PAPER 20

Jameson Cell: The "Comeback" in Base Metals Applications Using Improved Design and Flow Sheets

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ABSTRACT

The "Jameson Cell" flotation cell was developed at Mount Isa Mines in the late 1980's to address deficiencies in our flotation column installations. Early base metal installations had a variable record. The test work and trials showed they made an improvement metallurgically when operated correctly, but performance of the early installations was hindered by a range of operational and maintenance issues. The installations needed to be more robust, and we needed a better understanding of how to successfully integrate the cells into the plant flow sheet.

During the 1990's, Jameson Cells had great success in coal fines flotation and organic removal in SXEW applications, and became the standard in these applications in Australia. These installations improved the cell design and materials of construction and the cell flow sheet design, to make it low wear with self-regulating control, producing good performance with little operator input.

These improvements have enabled a fresh look at the use of Jameson Cells in base metals. Recent new installations have shown significant benefits in "hybrid" circuits, that combine the best features of both Jameson Cells and conventional flotation cells, achieving better overall circuit performance in a smaller footprint than either technology could do by itself.

Case studies of successful base metal applications are discussed, using size-by-size mineralogical performance to explain the improved circuit performance. The new methods of flow sheet test work design are also described.

INTRODUCTION

The Jameson Cell combines a novel method for air and slurry contact where a plunging jet naturally entrains air, achieving high voidage, fine bubbles and intimate bubble particle contact (Figure 1). Small bubbles (0.3-0.5 mm) are consistently produced, and intense bubble-particle contact occurs in a short time (6-10 secs) in the downcomer. As a result, the Jameson is a high intensity cell producing fast mineral flotation rates, especially for fines. Since bubble/particle contact occurs in the downcomer, the purpose of the "cell" is simply for bubble-pulp separation, therefore cell volume is very small compared with columns. The high flotation rates resulting from the intense aeration mean a high productivity per surface area, making froth washing attractive to increase concentrate grade. Power consumption is lower than the equivalent mechanical or column flotation cells (the only power is the feed pump, with no blower or compressor) and the orifice and feed pump are the main wearing parts. The fundamentals of Jameson Cell operation have been described by numerous authors, including Clayton, Jameson and Manlapig (1991).

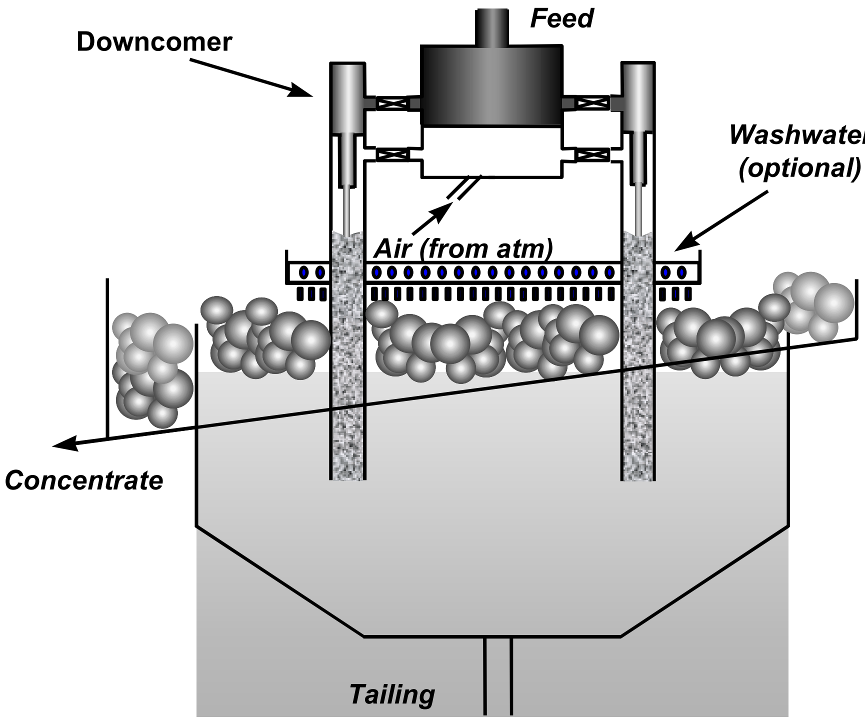

Figure 1: The Jameson Cell.

The first production Jameson Cells installed were lead cleaner units at Mt Isa, as described by Jameson and Manlapig (1991). This installation showed a vast difference in flotation kinetic rates between the Jameson Cell, mechanical cells and flotation columns. Additionally the size, footprint and cost of the Jameson Cell installation were much lower than conventional mechanical cells and flotation columns. Figure 2 is a visual demonstration of this – it shows side-by-side installations of flotation columns and Jameson Cells with similar operating capacities at the Mount Isa lead-zinc concentrator. As well as the reduced installation costs operating costs are lower – less spargers, lower pumping costs and induced air rather than compressed air in columns.

Early Jameson Cell installations were applied in cleaning duties due to the ability of the cell to produce high-grade concentrates from a single pass (Jameson, Harbort, Riches, 1991). These installations however only achieved moderate unit recovery of 50 to 80%. To obtain high overall circuit recovery the Jameson Cells needed to be operated in closed circuit with other flotation banks. Work by Riches (1991) and Harbort (2002) supported these findings highlighting the fact that a single pass Jameson Cell could produce final concentrate grade from rougher feed at recoveries between 60% and 70%, which was significantly better than mechanical cell test work.

