PAPER 21

Removal of Organic Carbon with a Jameson Cell at Red Dog Mine

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ABSTRACT

The lead and zinc flotation circuits at Red Dog Mine are preceded by a preflotation circuit which recovers naturally-floating organic carbon contained in the ore. Organic carbon is a potential contaminant in the lead concentrate and is detrimental to lead-zinc selectivity. Prior to 2007, the Red Dog preflotation circuit consisted of a single stage bank of tank cells which floated the organic carbon. The preflotation concentrate was discarded directly to tailings, however, this stream contained significant amounts of lead and zinc. Zinc loss to preflotation ranged from 2% to 6%, relative to the zinc in the mill feed and was proportional to the amount of organic carbon in the ore. The main mechanism of the zinc loss was entrainment.

Pilot plant and modeling testwork were conducted to examine the use of a Jameson Cell to clean the preflotation concentrate. Results indicated that up to 90% of the zinc deporting to preflotation concentrate could be returned to the flotation circuit for recovery. The installation of a 5.4 m Ø Jameson Cell with 18 downcomers was initiated in June 2006. The new preflotation cleaning circuit was commissioned in March 2007. Conservatively, preflotation cleaning has resulted in zinc and lead absolute recovery gains of 1.0% and 1.5%, respectively. The $9.1M project has a payback period of approximately 1 year at current metal prices.

INTRODUCTION

Red Dog Preflotation Circuit

Red Dog Mine is located above the Arctic Circle in northwest Alaska. It is the world's largest zinc concentrate producer with a production rate of more than 1.0M t/yr. Red Dog is operated by Teck Cominco Alaska Incorporated under an operating agreement with the Northwest Alaska Native Association (NANA). Due to the remote location of the mine, it is accessible only by air, or seasonally, by ocean-going barges.

The Red Dog deposit is a rich sedimentary exhalative (sedex) zinc-lead-silver deposit. The major sulphides, in decreasing order of abundance, are sphalerite, pyrite, galena and marcasite. Due to the complex nature of the ore body, run-of-mine ore is blended in stockpiles before being crushed and processed through the concentrator. The average mill feed grade for 2006 was 6.1% lead, 20.6% zinc, 8.0% iron and 0.67 % organic carbon.

When Red Dog Mine began production in November 1989, the lead and zinc flotation circuits were not preceded by preflotation. The initial mill feed was highly weathered and contained high levels of elemental sulphur and organic carbon both of which are naturally hydrophobic. Without preflotation, these contaminants reported directly to the lead concentrate and resulted in poor concentrate quality. As a makeshift measure, the first two lead rougher cells were converted to preflotation duty. In 1991, two SK-50 Outokumpu Skimair® cells were installed ahead of the lead circuit for preflotation. The Skimair® cells along with the first two lead rougher cells were operated in preflotation duty until the depletion of the weathered ore in 1995. The rougher cells were then returned to lead flotation duty. Unlike elemental sulphur, which was found predominantly in the surface ore, organic carbon is present throughout the orebody. Organic carbon occurs as disseminated organic matter in the black shale host rock.

The preflotation circuit was subsequently modified during major circuit expansion projects in 1998 and 2000. In 2001, the preflotation circuit consisted of six tank cells as shown in Figure 1. The first two cells were Maxwell MX14 cells which were retrofitted with OK-50 Outokumpu agitators. The other four cells were OK-50 Outokumpu cells arranged in two parallel banks. Concentrate from these preflotation rougher cells reported directly to the final tailings stream even though it contained significant amounts of lead and zinc.

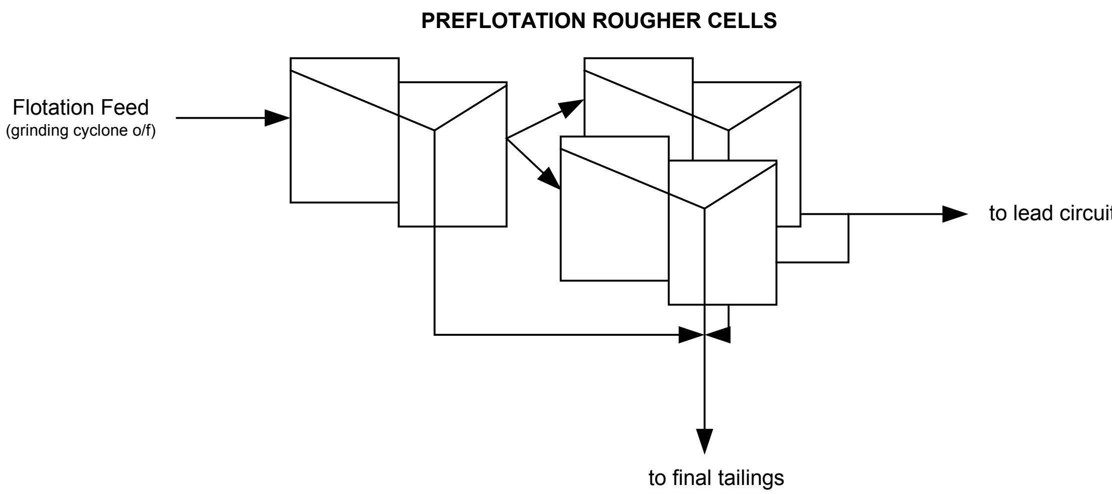

Figure 1: Red Dog preflotation circuit from January 2001 to March 2007.

