CiDRA CYCLONEtrac^{SM} at Kennecott Utah Copper

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Introduction

Rio Tinto's Kennecott Copperton Concentrator has four grinding lines each consisting of one SAG mill feeding two ball mills in a closed circuit with a hydrocyclone battery (*Figure 1*). The aim of the ball mill / hydrocyclone circuit is to produce the optimum flotation feed particle size while maintaining grind throughput. The optimal operating point is a trade-off between throughput, recovery, and grinding cost. Copperton has recently focused on the role of the hydrocyclone battery and how to monitor the performance of each individual hydrocyclone. Variation in the performance of the grinding circuit flows through to the hydrocyclones and in many cases the hydrocyclones will report coarse material to the overflow when not operating as designed. Coarse material in the flotation feed reduces the economic performance of the concentrator through lower valuable mineral recovery and in extreme cases, through blocking of the flow path in the flotation cells.

The existing oversize detection system is installed on the combined hydrocylcone battery overflow line. Operationally, troubleshooting the cause of oversize is difficult and time consuming, resulting in considerable disruption to the flotation circuit before the offending hydrocyclone is taken offline. Copperton and CiDRA have installed a new technology for monitoring individual hydrocyclone overflow lines for coarse material discharge.

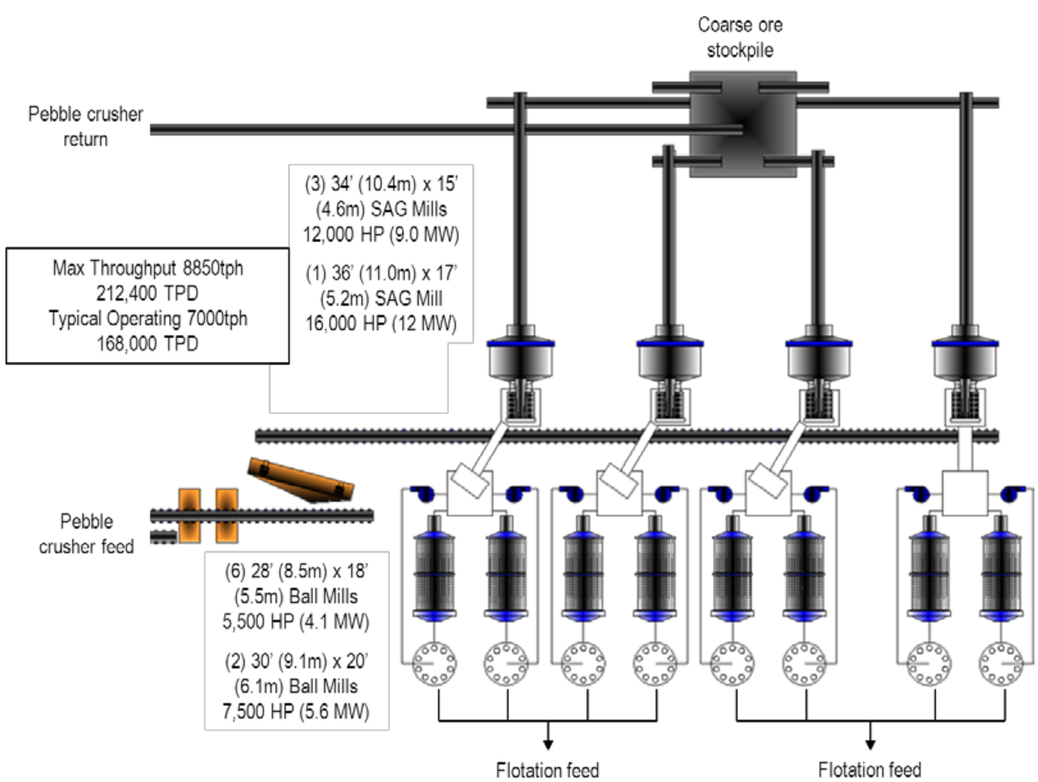

Figure 1 - Rio Tinto Copperton Concentrator grind flow sheet

The value

The target grind size for flotation feed at Copperton is 32% +150micron (100 mesh). Hydrocyclone product greater than 150micron is considered coarse or oversize. Particles 6mm (~1/4") or greater can be considered "rocks" and a large flow of this material can block the internals of the flotation cells, significantly impacting their performance. *Figure 2* shows an example of the material that is flushed from a rougher row after a severe rock event. Some causes of "rock" events include:

- SAG mill grate or trommel panel failure
- Hydrocyclone failure
- Degradation or failure of SAG mill pebble removal system

It is difficult to quantify the economic impact of large rock events due the widespread impacts and flow on effects across areas. However, qualitatively the losses are associated with:

- Rougher row downtime (recovery loss through lower residence time)
- Reduced throughput
- Equipment damage (flotation cell internals, slurry pumps etc.)
- Cleanup costs
- Decay in flotation cell performance over time (event not large enough to lead to shut down)

Figure 2 – Rock flushed from a rougher row after a significant rock event

Recovery of liberated and middling +150micron mineral particles in the flotation circuit is significantly lower than -150micron particles. Based on mineral liberation analyzer (MLA) data, the long term average +150micron copper recovery is significantly lower compared with recovery of -150 micron particles (see *Figure 3*). It is also worth noting that the recovery of +150micron size fraction is considerably more variable than for the -150micron size fraction.

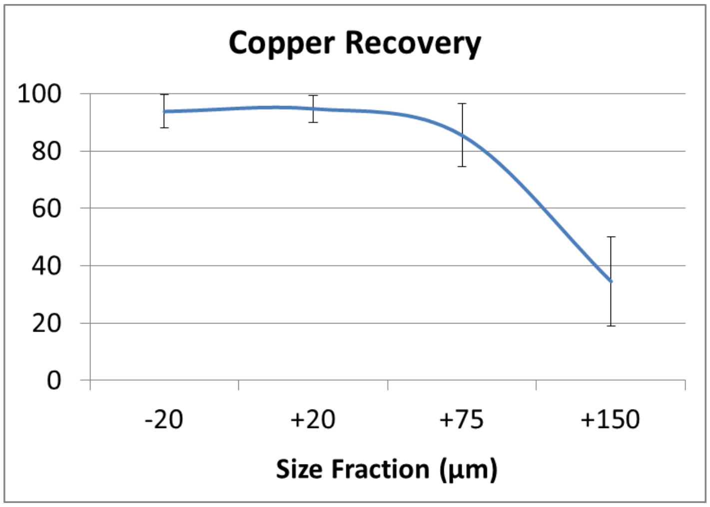

Figure 3 - Copper recovery by size fraction

The value lies in being able to detect a rock event early and optimize hydrocyclone performance in order to reduce the amount of +150micron in the flotation feed. The new technology aims to:

- Provide rock detection
- Identify hydrocyclone failures
- Identify which hydrocyclone/s are producing rocks or oversize

CYCLONEtrac Development

One approach to confront the previously described grind challenges is to optimize grind system performance at the individual hydrocyclone level, rather than the battery level. This approach has the advantage of allowing a hydrocyclone battery to remain in operation while a performance issue is isolated to one or more individual hydrocyclones. However, this requires a new class of instrumentation, one that monitors the performance of each hydrocyclone in real-time.

One of CiDRA's core competencies is the measurement of acoustic information through the wall of a pipe. This technology is not only well suited for monitoring individual hydrocyclones, but is also non-intrusive. The sensor is attached to the external surface of the pipe, allowing sensors to be installed and maintained without interruption to the process.

CiDRA's acoustic measurement technology, CYCLONEtrac, provides a novel solution for problems such as rocks reporting to the overflow and unreliable feed isolation valve position (limit switch failures). Additionally, the system provides the control room with an indication of the operating mode of each hydrocyclone. CYCLONEtrac can differentiate between a hydrocyclone that is off (feed isolation valve shut), operating normally (fines reporting to overflow and coarse to underflow), or abnormal states such as rocks reporting to the overflow.