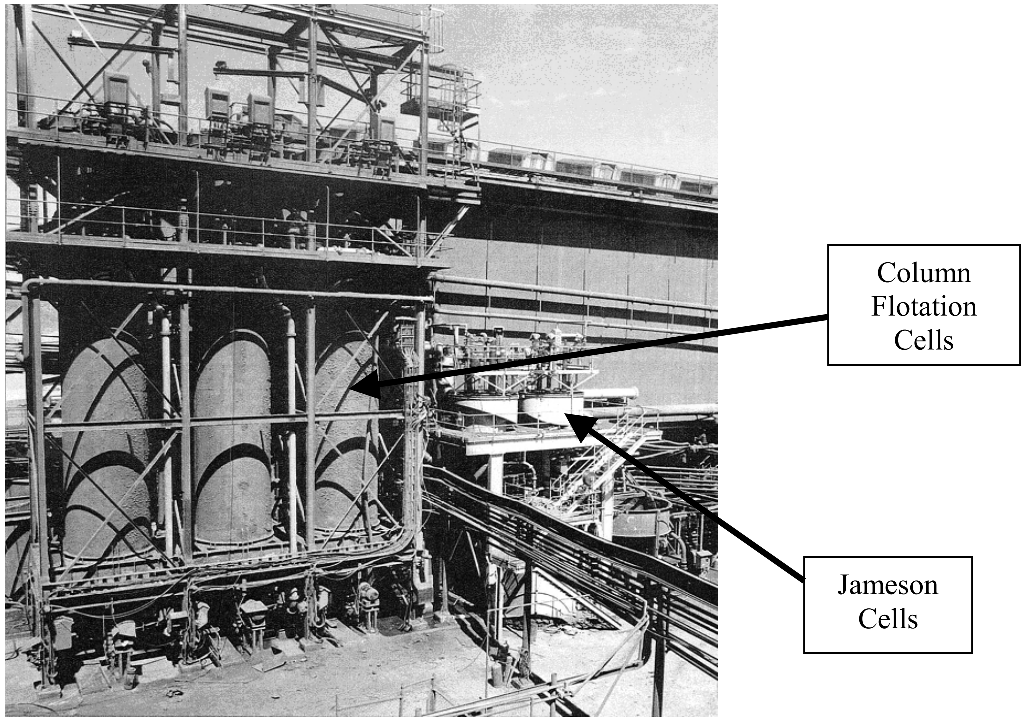

Figure 2: Comparison of column and Jameson Cell sizes of similar capacity.

In spite of the significant metallurgical and cost advantages of Jameson Cells, early base metals installations were hindered by a lack of operational "robustness". Pilot plant test work was always favourable, but we hadn't perfected either the design of full-scale cells, or the best way to integrate cells into a circuit.

The biggest operational issue was that the Jameson Cell should be fed at constant volume and pressure for consistent operation. Early installations did not ensure this – cells were fed in a "single pass", or in closed circuit with roughers. Feed rate varied, which meant that downcomer operation varied, affecting metallurgical performance and stability of the cell. If feed rate dropped then individual downcomers had to be shut off to keep constant velocity in other downcomers. This was not a practical solution. Further, while the high intensity bubble contact in the downcomer means very fast flotation rates, it also means only one opportunity for bubble/particle contact. As a result, the Jameson Cell produces a high-grade concentrate very quickly, but a single cell will not achieve high recovery (typically 50-80% in a single pass of base metals). Either multiple cells in series were needed (reducing the capital cost advantage), or the cell needed to run in closed circuit with roughers to achieve high overall circuit recovery.

While we hadn't learnt how to properly apply the Jameson Cell to base metals it was having great success in coal fines flotation and SXEW organic removal in the 1990's (Jameson, Goffinet, Hughes, 1991; Dawson, Jackson, 1995). This success was due to the Jameson Cell ability to achieve final product specification at very high recoveries (95-98%for coal) in a single pass. Also the high intensity of the Jameson Cells allowed them to treat huge volumes in a small installation compared with other technologies. The Jameson Cell has now become the standard in these applications.

The success in coal forced us to re-examine the disappointing performance in base metals. The difference in performance between coal fines flotation and base metal flotation was that while a single pass Jameson Cell could achieve final product quality at 95-98% recovery in coal flotation it could only achieve 50-80% recovery in base metals applications. Fundamentally base metals flotation has slower differential kinetics and higher upgrading ratios than coal. The difference in kinetics and upgrade ratios requires the base metals Jameson Cell be operated in closed circuit with other flotation units (mechanical or Jameson Cells) to achieve high overall circuit recovery.

JAMESON CIRCUIT DESIGN IMPROVEMENTS

The two key issues that had to be addressed for base metals were:

- A practical way to feed the Jameson Cells at a constant volume, in spite of the normal fluctuations in operating plants.
- Designing installations that accounted for low single-pass recovery, but took advantage of the fast flotation rates and high concentrate grades, in an overall low cost circuit.

The first of these problems was simply solved by introducing a "tailings recycle" into cell feed. Installations are designed to handle 30-40% higher volume than maximum expected throughput. The cell is fed by a fixed speed pump, delivering constant volume and pressure to the downcomers. Cell tailings are recycled to the feed pumpbox as necessary to provide the constant volume. Even if new feed is lost completely the cell will continue to operate on fully recycled tailings, producing the same bubble size (and protecting the feed pump). An added advantage of this system is that it increases first pass recovery, as typically 40% of the feed gets two "chances" in the downcomer. Such a simple concept has made a remarkable change to the operability of Jameson Cells – they produce constant bubble size and performance and self-adjust to circuit conditions, requiring very little operator input. Recycle has now become an integral part of the Jameson Cell with internal (IRC), external (ERM) (Figure 3) and detached external options available (Cowburn, Stone, Bourke, Hill, 2005).

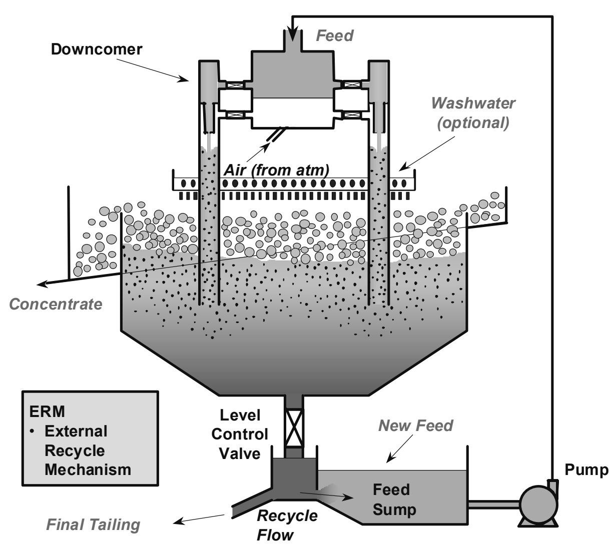

Figure 3: The Jameson Cell with external recycle mechanism to stabilise downcomer feed rates.

