportunities for increased throughput were identified in the PTI study.

Extended plant trials were conducted in July 2010 to provide justification for possible circuit modifications and if needed, additional equipment. The trials confirmed that a finer crusher product would reduce the build-up of material ahead of the coarse grinding chamber in the double-rotator. Also revealed were material transport and airflow restrictions in the dry grinding circuit that resulted in a high circulating load.

The secondary crushing plant demonstrated it was capable of reducing the amount of +¾" material in the mill feed thus increasing dry grinding throughput. However, wet and sticky feed affected screening efficiency resulting in low utilisation of the existing crusher capacity. The open circuit configuration also made it difficult to control crushing circuit product size.

For the dry grinding circuit, changes in grinding media size, transfer grate design and increased airflow were recommended to reduce circulating load issues and increase circuit capacity.

This paper summarises the crushing and grinding circuit review, the extended site trials performed by PTI and the improvements in dry grinding operation that resulted from this study.

KEYWORDS

dry grinding, crushing, optimisation, simulation, modelling

BACKGROUND

Newmont's four mining operations in Nevada include the Carlin Trend, Twin Creeks, Phoenix and Midas mines, all of which are located in the high desert along a 100-mile stretch of highway in the northern part of the state. The Nevada properties operate as an integrated unit and together, boast the widest variety of processing methods of any gold mining complex in the world. This allows Newmont to maximize economic recovery of gold from a wide range of ore types and grades.

Carlin's Mill 6 facility receives crushed refractory ore and processes it in a dry grinding circuit that includes a double rotator ball mill as well as static and dynamic separators ahead of a baghouse and fine ore bin. The ground material is then sent to the roaster prior to leaching and gold recovery.

The Newmont Carlin ("Carlin") operation contracted Metso Process Technology & Innovation ("PTI") to review their secondary crushing and Mill 6 dry grinding circuits to determine opportunities for higher mill throughput. The opportunities could result from changes in crushing or dry grinding operating conditions or a combination of both.

Roaster feed is blended on fuel value, calculated from the sulphur and organic carbon content. Hot ore has a fuel value >2 while Cold ore has a fuel value <2. The Mill 6 feed fuel value is maintained between 2.5 to 3.0 with 70 to 80% of the blend coming from Cold ore. Due to these tight fuel value constraints, any differences in hardness or feed size distribution would likely impact dry grinding throughput and/or circuit product size to the roaster.

Crushing Circuit

The South Area Leach ("SAL") secondary crushing circuit processes both Hot and Cold ores from either underground or the open pit. The flowsheet for one of the two lines is shown below in Figure 1. Primary crushed feed is stockpiled ahead of two parallel crushing lines – each with a ½ to ¾ inch screen and the oversize reporting to an MP1000 crusher. The combined screen undersize and crusher product is then trucked to the Hot or Cold stockpiles ahead of Mill 6.

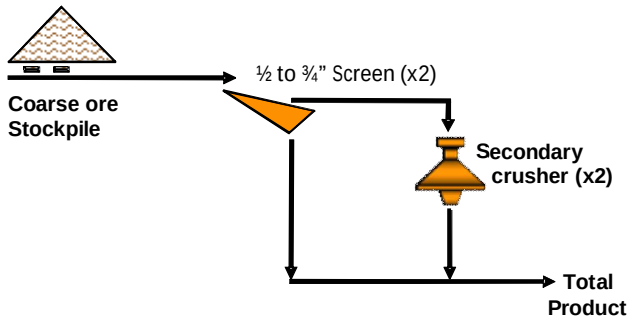

Figure 1: South Area Leach Crushing Circuit Configuration

Cold ore from the Leeville underground mine is generally dry, coarse and relatively easy to crush. Hot ore can have a lot of dust that is controlled with water sprays at different points ahead of the primary crusher as well as the truck load out. Either due to its wet/sticky nature or variable clay content, SAL crusher feed can be very difficult to screen, readily blinding the panels and sending sticky lumps into the crusher chamber. Therefore, the crusher cannot be operated to maximise the power draw due to the uncertainty of when these lumps may enter the crusher and result in uneven loading or 'ring bounce'.