System Installation

The prototype hardware was first installed on a hydrocyclone battery at Copperton to record real-time acoustic data directly to a mass storage device. The data was post processed and used to develop the initial CYCLONEtrac algorithms. Then the CYCLONEtrac system performance was compared to Copperton's existing oversize material detector installed in the combined overflow of the battery. The CYCLONEtrac detection algorithm was refined and the hardware and software designs were validated. A full system was then built and installed on all 8 hydrocyclone batteries in the grind plant. *Figure 4* shows the transmitters and junction box for one battery, the CYCLONEtrac band installed on an overflow pipe, and a full battery instrumented with CYCLONEtrac bands.

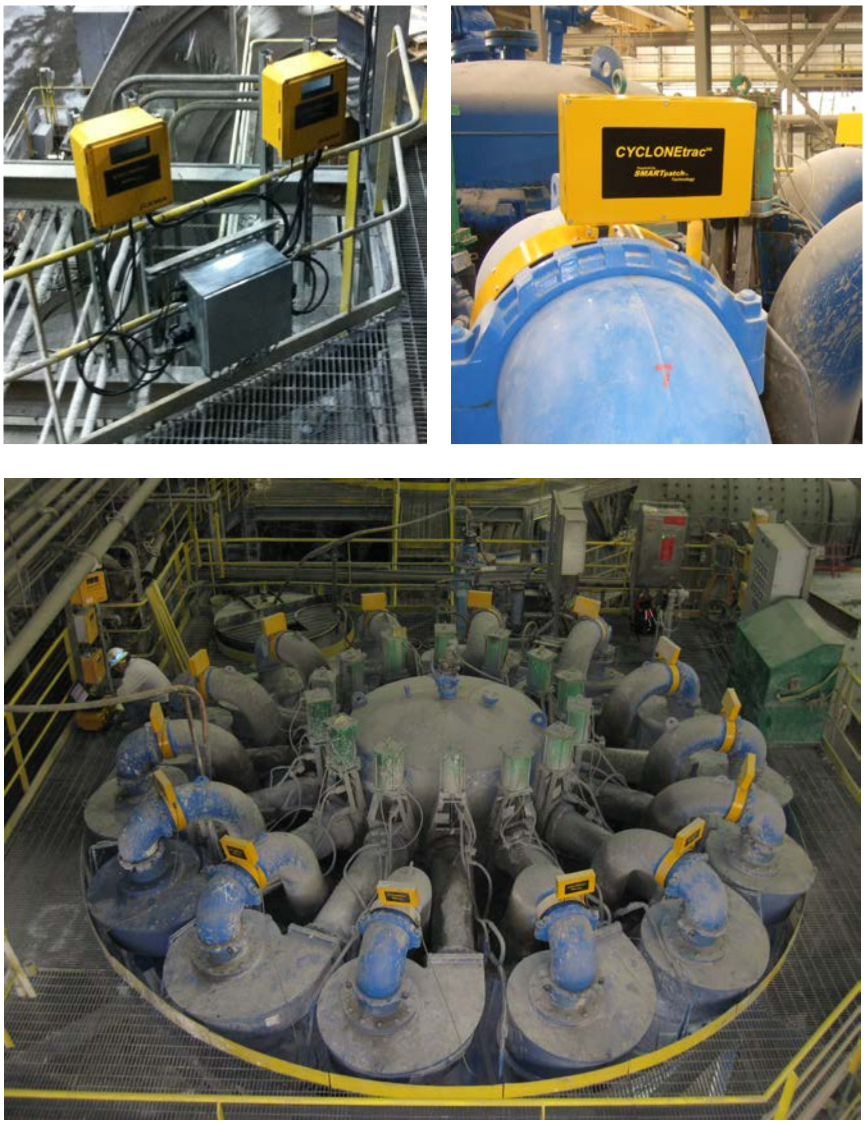

Figure 4 – CYCLONEtrac installed on hydrocyclone battery 8

The system consists of a sensor and preamplifier attached to the external pipe surface on the overflow of each hydrocyclone. A schematic of the system is shown in *Figure 5*. The preamplifier outputs are connected to transmitters which perform the first level data processing for each battery. The data accumulated by the transmitters is aggregated by a computer in the Copperton control room. This data is used by the CYCLONEtrac system to determine the operational state of each individual hydrocyclone and of each battery of hydrocyclones. In addition