By late 1995 the Philex Mining Corporation copper concentrator had installed Jameson Cells throughout the circuit. (Harbort, Murphy, Budod, 1997). This operation was the first base metals operation to apply the ERM system. The project precipitated the development of much larger Jameson Cells and so a large increase in Jameson Cell circuit capacity. The ERM system was further developed in the design of the Alumbrera concentrator that used Jameson Cells for its entire cleaning circuit (Harbort, Murphy, Launder, Miranda, 2000). By 1999 Internal recycle control (IRC) was being installed in the lead-zinc (Young, Pease, Fisher, 2000) and copper concentrators (Carr, Harbot, Lawson, 2003) at Mount Isa Mines. IRC lowered cell installation cost and made installations more compact. (Figure 4)

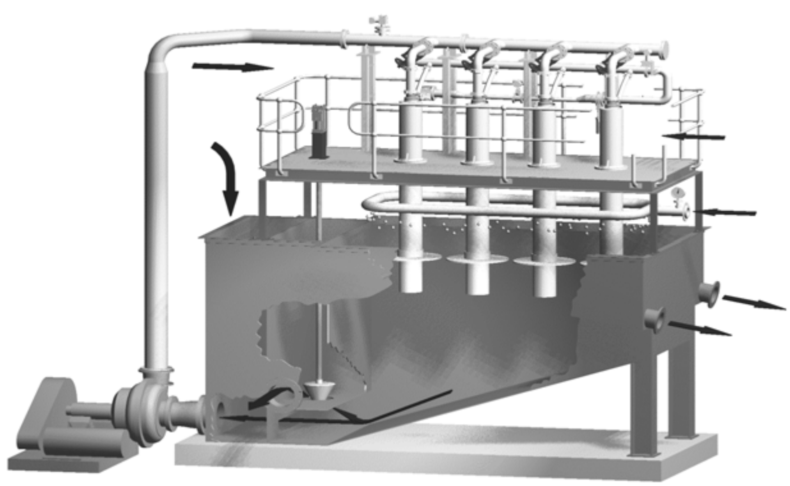

Figure 4: The Jameson Cell with internal recycle control (IRC) to stabilise downcomer feed rates.

While Tailings Recycle was introduced to stabilise Jameson Cell feed flow design work also progressed on improved operability of the downcomer, “the heart of the Jameson Cell”. In the 2000, the Mark 3 downcomer (Figure 5) was introduced halving the number of parts and allowing all parts to be located outside the downcomer simplifying access.

The replacement of the orifice plate with a slurry lens increased the component wear life while the improved slurry entrance design has increased the discharge coefficient and decreased feed pump power consumption by 10-15%. Additionally the location of the slurry lens compared to the orifice plate increased the effective length of the downcomer by 15%, improving mixing zone residence time and allowing operation at higher Air-to-Pulp ratios. Laboratory scale test work has shown that the longer length in downcomer allows increased air entrainment for a given vacuum (Cowburn et al, 2005).

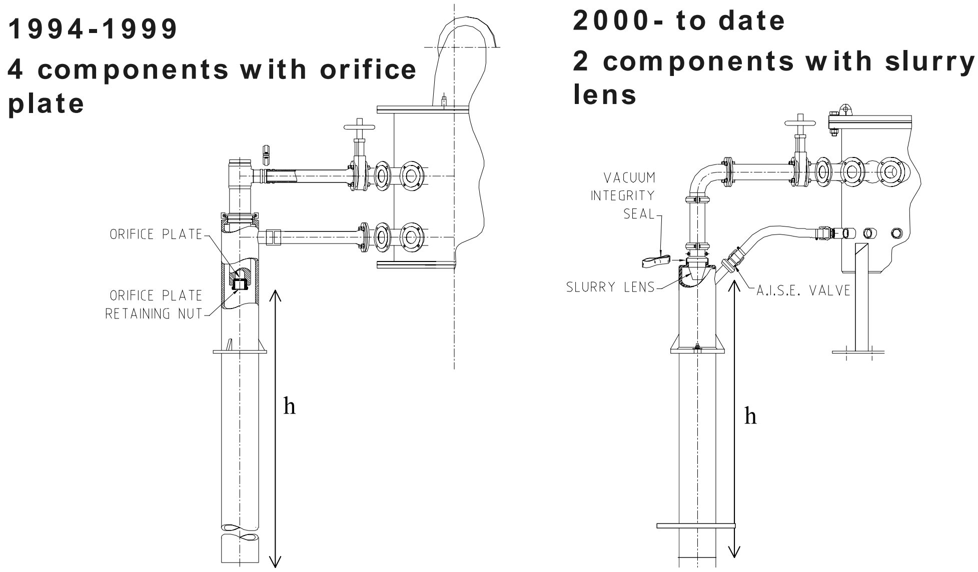

Figure 5: Old and new downcomer designs

The trend to larger cell capacities has led to an increase in Jameson Cell sizes with the largest installed base metals Jameson Cell, B6500/22, now able to handle a unit throughput of 22,000 t/d, and the largest installed Jameson Cell, J7200/10, capable of processing 40,000 t/d. Larger capacity Jameson Cells are easily designed, as the cell diameter and number of downcomers are easily increased and the overall height of the installation remains unchanged.

The second issue to be addressed so that Jameson Cells could be applied in base metal flotation was to design installations to account for low single-pass recovery, while taking advantage of the fast flotation rates and high concentrate grades, in an overall low cost circuit. To do this some basic characteristics of the Jameson Cell had to be recognised. Firstly the Jameson Cell is a high grade generating machine. It is a high intensity flotation device utilising induced air for flotation; the high shear rates generate fine bubbles in the downcomer. For fine bubble generation the Jameson Cell should be operated at low to moderate air/pulp ratios (0.2 to 0.5) and moderate to high vacuums (15 to 30 kPa). These operating conditions selectively collect the high kinetic minerals in the pulp giving a sharper separation of the high from low kinetic minerals

The Jameson Cell is configured with froth wash water and moderate froth depths that allow froth washing to minimise entrainment. This cell configuration generates high grade concentrates in one flotation stage. In operation wash water should be at a moderately positive bias (the ratio of the wash water added to the froth to the water recovered with the concentrate). Biases of 1.2 will help to minimise entrainment, while higher biases (up to 1.5) can minimise the recovery of composite particles that are weakly attached to bubble, thereby maximising concentrate grade.

While the high intensity, small bubble size and froth washing allow the Jameson Cell to produce a high grade concentrate in a single stage of flotation, these features also result in only low to moderate recoveries over this single stage. The low recoveries can be improved by increasing the recycle ratio to increase the air to new pulp ratio, contrary to the common misconception that recoveries can be improved by decreasing the vacuum and so increasing the air rate that actually results in increased bubble size and reduced performance. At full scale, increasing the recycle ratio is easy and cheap to install by increasing the number of downcomers installed.

The operation of conventional cells and columns is fundamentally different to Jameson Cells so the design of a base metals flotation circuit needs to acknowledge these differences. Where Jameson Cells increase the number of downcomers to increase their new pulp to air ratio, mechanical cells increase their use of pressurised air. While laboratory mechanical cells are good at producing small bubbles the lower shear intensity in larger cells mean that larger cells generate larger bubbles. Conversely Jameson Cells generate small bubbles at both laboratory and full-scale levels, as the shear intensity remains the same.