The open-circuit crushing flowsheet does not allow the crusher product to be checked and controlled for oversize (e.g. +½" or + ¾" material).The situation is made more difficult by the use of single-deck screening with feed up to 4 inches in size.

Dry Grinding Circuit

The Mill 6 dry grinding circuit consists of one 20.3 x 52.5 foot Polysius double rotator ball mill, one 31.2 foot Statopol Polysius static separator and one Polysius Sepol 380 dynamic separator with the flowsheet shown in Figure 2.

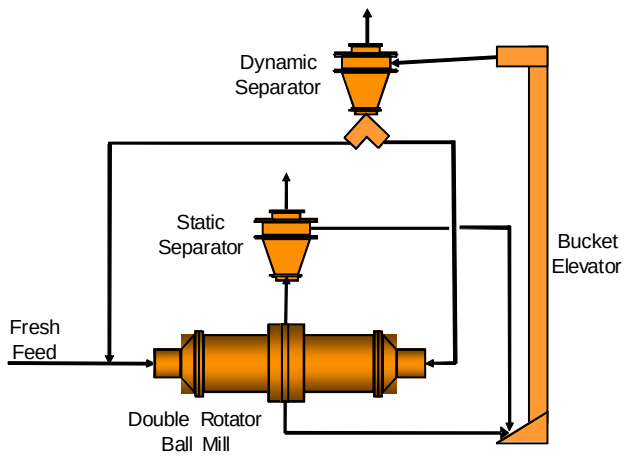

Figure 2: Mill 6 Dry Grinding Circuit

Fresh feed enters a drying chamber before being transferred to the coarse grinding chamber with 3½" steel media. Product passes through the central discharge grate where it's combined with the fine grinding chamber product (with 2½" media). The static separator pulls material through the mill and generates a final fines product that reports to the baghouse and onto the roaster feed bin. Static separator rejects (coarse) are combined with the rotator discharge and sent to the dynamic separator via the bucket elevator.

The dynamic separator produces a second fines product stream that is sent to a separate baghouse and combined with the static fines product in the roaster feed bin. The dynamic rejects are returned to the double rotator via a moveable splitter between the coarse and fine grinding chambers.

Modeling & Simulation Study

PTI conducted surveys on both the SAL crushing and Mill 6 dry grinding circuits during a site visit in August 2009. Samples collected during these surveys were then sized and tested for crushing and milling hardness. The survey results were reviewed by PTI and circuit models developed following mass balancing of the raw survey sizings. Models of both the crushing and dry grinding circuits could then be used together to investigate the interaction of the crusher product size on Mill 6 performance.

For the dry grinding circuit, it was originally planned to complete a full survey including samples of the two mill chamber contents. The full survey would require the circuit to be stopped to allow

personnel to enter the mill and collect samples down the length to the fine and coarse chambers. Instead, six 'mini surveys' were performed with samples of all circuit streams collected. The mini surveys did not allow PTI to accurately determine the individual chamber products as only a combined product was collected. Following a baseline Survey 1 under normal operating conditions, the mill speed was increased and then decreased for Survey 2 and 3. The dynamic rotor speed was then increased and decreased for Survey 4 and 5 and finally, a return to normal conditions for Survey 6.

For all six surveys, the feedrate was held at 450stph – reasonably high for Mill 6 at the time. Feed 80% passing ("P80") size was between 15 and 17mm and the mill power draw varied between 10.3 and 11.1MW at 11.8 to 12.9rpm. Final product P80 size ranged between 72 and 96 microns.

Steady-state models of the crushing circuit and dry grinding circuit were developed from the survey data collected during the August 2009 site visit. In the case of the dry grinding circuit, all six mini surveys were combined to generate a composite model of the two separators, with the model parameters adjusted with the operating conditions. The double rotator chambers were each modeled as perfectly mixed ball mills while the coarse chamber was in fact modeled as two stages of breakage separated by an internal classification stage.

ISSUES AFFECTING DRY GRINDING CIRCUIT

A review of the survey data collected around the dry grinding circuit, including model development and simulation study, identified a number of issues affecting Mill 6 throughput. Figure 3 below summarizes these issues.