to the real-time display, data is stored for local review and transmitted to the CiDRA data center for the generation of daily and weekly performance and utilization reports. Both the displayed data and the summary reports facilitate smart maintenance scheduling and aid in troubleshooting to reduce the downtime associated with periodic maintenance and repairs.

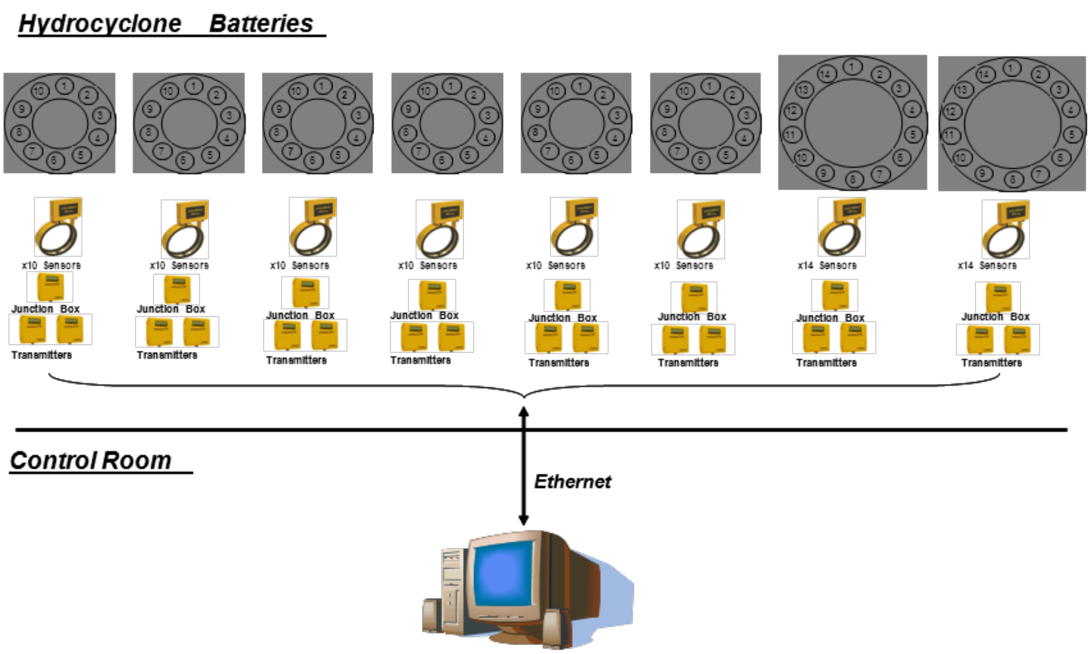

Figure 5 - CYCLONEtrac system diagram

CYCLONEtrac Validation

2009 Data

Throughout the development of the CYCLONEtrac system, real-time acoustic data for both normal and abnormal operating conditions were recorded, including 15 severe rock events. One of the events occurred on 3 February, 2009, and is analyzed here to demonstrate the system response.

Using the defined system threshold parameters the system successfully detects a sustained rock event. This data was then compared to Copperton's oversized particle detection system data from the data historian. The CYCLONEtrac system detected this event as displayed in *Figure 6*. The blue trace is the CYCLONETRAC sound pressure level (SPL) calculated by CYCLONEtrac. The blue trace shows that the SPL of the acoustic signal for hydrocyclone #3 increases more than 6 dB during the event. The overlaid maroon bars represent the number of impacts detected by CYCLONEtrac for each minute of the event (from rocks striking the inner pipe wall), as defined by the algorithm.