The fundamental differences between conventional and Jameson Cells mean that flow sheets need to be designed to maximise the inherent strengths of the respective cells and to optimise the response of the ore based on kinetics and upgrade ability.

From a construction point of view scale-up to full scale is much simpler and cheaper for Jameson Cells than for conventional cells. Jameson Cell circuit designs require only larger cells using the correct number of downcomers operating at low air/new pulp ratios, instead of a large number of extra conventional cells.

CIRCUIT DESIGN FOR BEST PERFORMANCE IN BASE METALS FLOTATION

In base metals flotation Jameson Cells have a variety of applications. They can be installed in new flow sheets or retrofitted into existing plants. Being a high grade flotation device they are perfect for installation into cleaning circuits however their ability to float a high grade concentrate at moderate recovery makes them equally applicable to roughing duties.

When designing a base metals flotation circuit it is essential that the flotation machine be matched with the duty it is to perform, just as a NASCAR will under perform in an off-road rally, the Jameson Cell will under perform if put into a duty of which they are not capable. It is essential that the correct machine be chosen to meet the task requirements.

So what are the appropriate places to use a Jameson cell?

1. **Jameson Cell in a primary cleaner duty in closed circuit with conventional rougher-scavenger circuit.**
   One of the original installation duties for Jameson Cells was as a single stage cleaner in closed circuit with the rougher scavenger circuit (Figure 6). This flow sheet works well producing a high concentrate grade when fast flotation kinetics and moderate upgrading ratios make the rougher concentrate easy to upgrade. Large recirculating loads (up to 300%) may be required to compensate for low first pass recovery, but well liberated high kinetic minerals can be upgraded with low circulating loads. Alternatively flotation recovery can be increased by installing a second Jameson Cell in series.

This circuit has been applied at the Mount Isa copper slag cleaning circuit and the preflotation cleaning circuit.

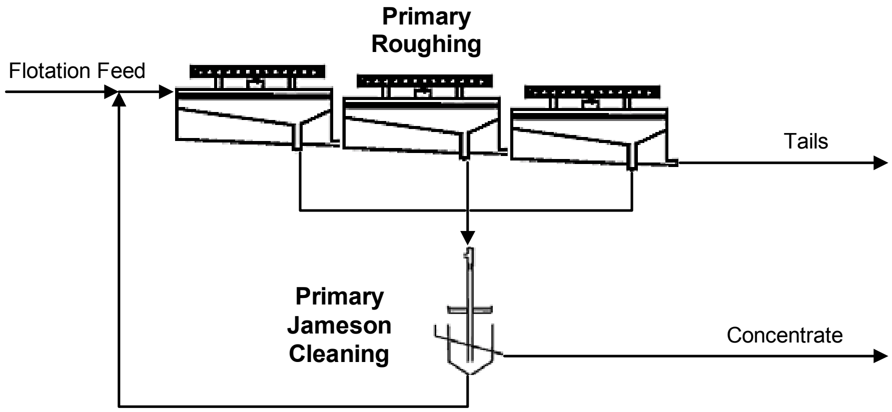

Figure 6: Jameson Cell primary cleaning circuit flow sheet

2. **Jameson Cell in a cleaner flash float duty.**
   Installation of a Jameson Cell as a cleaner flash flotation unit is ideal for plant expansions and retrofits, where a conventional cleaner circuit already exists (Figure 7). This circuit takes advantage of the best features of both technologies, Jameson Cells collecting fast floating material to produce a high grade and tonnage concentrate and conventional cells achieving final recovery. This is done in a smaller footprint and at lower CAPEX than if either technology had been used exclusively. Jameson Cells are a cheap expansion alternative used to alleviate load resulting in overall grade and recovery improvements. The use of froth washing will increase concentrate grade by reducing entrainment. By producing a high tonnage in a small footprint, the Jameson Cell allows froth washing to be applied economically to a significant part of the concentrate. Further, by reducing the feed to the subsequent conventional cleaners, these cleaners operate at lower density and lower froth rates, meaning entrainment is reduced there. So a relatively small area of froth washing can significantly reduce the total entrainment in this "hybrid" circuit. Modifications to this circuit include additional Jameson Cells however pumping costs mean that more than two Jameson Cells in series may be capital intensive.

   This addition of a Jameson Cell flash cleaner was retrofitted in the Mount Isa lead-zinc concentrator as described in Case Study 1.

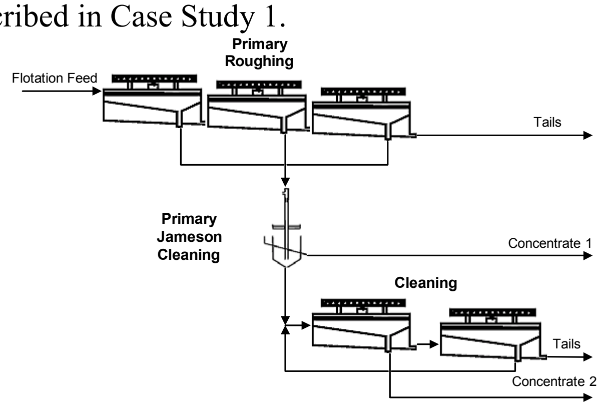

Figure 7: Jameson Cell flash cleaning circuit flow sheet

3. Jameson Cell as Flash Rougher Cell installed before conventional rougher scavenger circuit

The installation of Jameson Cells as flash rougher cells is ideal for both new plants and plant expansions. Jameson Cells are high throughput cells having the ability to pull high, final concentrate grade in one stage flotation (Figure 8). As a result of their small footprint they can be installed simply in existing plants making them the ideal flotation cell for any upgrade situation. The installation of two Jameson Cells in series further increases the applicability of Jameson Cells in this duty.

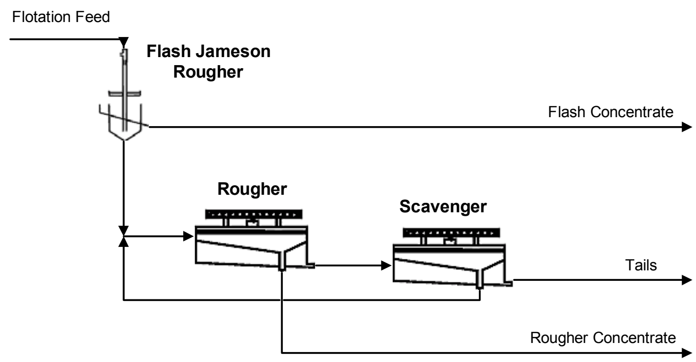

Figure 8: Jameson Cell flash roughing circuit flow sheet

The flow sheets shown above are by no mean exhaustive and simply show the range of applicable uses for Jameson Cell technology. By combining Jameson Cells in roughing and cleaning circuits the benefits from their use can be further enhanced.