Preflotation Concentrate Cleaning

Plant surveys identified that the deportment of zinc to the preflotation concentrate accounted for 2% to 6% of the total zinc loss, relative to the zinc in the mill feed. Mass balance data indicated that zinc and lead losses are proportional to the amount of total organic carbon (TOC) in the mill feed as illustrated in Figure 2. The zinc loss to the preflotation concentrate was as high as 8.3% for one stockpile in 2005. The majority of the zinc loss to the preflotation concentrate is due to entrainment. Zinc and lead losses to preflotation have been increasing as Red Dog mines higher TOC areas of the deposit. TOC in the mill feed is expected to remain high (>0.5% TOC) until 2012.

In 2000, laboratory batch flotation tests were conducted which demonstrated that it was possible to recover zinc from the preflotation concentrate stream by cleaning it. The testwork also showed that an acceptable zinc rougher concentrate could be subsequently generated from the preflotation cleaner tailings. A preflotation cleaning plant trial was conducted in 2002 utilizing a 4.1 m Ø flotation column with the column tailings sent to the zinc circuit. The preflotation cleaner tailings could not be sent to the lead circuit since lead flotation circuit capacity limited throughput at that time. Unfortunately, this trial was unsuccessful since significant short-circuiting in the column resulted in low unit TOC recovery making the column tailings unsuitable for the zinc circuit.

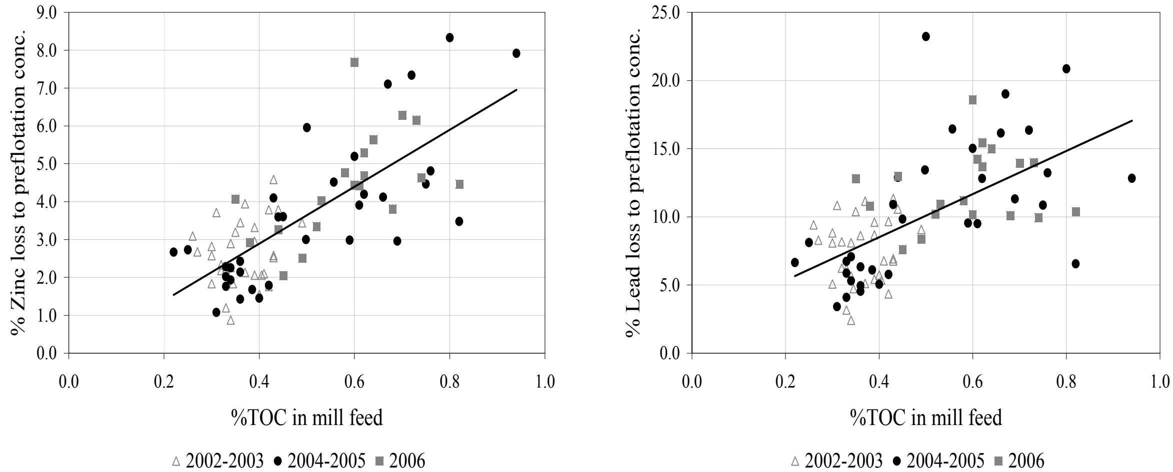

Figure 2: Relationship between mill feed TOC and zinc and lead losses to preflotation concentrate.

Additional lead flotation capacity was added in 2005 which allowed the consideration of other circuit configuration options for preflotation cleaning. It was proposed that preflotation cleaner tailings be re-circulated to the head of the flotation circuit instead of introduced to the zinc circuit. Re-circulating the preflotation cleaner tailings to the head of the flotation circuit provided an opportunity to recover both lead and zinc while rejecting TOC. A Jameson Cell was considered for preflotation cleaning duty.

The Jameson Cell

The Jameson Cell operating fundamentals have been described by numerous authors including Harbort et al (2003). A schematic of the Jameson Cell is shown in Figure 3. The most notable feature of the Jameson Cell is the downcomer where a plunging jet of slurry entrains air and bubble/particle contact occurs. The Jameson Cell typically operates with tailings recycle via the external recycle mechanism (ERM). A portion of the tailings stream is directed back to the feed pumpbox where it mixes with the fresh feed stream and is pumped to the Jameson Cell downcomers. The tailings recycle maintains a steady feed rate to the downcomers despite fluctuations in the fresh feed rate and increases unit cell recovery without adversely affecting concentrate grade. The circuit design and the benefits of a Jameson Cell in base metal applications have been described by Young et al (2006).