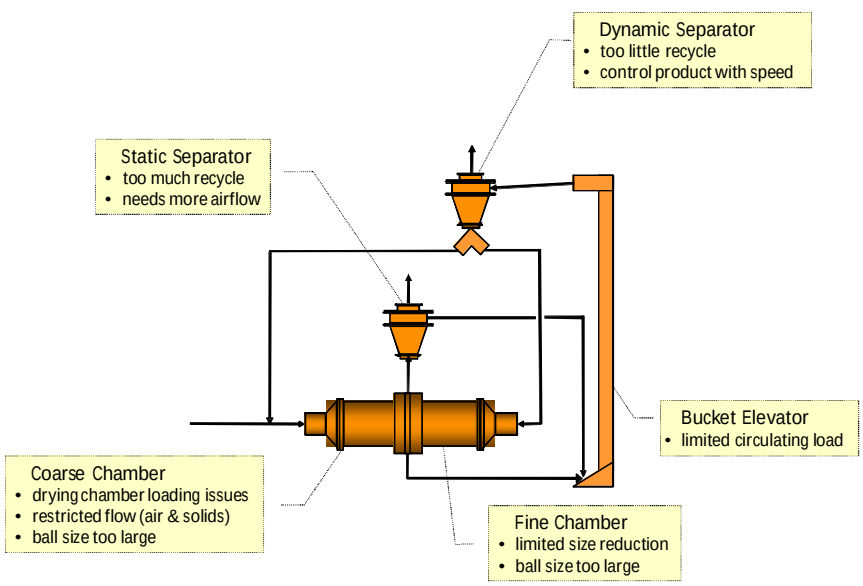

Figure 3: Issues with Mill 6 Dry Grinding Circuit

The survey data indicated that the coarse chamber was performing the majority of the grinding with very little size reduction occurring in the fine chamber. It was clear from observations made during the surveys that, the drying chamber ahead of the coarse chamber was accumulating coarse particles due to a flow restriction in the transfer grates between the two chambers. Once particles pass through these grates into the coarse chamber, they are reduced in size quite effectively. The challenge was getting the coarser

particles to pass through the drying chamber.

The bucket elevator capacity had limitations and recirculating loads in excess of 900stph could not be sustained for long periods. Airflow restrictions on the baghouses meant that the two separators were out of balance: the static separator was passing back to the rotator too much material while the dynamic separator was pulling too much out of the circuit. The fines sizes were quite different with a P80 size of 42 to 55 microns for the static and 78 to 108 microns for the dynamic. The airflow restriction also prevented the dynamic separator rotor speed from being slowed down to control the circulating load of material.

Drying Chamber/Transfer Grates

The Mill 6 double rotator was affected by material transport problems in the drying chamber. During periods when the mill processes coarser feed, the drying chamber loads up with particles that cannot pass through the grates and into the coarse chamber. The result is an increase in floating-end bearing pressure and reduction in air flow across the mill that is resolved only by cutting feed and allowing the mill to grind out.

This issue has not always been present and, in the past, the mill has processed even coarser feed without loading up. It is not clear if the problem is due to the grate size, open area, or positioning of the grates, but coarser particles are slow to find their way through the transfer grates and consequently, load up in the drying chamber.

The photos below in Figure 4 show the drying chamber after removing most of the accumulated particles. A significant amount of 1 to 1½ inch balls was also present that are accomplishing 'unplanned size reduction' in the drying chamber. Unfortunately, the ball size is too small to perform any serious comminution on particles up to 1 inch in size. It seems that material accumulation or mill loading is occurring in the drying chamber and not the coarse or fine grinding chamber.

Figure 4: Drying Chamber Grates & Impromptu Ball Load

Mill Power Draw

To illustrate the effect of particles building up in the mill, a breakdown of the mill power draw was calculated for the conditions observed during one of PTI's site visit (see Figure 5). The drying, coarse and fine chambers represent 24%, 39% and 37% respectively of the overall mill length. Measurements of the ball load by Carlin personnel shortly before and during the site visit, estimated the coarse chamber to

be 25% full and the fine chamber to be 22% full (by volume).