CASE STUDIES

Case Study 1: Mount Isa Lead Cleaner Circuit

The George Fisher ore treatment upgrade at the Mount Isa lead-zinc concentrator required an increase in the lead circuit cleaning capacity. This was done by installing a lead cleaning Jameson Cell to treat the fine (P80=12 microns) IsaMill regrind product and produce a high grade lead concentrate (Young et al, 2000). The IsaMill product is fed directly to the lead cleaning Jameson Cell as shown in Figure 9. The Jameson Cell produces a concentrate of 60% lead grade at 35% lead recovery and consequently reduces the circulating load from the original conventional 3 stage, closed circuit lead cleaners. Combined with the conventional cleaners (which achieve a 51% lead grade at 45% recovery) the final concentrate grade is 55% lead.

The lead Jameson Cell installed for this duty was an E1732/4 Model with IRC. It has surface area of 5.2 m2 and volume of 8.2 m3. Compared to the conventional cleaners that have a surface area of 156 m2 and volume of 200 m3 and achieve 45% Pb recovery, the Jameson Cell achieves 35% lead recovery using an order of magnitude less surface area and cell volume. The high performance of the Jameson Cell is a result of its high intensity, small bubble size and efficient froth washing.

The high production rate from the small surface area of the Jameson Cell makes froth washing economic increasing the overall concentrate grade. The resulting lower feed to the conventional cleaners allows them to operate at lower density and froth loadings, reducing entrainment and improving performance. Although the circuit performance has improved it is difficult to attribute how much of the improvement is a result of Jameson Cell or the extra IsaMill capacity (they were installed at the same time). Irrespective of this the overall effect is an increase in concentrate grade of 5% to 55% lead with an increase of 5% lead recovery

The circulating load between rougher and the Jameson/cleaner circuit is low, often only 110% of the new cleaner circuit feed lead content. So using this mineral set, liberation and circuit configuration, high overall plant recoveries can be achieved with low circulating load.

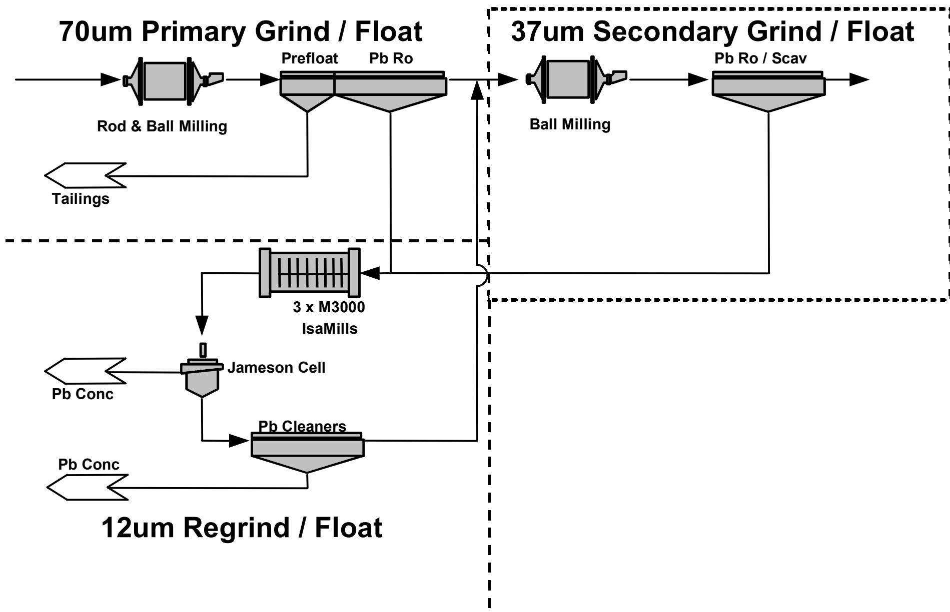

Figure 9: Mount Isa lead rougher-cleaning circuit flow sheet

The Lead Cleaning Jameson Cell is very successful at recovering fine, liberated, fast floating galena particles. As shown in Figure 10, 93% of the galena occurs in sub 12micron particles with most of this finer than 6microns. While the Jameson Cell is better at recovering these fine particles the conventional cleaning circuit has been better at recovering the coarse particles (Figure 11). The Jameson Cell achieves higher fines recovery at a much higher concentrate grade (60% lead grade), with decreased fine gangue recovery, compared to the conventional cleaning circuit (51% lead grade). The combination of the Jameson Cell and the conventional cleaning circuit is successful at recovering both fine liberated and coarser less-liberated galena resulting in good recovery to the lead final concentrate with less fine particle entrainment.

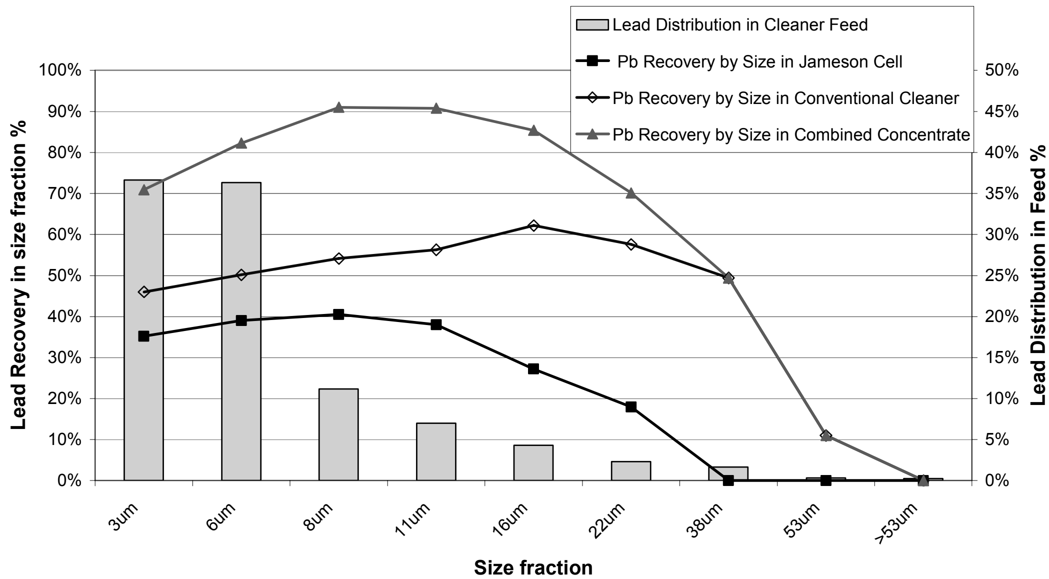

Figure 10: Size-recovery performance in the lead cleaner circuit at the Mount Isa lead-zinc concentrator