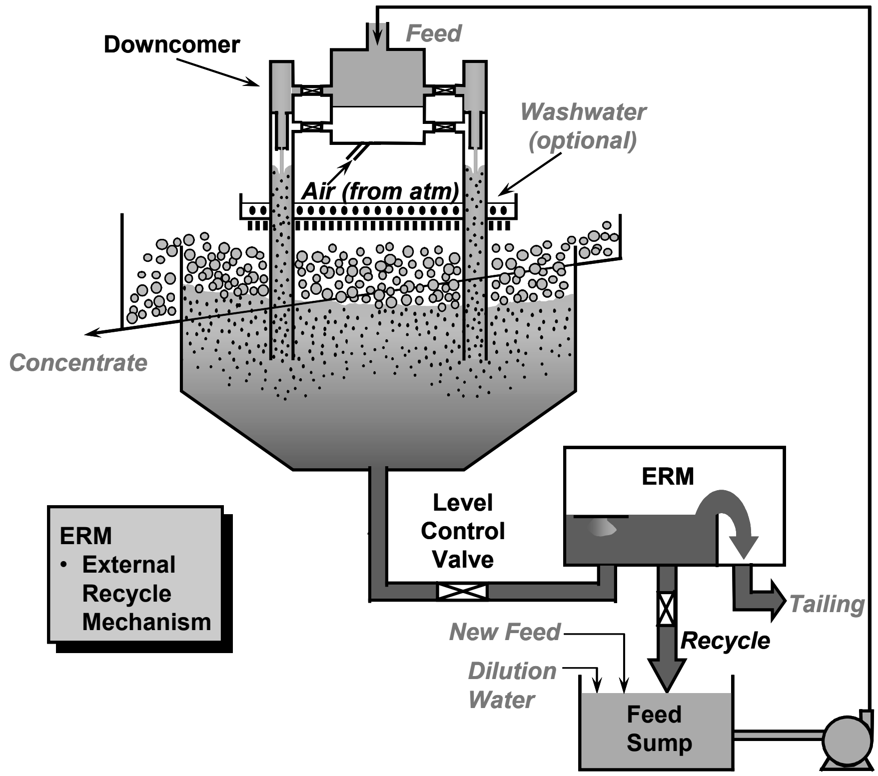

Figure 3: Jameson Cell schematic with external recycle mechanism (ERM).

RESULTS AND DISCUSSION

Pilot Plant Testwork

In April 2005, Xstrata Technology was invited to Red Dog to conduct pilot plant tests on preflotation concentrate cleaning. A 300 mm Ø Jameson Cell pilot rig was installed and tests were conducted in open circuit configuration (i.e., the Jameson Cell tailings were not returned to the preflotation circuit). It was not possible to simulate full scale closed circuit operation due to the small capacity of the pilot cell.

The testwork program was performed in a two week period. The aim was to minimize zinc loss to the preflotation concentrate while maximizing TOC removal. Feed for the Jameson Cell was bled from the discharge of the preflotation concentrate disposal pump. The mill feed TOC assays ranged from 0.7% to 0.8% during the course of the pilot plant testwork.

A summary of the pilot plant test results is shown in Figure 4. The Jameson Cell was able to achieve a maximum TOC unit recovery of 70%. Under optimized conditions, the zinc unit recovery was as low as 10% (i.e., 90% zinc rejection).

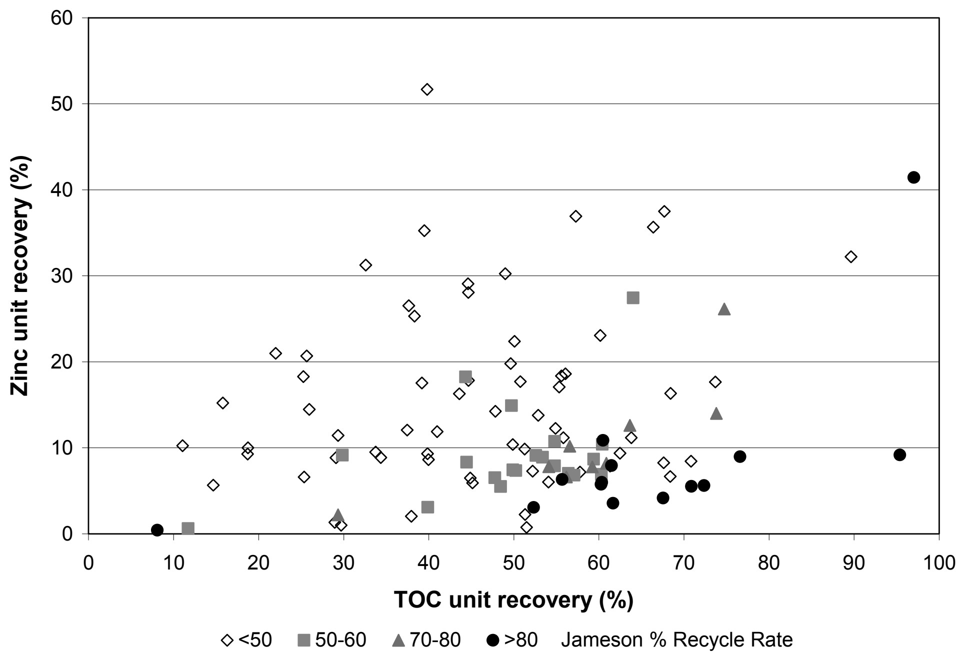

Figure 4: Relationship between TOC and zinc unit recoveries for the Jameson pilot plant.

The test program evaluated the following parameters: recycle rate, froth depth, jet velocity, feed density, air to pulp ratio (APR), superficial gas velocity (Jg), frother addition and wash water. Recycle rate and feed density were found to have the most significant effect on selectivity as seen with other Jameson Cell preflotation cleaner applications (Pokrajcic et al, 2005).