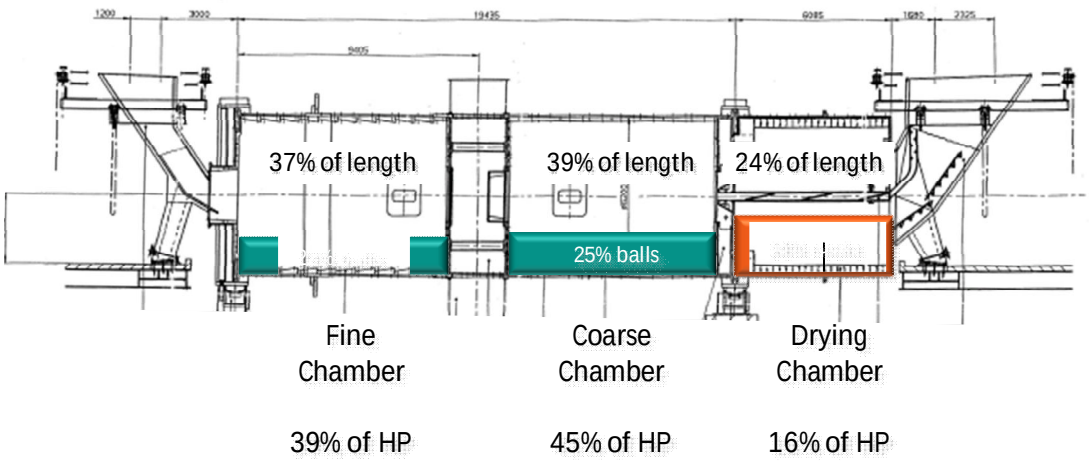

Figure 5: Double Rotator Mill Power Distribution

From the mill speed and power draw conditions before and after a rotator grind out, it was estimated that the drying chamber was loaded to 38% of its volume with coarse particles. For the ball and rock loads shown in Figure 5, the drying chamber was consuming 16% of the power, while the coarse and fine chambers were consuming the remaining 45% and 39%. This suggests that less than half of the double rotator power draw was being used for size reduction as grinding was effectively occurring only in the coarse chamber.

In terms of capacity, the dry grinding circuit was limited due to restrictions in airflow, baghouse and transfer grate material transport, but not mill power draw. Accessing the remaining power would allow the Mill 6 circuit to process a higher tonnage and achieve a finer product size.

Circulating Load Issues

At times, the bucket elevator tonnage (or circulating load) becomes the limiting factor of the dry grinding circuit even when the drying chamber is not loading up in the double rotator. As the fine chamber was contributing little to the size reduction, the coarse chamber was left with the duty of not only reducing fresh feed but a portion of the static and dynamic classifier rejects (or coarse) streams. The 3½" balls in the coarse chamber are too large to efficiently grind fine particles such as these to the final product size.

The static separator should be set up to extract as much material as possible off the top of the mill and reduce the circulating load. To control overall grind size, the dynamic rotor speed can be changed to adjust the size split of this classifier. Finally, the split of dynamic rejects can be shifted as required between the coarse and fine chambers.

EFFECT OF FEED SIZE ON MILL 6 THROUGHPUT

Mill 6 throughput was being restricted for two main reasons: coarse particles building up in the drying chamber or mill loading and high circulating load of dynamic rejects. Both of these conditions were not due to a lack of mill power but rather material transport and/or inability to operate at higher airflow

because of baghouse limitations.

For the mill loading problem, the issue appears to be the top size fraction of feed, or the +½" and +¾" material. The double rotator has the ability to process a certain amount of +¾" material, but higher amounts result in mill loading issues. The immediate solution was to regulate the amount of +¾" material entering in the mill through finer crushing. The longer term solution was to alleviate the drying chamber transport issue.

For the high circulating load issue, there are a number of options to consider: smaller grinding media in both chambers (with a preference for a blend of sizes in the fine chamber), higher airflows to both separator combined with a slowing of the dynamic separator rotor speed when necessary and finally, adjustment of the splitter position between the two chambers.

Photographs of Cold and Hot ore feed size distributions are shown in Figure 6. Cold ore consistently contains more +¾" material, which offers potential mill loading problems particularly as it represents 70 to 80% of the Mill 6 feed. However, the finer Hot ore has other issues with a higher Bond Work Index (up to 40% higher) than Cold ore. This means that, with the power available in the coarse chamber, the double rotator product size will coarsen for Hot ore. The result is an increase in circulating load as more material returns to the mill as separator rejects.