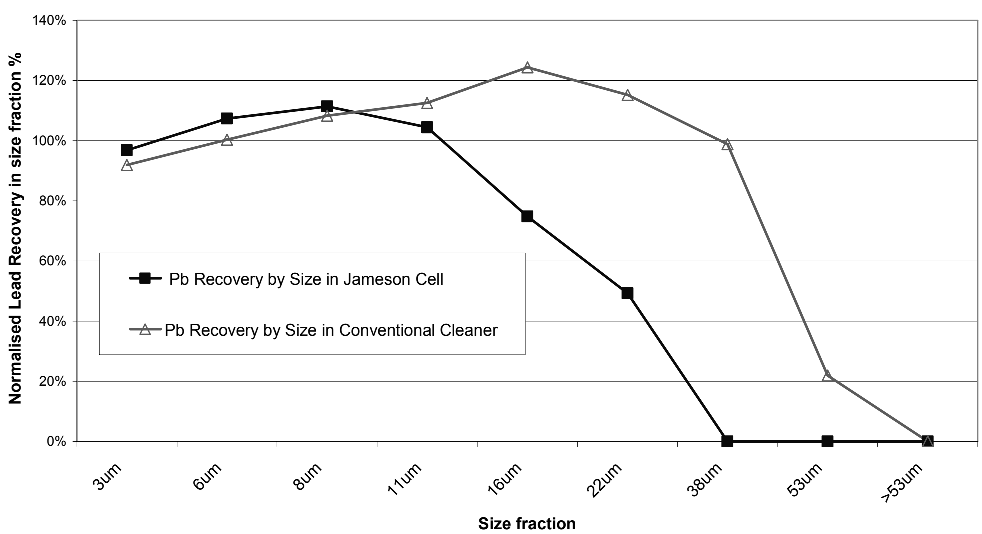

Figure 11: Normalized size-recovery performance in the lead cleaner circuit

Prior to the upgrade the main gangue mineral being removed in the lead cleaning circuit was sphalerite, the main zinc losses in the flotation circuit occurred as sphalerite/galena binaries reporting to the lead concentrate. Regrinding the lead cleaner feed to 12 microns liberated a significant portion of these binaries, allowing better rejection of the sphalerite to the zinc circuit (and more effective rejection of the pyrite contamination). Figure 12 shows the successful rejection of sphalerite from the lead concentrate particularly from the Jameson Cell. The very good rejection of fine zinc and pyrite in the Jameson Cell compared with conventional cells demonstrates that the high intensity in Jameson Cell recovers the fast floating minerals quickly, and is good at rejecting minerals with a low rate constant. Compared to conventional cells the Jameson Cell amplifies the difference in flotation rates between fast floating and slow floating minerals.

If more Jameson Cell capacity had been installed the sphalerite rejection from the lead concentrate may have been further improved.

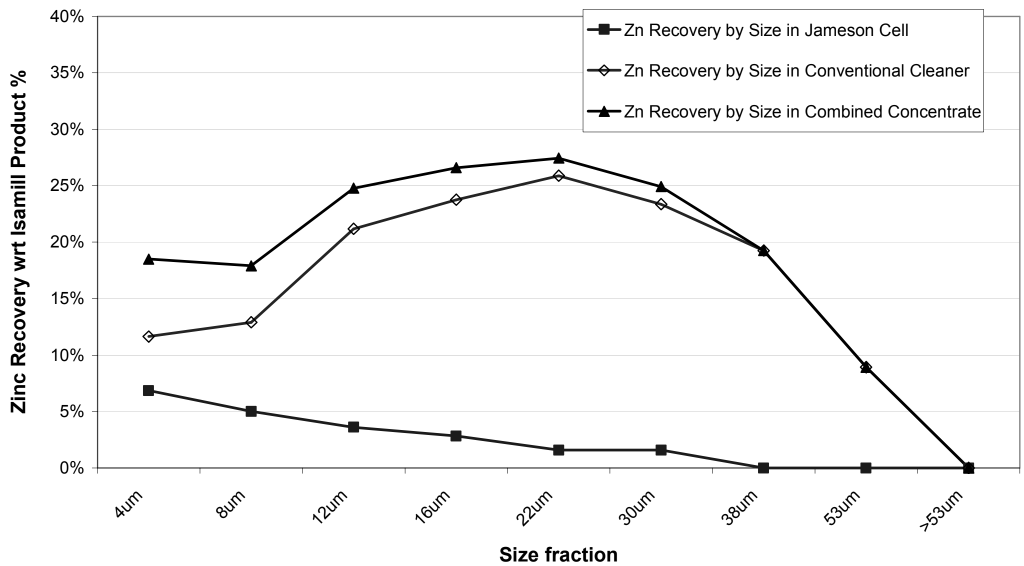

Figure 12: Zinc size-recovery in the lead cleaner circuit

Case Study 2: Mount Isa Copper Preflotation Jameson Cell Performance

The Mount Isa copper ore bodies contain naturally floating fine-grained carbonaceous pyrite and naturally floating talc that contaminate the copper concentrate. The pyrite contamination lowers the grade of the copper concentrate decreasing the throughput of the copper smelter and increasing the copper losses to smelter slags. The talc contamination increases the magnesium content of the copper concentrate which significantly decreases the copper smelter availability and overall copper output by increasing the slag melting point and therefore the operating temperature (which accelerates refractory linings degradation decreasing smelter campaign life), while the magnesium attacks the smelting vessel refractory linings also decreasing the campaign life.

Early treatment in the Mount Isa Copper Concentrator comprised of flotation followed by depression of carbonaceous pyrite and talc. Studies in the 1990s showed that preflotation of this naturally hydrophobic gangue was preferable to depression. The first prefloat circuit configuration consisted of flotation columns. These columns were reassigned in 1996 however increasing amounts of talc and carbonaceous pyrite in the ore bodies necessitated the reintroduction of a prefloat circuit. During the late 1990's, increasing concentrate contamination and copper losses to the preflotation concentrate justified the installation of preflotation cleaning using a Jameson Cell. The preflotation cleaning Jameson Cell, model E2514/3 with IRC, was installed in the flow sheet as shown in Figure 6, as part of the 2002 concentrator expansion project (Carr, Harbort, Lawson, 2003).