As a result of this testwork, Xstrata outlined the following design criteria for a Jameson Cell preflotation cleaner at Red Dog:

- Minimum of 80% cell recycle rate. The data indicated that for a given TOC recovery, improved selectivity of TOC over zinc was achieved at higher recycle rates.
- Jameson Cell feed density < 16% solids. Dilute feed improves dilution cleaning.
- Jet velocity at 15 m/s. Test data showed no significant impact on cell performance across the range of jet velocities tested.
- APR of up to 1.5. This is higher than normal for cleaning operation, but was selected to assist TOC recovery.
- Wash water addition was not required.

Batch kinetic flotation tests were also performed on each stream of the pilot plant. This permitted the construction of a mathematical model of the preflotation circuit with a Jameson Cell in preflotation cleaning duty using the principles of the AMIRA P9 project (Harris, 2002). Simulation results showed that at a maximum mill feed rate of 455 tph and a high TOC feed grade of 0.8%, the Jameson Cell would be required to handle 75 tph. The simulations also concluded that closed circuit Jameson Cell cleaning could reduce preflotation concentrate zinc loss by up to 80% in high TOC stockpiles.

Based on the above data, Xstrata Technology determined that a 5.4 m Ø Jameson Cell with 18 downcomers (B5400/18) should be selected for preflotation cleaning. The B5400/18 met Red Dog's requirement for a nominal feed rate of 50 tph and would be capable of handling up to 80 tph with an 80% minimum recycle rate.

Construction of Preflotation Cleaning Circuit

Engineering and procurement for the addition of a B5400/18 Jameson Cell in the preflotation circuit began in February 2006. Major equipment and construction materials were brought to site during the 2006 summer sealift with additional materials arriving by air freight. Due to limited space within the existing Red Dog concentrator, a new module was constructed to house the Jameson Cell. Construction began in June 2006. The project also required upgrading the preflotation rougher concentrate pumpbox and pumps within the existing module. Photos from construction of the new module and the completed Jameson Cell are shown in Figures 5 and 6.

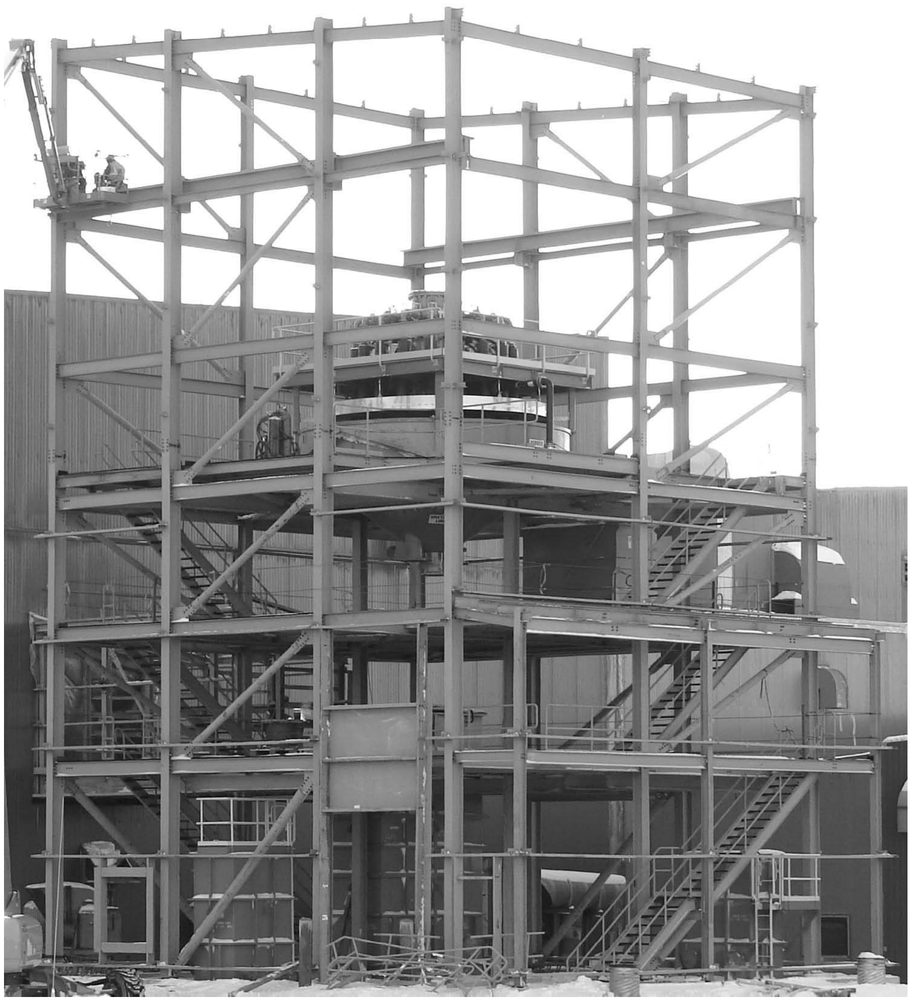

Figure 5: Construction of the new module for the Jameson Cell.

Figure 6: The preflotation Jameson Cell during commissioning at Red Dog Mine.

Commissioning Surveys

The preflotation cleaning circuit was commissioned in mid-March 2007. A schematic of the circuit is shown in Figure 7. Commissioning surveys of the new preflotation circuit were conducted over the next few months. During the first month, the mill treated an unusually low TOC stockpile; mill feed assays ranged from 0.2% to 0.3% TOC compared to the expected 2007 average of 0.6% TOC. Additional surveys were later conducted when the mill feed was 0.5% to 0.7% TOC.