Figure 6: Cold vs. Hot Ore Crushed Size Distributions (3½" card width for scale)

Finer Crusher Product Size (Control of Topsize)

During monitored plant trials, the SAL crushing circuit demonstrated it could generate a finer product size and increase Mill 6 throughput. A target of 10% or less +¾"for Cold ore was established to help with the drying chamber restriction for coarse material. When processing dry, Cold feed, the current SAL equipment could deliver a finer product, but due to problems in treating wet/sticky feed and limitations of the flowsheet, it could not be relied upon to consistently generate this product size. Instead, an additional screening and/or crushing stage would be needed to ensure the product size can be maintained under a variety of feed conditions. Alternately, the addition of a drying stage ahead of crushing as is done at the Yukon-Nevada Gold, Jerritt Canyon operation.

Handling of Excessive Fines

Circulating load problems were likely due to the lack of grinding in the fine chamber as well as inadequate airflow to both static and dynamic separators. It appears that the dynamic rejects have a greater

influence on circulating load than the static rejects, as they are coarser in size. With greater airflow, it would be possible to slow down the dynamic rotor speed while preventing a buildup of coarse particles in the separator outlet. Shifting the split of dynamic rejects away from the fine chamber would also help with the circulating load.

Balance of Coarse & Fine Material

Based on the results of the trials conducted at site, it appeared that issues with the Mill 6 dry grinding circuit were minimized within a relatively narrow range of feed size: too coarse and the mill loads up and too fine and the circulating load is an issue. This is illustrated below in Figure 7 where cumulative feed size distributions from selected samples are shown and the associated Mill 6 tonnage.

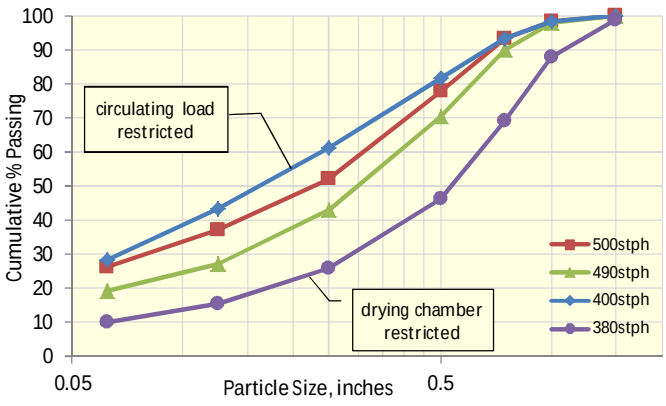

Figure 7: Mill 6 Feed Size Distributions (Coarse vs. Fine)

The red and green lines (500stph and 490stph) show optimum feed size distributions for the current equipment conditions: <10% +¾" with 20 to 30% +½". Finer than this (blue line) and the tonnage drops off due to circulating load problems. Coarser than this (purple line) and the mill loads up and tonnage falls off as well. The optimum region is highlighted in the dark red shaded are in the figure below.

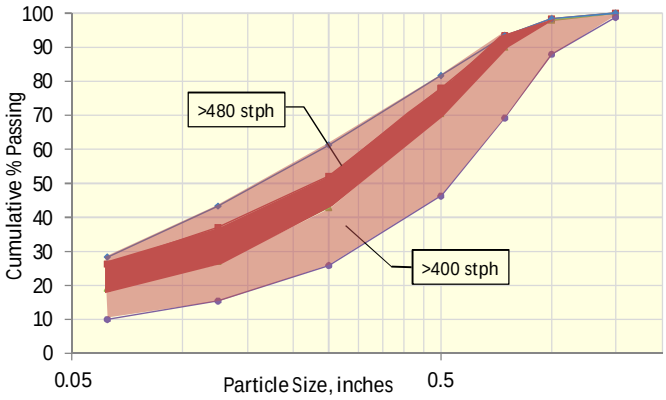

Figure 8: Range of Ideal Mill 6 Feed Size Distributions

Overall, the % -¼" size fraction was found to be the most sensitive to Mill 6 tonnage (see Figure 9). The graph shows how quickly Mill 6 throughput lowers outside of the 40 to 50% -¼" range. The dotted blue line in Figure 9 indicates how the Mill 6 throughput may be affected by feed size in the future once the dry grinding circuit issues have been addressed. A lessening of the drying chamber restriction will make Mill 6 less sensitive to coarse feed while addressing the circulating load problem should make it easier to handle finer feed. With careful control of feed size within the 40 to 50% -¼" range, Mill 6 tonnage should be maintained above 475stph.