The main outcome of the installation of the Jameson Cell for preflotation cleaning was decreased contamination of the copper concentrate by naturally floating gangue. Figure 13 shows the pyrite contamination of the copper concentrate was significantly decreased after the commissioning of the Jameson Cell even with an increase in pyrite in the feed at this time.

The copper losses to the preflotation concentrate were also decreased. Prior to the Jameson Cell installation the preflotation concentrate contained 2-2.5% copper grade, this was decreased to 1-1.5% copper. The amount of naturally floating material in the feed increased and the new circuit mass recovery was doubled during times of high naturally floating gangue material in concentrator feed, while maintaining low copper losses.

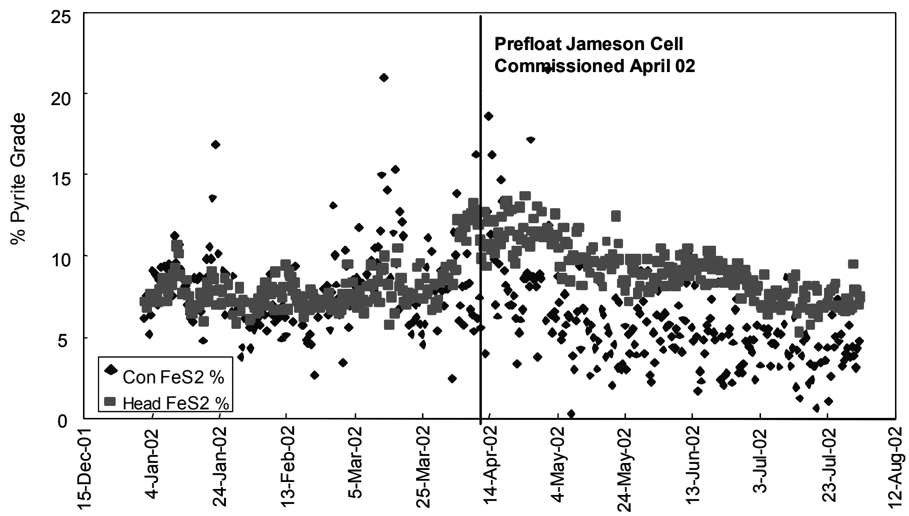

Figure 13: Pyrite contamination of copper concentrate before and after Jameson Cell commissioning

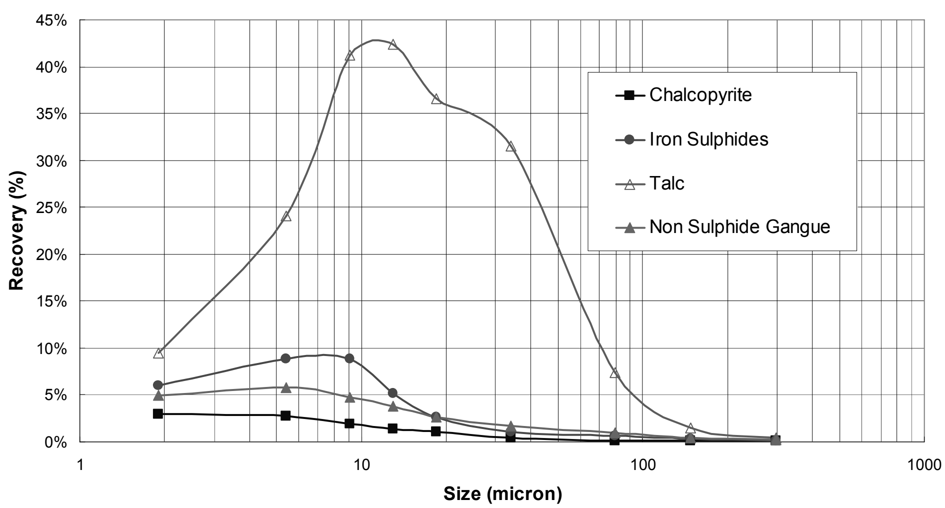

Figure 14: Preflotation circuit size-recovery performance

The preflotation circuit size-recovery performance (Figure 14) shows very good collection of the mid sized range talc particles and naturally floating carbonaceous pyrite, while the copper losses are minimised. The copper assay of the preflotation concentrate in the survey was 1% Cu. It should be noted that the copper recoveries are now lower than the non-sulphide gangue recoveries, indicating good performance in copper rejection.

Case Study 3: Mount Isa Copper Slag Circuit Performance

Copper smelter slags are re-treated in batch campaigns at the copper concentrator, using one line of grinding and rougher flotation. Historically the conventional cleaners were used for slag cleaning. Following successful use of column flotation at the Hilton concentrator the copper concentrator slag circuit was converted to column flotation. As part of the 2002 copper concentrator upgrade, a dedicated, slag cleaning, Jameson Cell, model E2532/6 was installed for cleaning of both converter and RHF slags (Figure 15) (Carr et al 2003).