The Jameson Cell was operated under different air rates, froth depths and pulp densities during the commissioning period. Since the pilot plant work indicated wash water was not necessary, all but three tests were conducted without wash water. Feed density to the Jameson Cell ranged from 12% to 19% solids. Recycle rates were >80% as per design.

For comparison, surveys of the preflotation circuit were conducted with and without the Jameson Cell in operation. A summary of these results are shown in Figures 8 and 9. These figures show TOC selectivity against zinc and lead for both configurations. Preflotation cleaning was found to be effective at reducing zinc and lead losses to the preflotation concentrate stream. There is a statistically significant difference between the regression curves with and without the Jameson Cell on-line. At 35% TOC recovery, zinc and lead losses were reduced by an absolute of 1.5%

and 2.5%, respectively. The magnitude of the reduction is dependant upon the mill feed TOC grade and the preflotation recovery target. Since the Jameson Cell tailings returns to the head of the circuit, zinc and lead rejected by the Jameson Cell has the opportunity to be recovered in their appropriate flotation circuit.

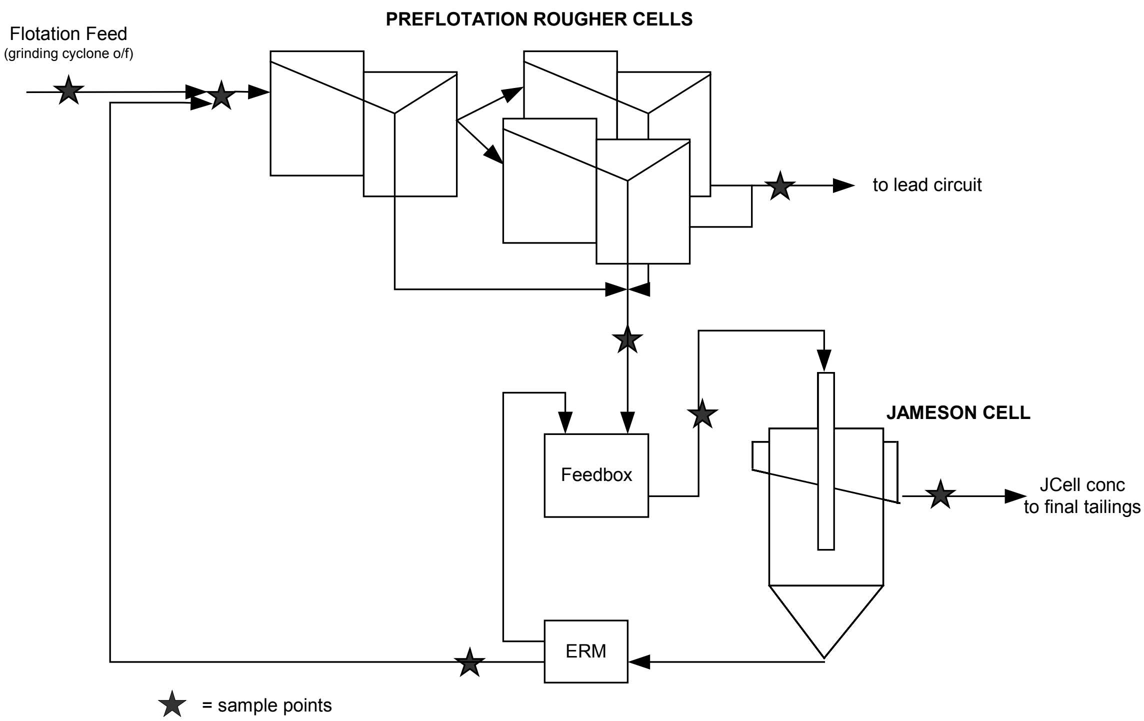

Figure 7: Red Dog preflotation circuit with the Jameson Cell preflotation cleaner.

It should be noted that prior to the Jameson Cell commissioning, Red Dog implemented the addition of dextrin (an organic depressant) to the lead cleaner circuit which allows for lower preflotation TOC recovery. Regardless of whether the Jameson Cell is on-line or not, lower TOC recovery helps minimize zinc and lead losses via entrainment to the preflotation concentrate.