This event was isolated to a single hydrocyclone, as shown on a screen shot of the control room interface in *Figure 7*, and the excursion in SPL and rock count is not detected on any of the other hydrocyclones. The solid black line plotted with SPL is from Copperton's oversize particle monitor (in percentage of sample) from the combined overflow of all 10 hydrocyclones in the battery. Thus an event that would have been generally associated with the whole battery has been isolated by CYCLONEtrac to the single hydrocyclone affected.

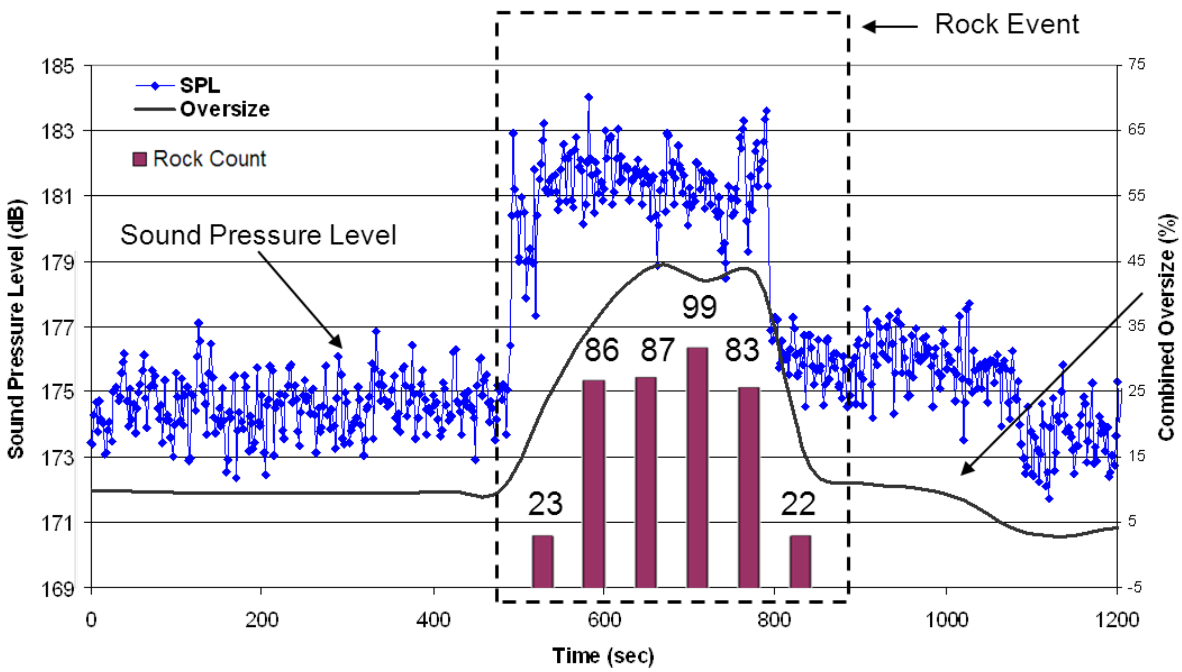

Figure 6 - 2/3/2009 rock event data

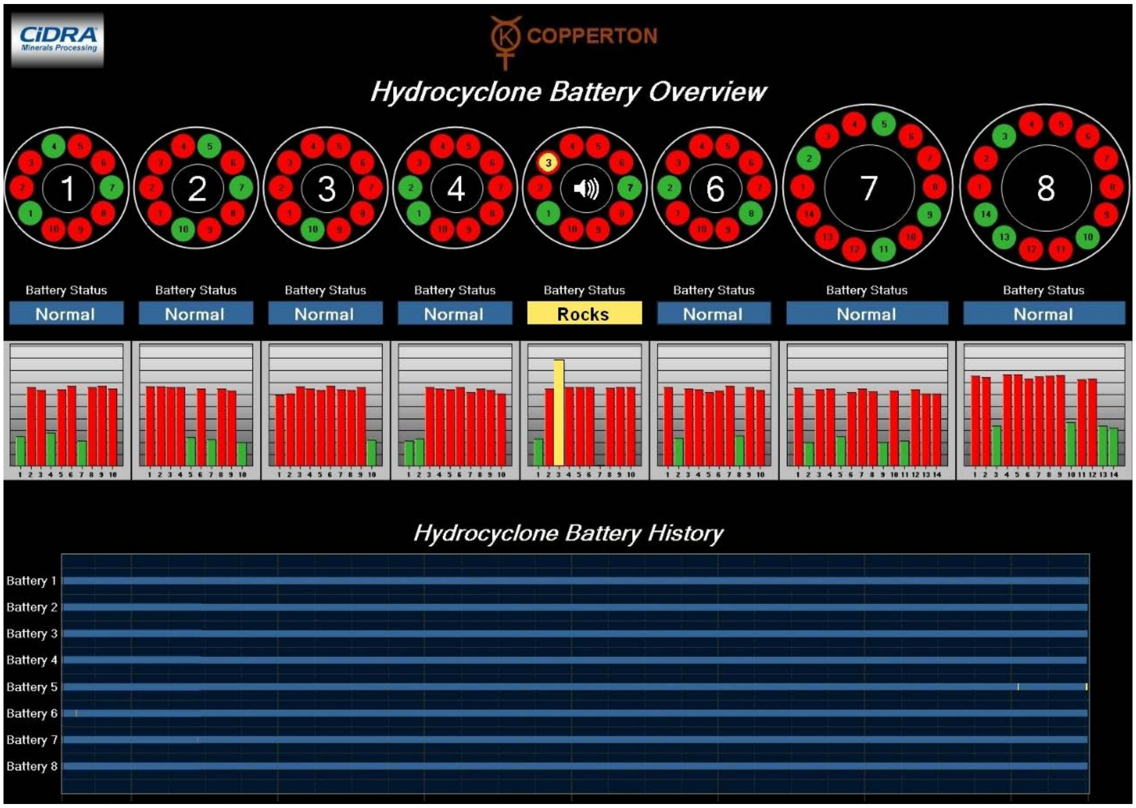

Figure 7 - Screen capture of control room computer monitor

The event terminated rapidly (at 800 seconds on the plot) when feed flow stopped to the effected hydrocyclone by closing the isolation valve. The SPL dropped very quickly while the number of rocks and the oversize detector signal roll off more slowly due to slower sample rates.

When rock events occur, the CYCLONEtrac system will alert the control room operator that rocks are reporting to the flotation system rougher banks allowing the operator, or the control system, to correct the problem without shutting down the entire battery.

Overflow Sampling

A short sampling campaign completed in July of 2011 was designed to further confirm the performance of the system. A sample basket assembly was attached to the overflow discharge of two hydrocyclones on separate batteries for 24 hours and 48 hours respectively. During these two sampling periods, the CYCLONEtrac system was utilized to determine the number impacts on the pipe wall, indicating that rocks were reporting to the overflow of the particular hydrocyclone under test. At the conclusion of the sampling period, the material collected in the basket was removed, dried and analyzed. There was a correlation between the number of rocks (wall impacts) detected and the number of rocks collected. Of interest is that at the point where the rocks were detected, the combined overflow % oversize detector signal also spiked.