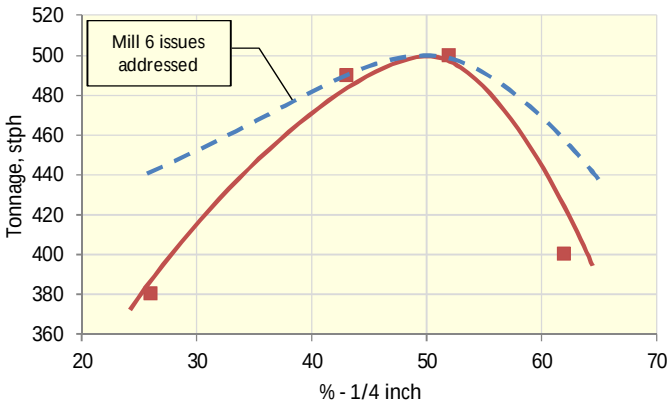

Figure 9: Effect of % – ¼ inch in Feed on Mill 6 Throughput

ONGOING CIRCUIT CHANGES

The list of recommendations that was generated during the site trial was reviewed and prioritized based on complexity of task and perceived value. The 'quick hits' list was given to site personnel to accomplish and the largest task was turned into a black belt, continuous improvement project.

At the SAL crushing circuit, an increased awareness of water management has been implemented. This includes how feed stockpiles are watered and making sure dust suppression sprays are working properly. In regards to product quality, the SAL crushing circuit has relied on visual inspection of product size; however, survey results indicated it would be difficult to see the target percentage of -½ inch material visually. Carlin is currently installing an image analysis camera and system to help monitor the product size, with the intention of warning the operator that the product size is incorrect and additional steps need to be taken.

In late 2010, the double rotator fine chamber grinding media size was changed to a mixed charge of 2½" and 1½". It is expected to take six months to achieve a 50:50 mix of ball sizes. Once the charge is at the required blend, additional surveys will be conducted to determine the effect of the change. During the annual Mill 6 plant shutdown in April 2011, the transfer grate open area was increased by 10% by changing from a ¾" to 1" opening.

The highest value project was considered to be increased airflow around the static and dynamic classifiers with a focus on baghouse efficiency and the ability to operate the dynamic separator over a different range of rotor speeds. This project is in the analysis stage with a projected completion date of September 2011.

CONCLUSIONS

A review of the crushing and dry grinding circuits at Newmont's Carlin operation revealed the double rotator ball mill was quite sensitive to feed size that resulted in a loss of tonnage. While the double rotator had sufficient power available to operate at higher throughput, only around half of the power was being used to grind material – entirely in the coarse chamber alone. Issues with material transport meant that coarse particles tended to load up in the drying chamber (despite the presence of rogue grinding media).

In addition, the fine chamber was contributing very little to the circuit and a harder and/or finer feed size distribution resulted in a high circulating load. Baghouse restrictions meant that airflow had to be limited to both separators, resulting in overgrinding of material and at times, high circulating loads.

The results of plant trials showed that the coarse fraction of Cold ore could be maintained at or below 10% +¾", with careful control and monitoring of the SAL crushing circuit. However, problems with wet/sticky ore and flowsheet limitations meant that the circuit could not always ensure a fine product to Mill 6. Additional screening, crushing and/or ore drying stages would be needed to maintain a product size that did not affect mill loading in the double rotator.

Issues with transfer grate restrictions between the drying and coarse grinding chambers can be resolved to reduce the impact of coarse material on mill loading. Carlin did not experience this problem in the past and a redesign of the transfer grates should alleviate the frequency of mill loading. In addition, increased airflow to both the static and dynamic separators will allow the circulating load to be managed better and the dynamic rotor speed used to control the circuit product size.

Carlin is in the process of implementing a number of changes at the SAL crushing circuit and the Mill 6 dry grinding circuit to increase throughput. These initiatives are expected to be completed by the end of 2011.

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