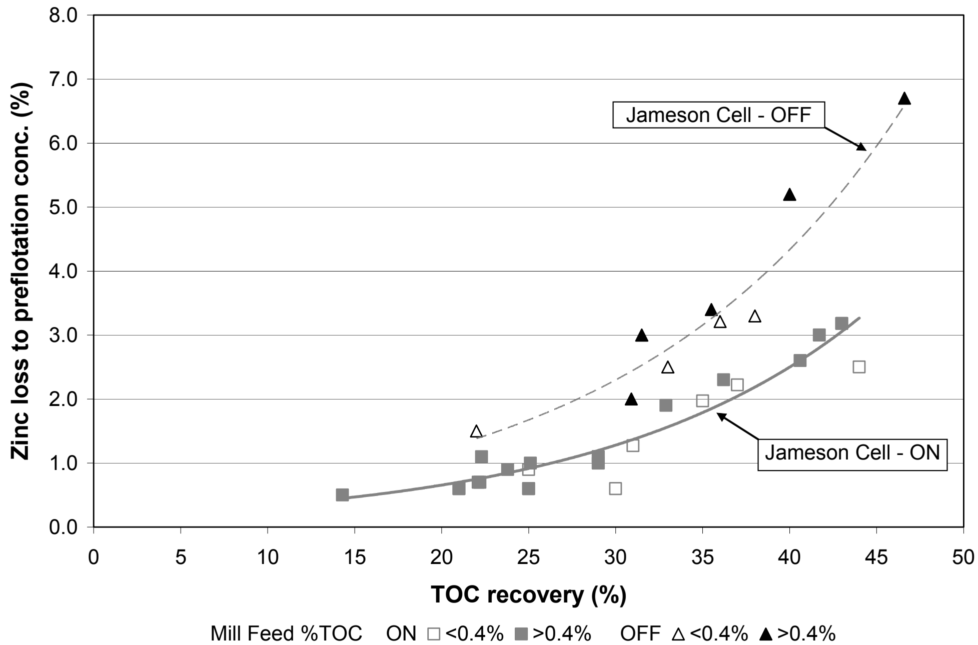

Figure 8: Overall TOC recovery versus zinc loss for the preflotation circuit.

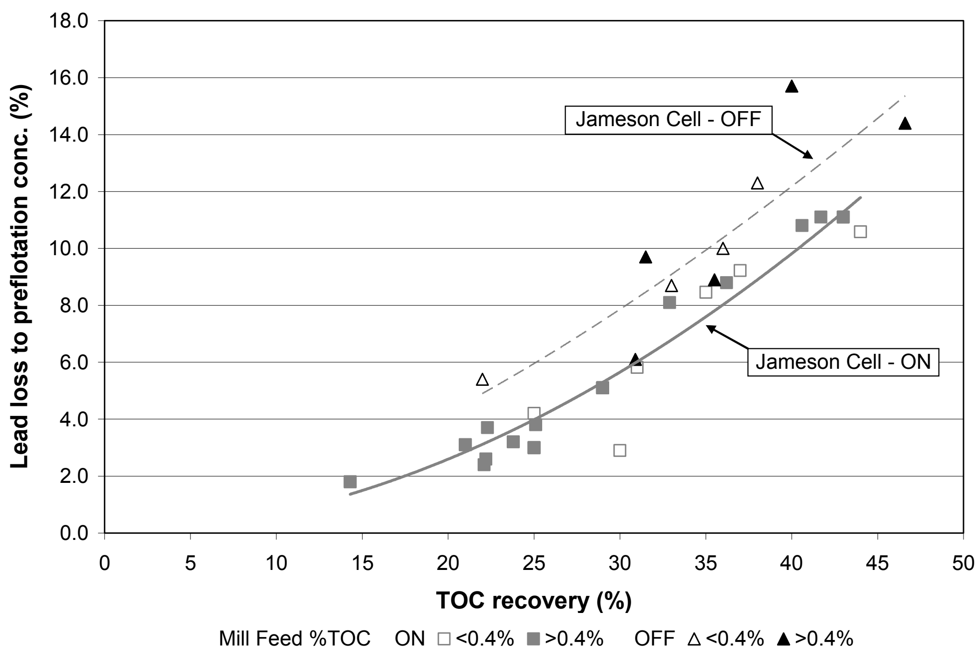

Figure 9: Overall TOC recovery versus lead loss for the preflotation circuit.

Figure 10 shows the unit TOC and zinc recoveries for the Jameson Cell during these surveys. At 70% TOC unit recovery, 34% of the zinc was recovered (i.e., 66% zinc rejected to Jameson Cell tailings). Future optimization of the Jameson Cell is expected to improve performance.

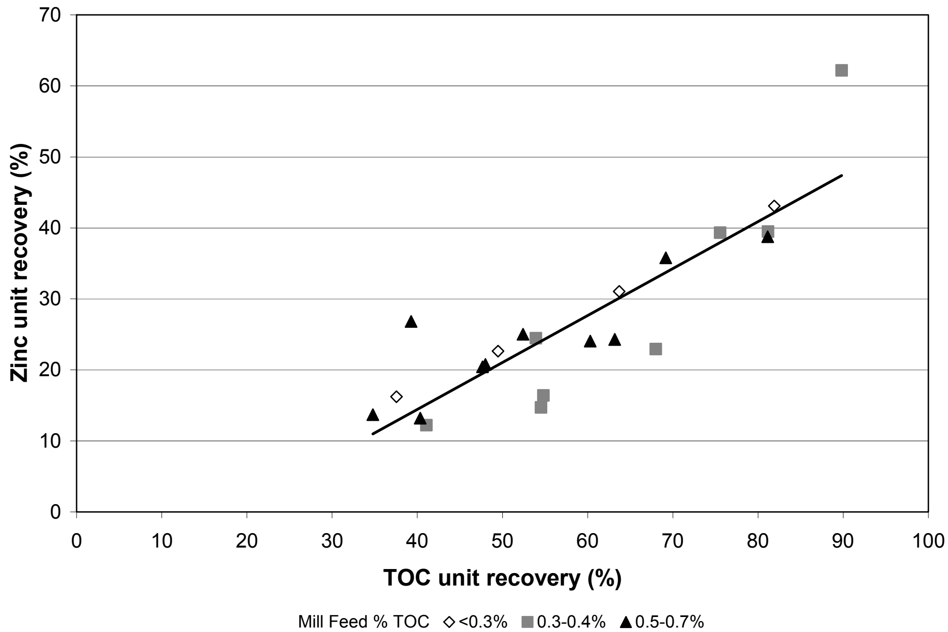

Figure 10: TOC unit recovery versus zinc unit recovery for the Jameson Cell.