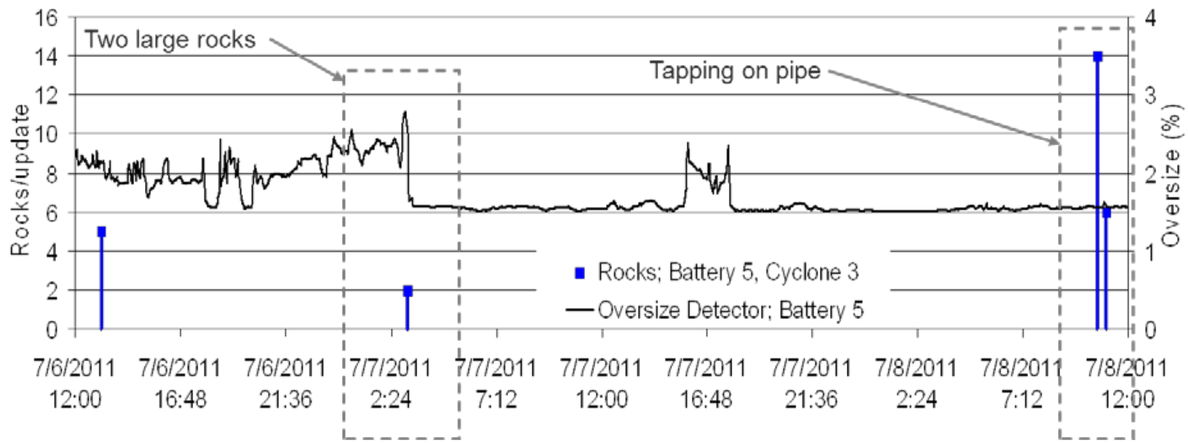

Figure 8 - Sample basket test data

The number of rocks large enough to be detected was small, so it is only an assumption that the rocks collected were those causing the impacts. The highlighted region on the left side of *Figure 8* shows the corresponding rise in the output of Copperton's oversize particle detector, at about 2:24 on 7/7/2011, and the two wall impacts that were detected by CYCLONEtrac at the same time (assumed to be the two large rocks that were recovered from the sample basket).

Another simple verification test was performed by tapping on the overflow pipe adjacent to the sensor with a metal wrench to simulate wall impacts. While the impacts on the outside of the pipe cannot completely simulate those created by rocks on the inside of the pipe, they do test the capability of the system to respond to a series of sharp impacts. As a result of this test, the CYCLONEtrac system detected a rock event on hydrocyclone #3, on the right side of *Figure 8*, at 10:00 on 7/8/2011. When the rock event was detected, it triggered an alarm in the Copperton control room and initiated notifications to the CYCLONEtrac development team. Note that the oversize particle detector did not respond in this case as there was no change to the distribution of particles reporting to the overflow of the hydrocyclone.

Value Realization

The measurement system was developed to support detection of rock events, however the main focus for Copperton was identifying and resolving system and operating issues to eliminate the source of oversize. Since the full installation of the CYCLONEtrac system there has been no significant oversize events to fully realize the value of the CYCLONEtrac. In parallel with the CYCLONEtrac development, beginning in 2009, root cause analyses on some oversize events identified the SAG mill discharge as a problem. As a result Copperton asset maintenance tactics were improved, with a greater focus on the health of:

- Paddle wheels (removes rocks from trommel to form pebble crusher feed)
- Rubber skirts (prevents rocks from entering SAG mill discharge sump)
- Jet nozzles (returns rocks to SAG mill when pebble crusher is off line)

Operations tactics around oversize events also improved. More attention has been paid to equipment inspections and the response to events has been more immediate due the appreciation at the operating floor level of the significant economic impacts of such events.

The continued focus on the root cause of oversize events and immediate response to early indicators (in the SAG mills) has dramatically reduced large events impacting flotation. Nevertheless, the Copperton Concentrator now has a system that will detect rock events, is non-intrusive to the process and requires limited maintenance.

Path Forward

The CYCLONEtrac system has yet to be formally integrated into Copperton operations, primarily due to the fine tuning of the threshold parameters.

The response to a hydrocyclone in alarm state has been for an operator to sample the individual overflow stream for oversize and then sample the remaining hydrocyclones in the battery. If the sample confirms there is oversize, the hydrocyclone is isolated. If no oversize exists, the alarm is acknowledged and normal operation continues. The operating strategy and control response plans for such events require finalization and all operating crews will then be trained on the system.

Importantly, performance data is now available for each individual hydrocyclone rather than the battery as a whole unit operation. The full potential of this data hasn't been fully explored but there exists potential for utilization data, from the operating mode output, to be incorporated into routine hydrocyclone maintenance and replacement frequency.