Recent changes have been made to the Jameson Cell:

- The 40 mm slurry lenses on the downcomers were replaced with 44 mm lenses per the original Xstrata design criteria. This has increased the Jameson Cell recycle rate.
- A frother addition point was added to the Jameson Cell feed for use when the TOC in the feed is >0.7%. The additional frother increases the amount of air entrained in the downcomers and increases unit recovery.

Future testwork will be conducted to evaluate these changes. Wash water addition will also be evaluated.

Recoverability of Jameson Cell Tailings

To quantify how much lead and zinc rejected by the Jameson Cell reports to their appropriate final concentrate, laboratory batch cleaner flotation testwork was conducted on Jameson Cell tailings. The flotation performance of the Jameson Cell tailings was expected to be significantly worse than that of fresh feed for the following two reasons:

- Zn/Pb, Zn/Fe and Zn/TOC ratios are significantly lower than typical feed grade.
- The majority of Jameson Cell tailings is fine (<15 μm) and thus presents a potential challenge in lead and zinc flotation.

Results from the batch flotation tests are summarized in Figures 11 and 12. This testwork was performed only on the initial low TOC stockpile.

In Figure 11, one stage of lead cleaning yielded concentrates that graded from 39% to 54% lead with lead recoveries ranging from 47% to 59%. In Figure 12, four stages of open circuit zinc cleaning yielded concentrates that graded from 47% to 52% zinc at recoveries ranging from 54% to 61%. Cleaning circuits in the plant operate in closed circuit, thus plant recoveries will be higher than in open circuit batch tests. It is expected that at a minimum, 60% of the lead rejected by the Jameson Cell will be recovered to lead final concentrate and 70% of the zinc will be recovered to the zinc final concentrate.

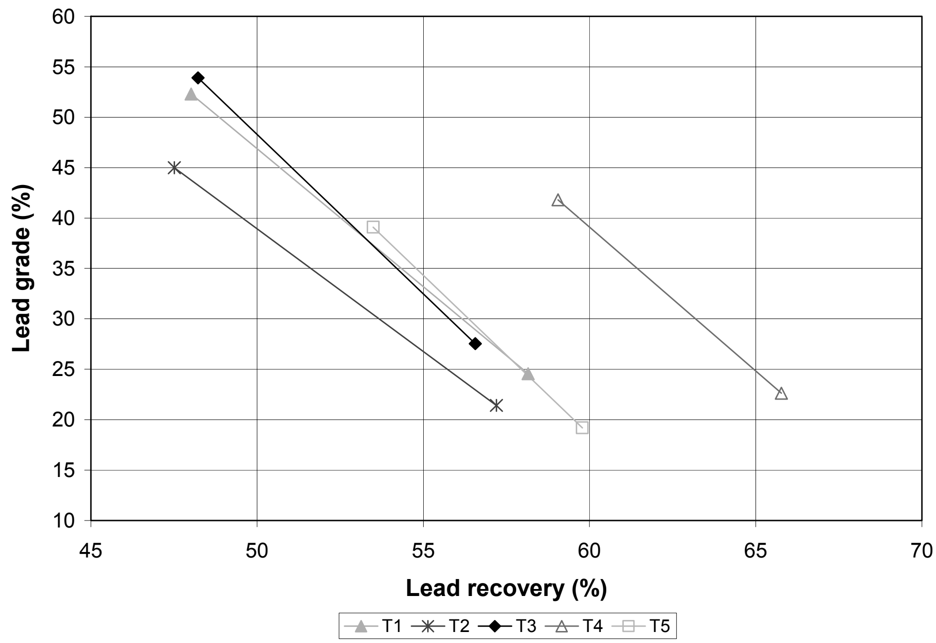

Figure 11: Lead grade-recovery relationship for the flotation of Jameson Cell tailings.

Project Economics

At a zinc price of $1.30/lb and a lead price of $1.20/lb, this $9.1M project has an approximate payback period of 1 year based on the following:

- A 1.5% absolute reduction in the zinc loss to preflotation concentrate equates to a 1.0% increase in overall zinc recovery (assuming 70% zinc recovery of the rejected material).
- A 2.5% absolute reduction in the lead loss to preflotation concentrate equates to a 1.5% increase in overall lead recovery (assuming 60% lead recovery of the rejected material).

Figure 13 shows the daily zinc and lead flotation circuit recoveries before and after the Jameson Cell was commissioned. On average, zinc recovery increased 2.1% and lead recovery increased 3.0% since March 2007. The increase in flotation circuit recoveries has been attributed to the synergy between the Jameson Cell preflotation cleaner and the use of dextrin in the lead circuit.

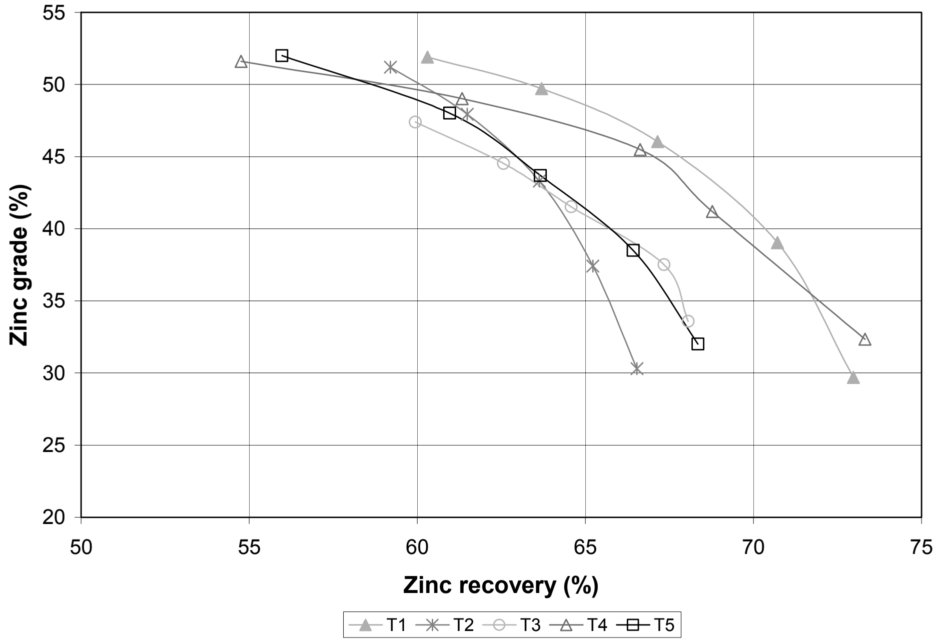

Figure 12: Zinc grade-recovery relationship for the flotation of Jameson Cell tailings.

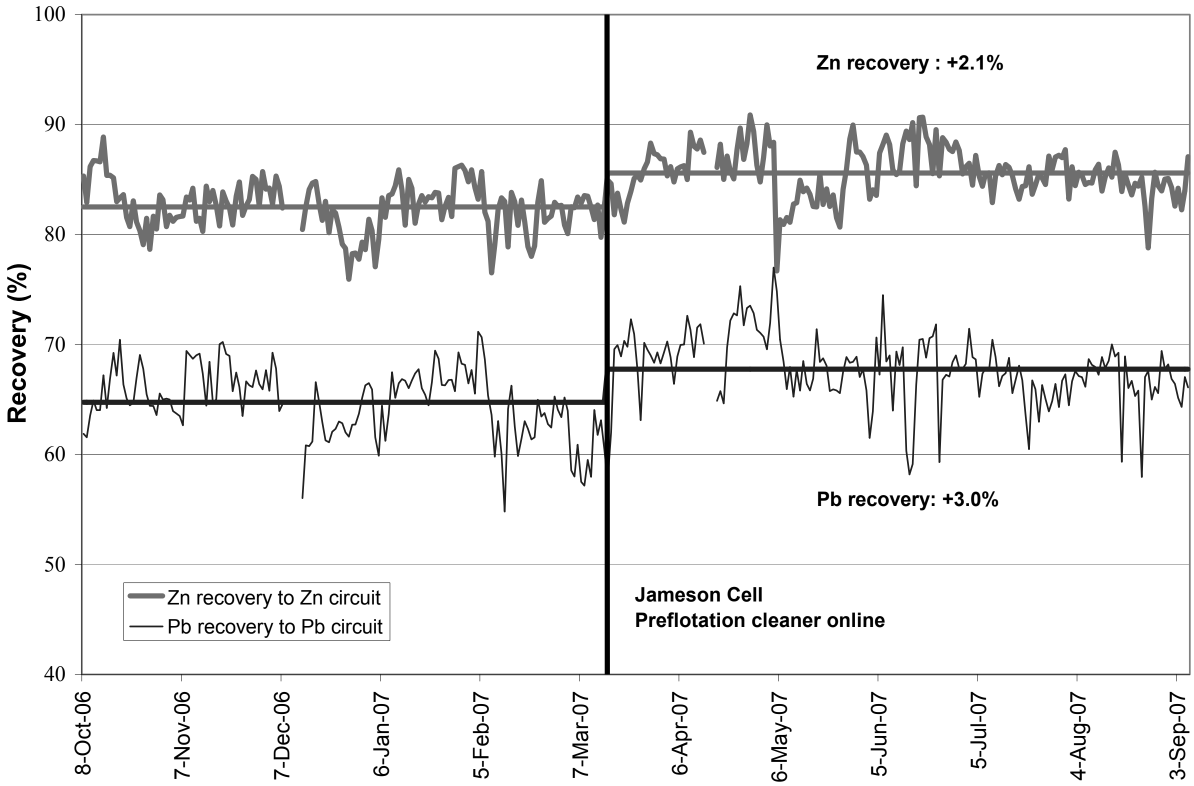

Figure 13: Zinc and lead circuit recoveries pre/post Jameson Cell.

CONCLUSIONS

Survey and operating data have shown that the installation of a Jameson Cell for preflotation concentrate cleaning has improved flotation circuit performance at Red Dog. Conservatively, preflotation cleaning has resulted in zinc and lead absolute recovery gains of 1.0% and 1.5%, respectively. The $9.1M project has a payback period of approximately 1 year at current metal prices.

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