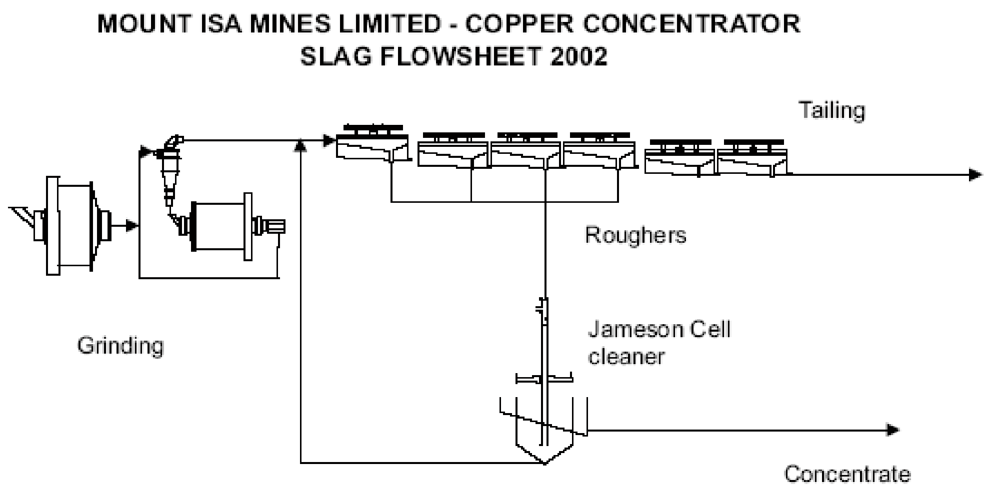

Figure 15: Copper concentrator slag circuit flow sheet

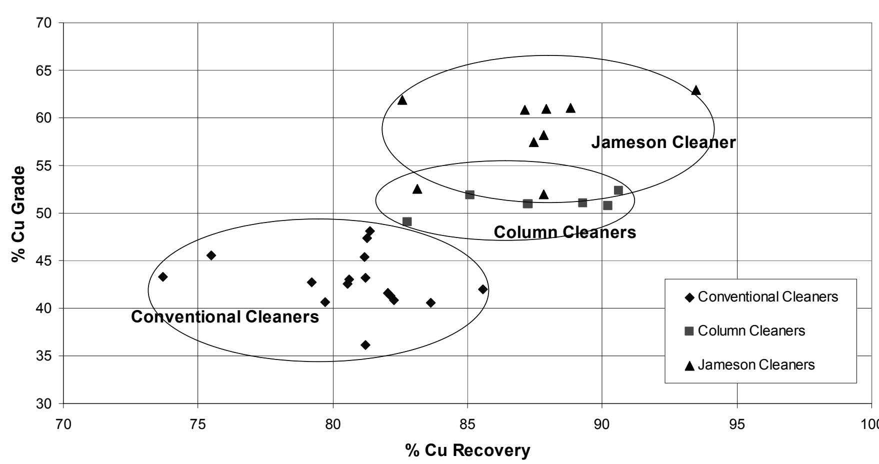

Figure 16: Copper concentrator slag circuit performance using different cleaning cells.

The performance of the copper concentrator slag cleaning circuit over a number of years and using different flow sheets is shown in Figure 16. The installation of the three 2.5m diameter 17m high columns as slag cleaners improved both the grade and recovery of the copper concentrate from the slag circuit however this was further improved by the installation of the E2532/6 Jameson Cell, to replace the columns. The slag concentrate is now blended with the chalcopyrite copper concentrate to maintain a steady feed quality to the copper smelter.

Case Study 4: Mount Isa Copper Flash Roughing Jameson Cell Pilot Plant Circuit.

Pilot plant trials of copper flash rougher and rougher flotation using Jameson Cells (Figure 17) were conducted during the test work program for the Copper Concentrator Flotation Upgrade Project (Harbort, 2002). This flow sheet is to be implemented as part of phase two of the upgrade.

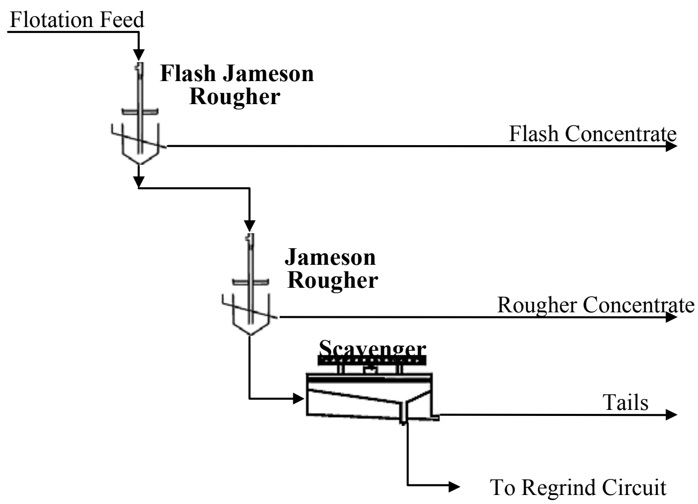

Figure 17: Jameson Cell flash rougher and rougher flotation circuit

The first stage of flash rougher flotation tests targeted a copper recovery of 60% with a concentrate grade of 30%Cu. The test work achieved an average copper recovery of 63.37%, with an average concentrate grade of 29.4%Cu (Figure 18). Eighty percent of test work achieved results better than the targeted recovery although at a slightly lower concentrate grade. These results would allow flash rougher concentrate to be directed straight to final concentrate, unloading cleaner and re-treatment circuits.

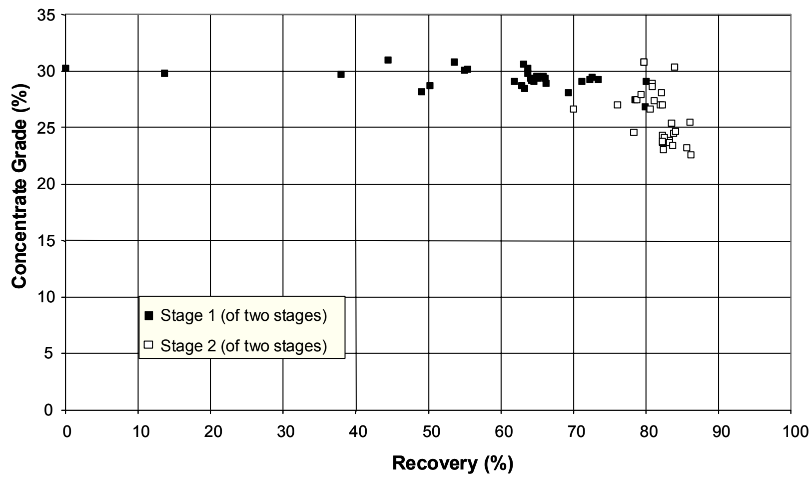

Figure 18: Two-stage Jameson Cell copper rougher test work

The rougher flotation Jameson Cell treating the flash rougher tailing extended the copper recovery to 87%, with a combined rougher/scalper concentrate grade of 25%Cu (Figure 18). This can be compared to the existing rougher flotation cells achieving 17% copper grade at 89% copper recovery. Individually the Jameson Cell copper roughing achieved 60% copper recovery at 15% copper grade. This rougher concentrate would be directed to the cleaning circuit for further upgrading.

An interesting point to note is that the residence time in the Jameson Cell in these duties is approximately 1 minute for each stage.

Under the proposed circuit the two-stage Jameson Cell rougher circuit would replace the current 30-year-old rougher flotation cells. The Jameson Cell rougher tailings would feed the 4x100m^3 WEMCO scavenger flotation banks, that were installed as part of phase one of the upgrade. The scavenger concentrate feeds regrinding circuit, which then goes to cleaner flotation.

High mass recovery is another benefit of the Jameson Cell in a flash roughing duty. At 1000tph at a feed grade of 3.5%Cu, the Jameson Cell produced an average copper recovery of 63.37%, with an average concentrate grade of 29.4%Cu, meaning 75tph of final concentrate is recovered in one stage of flotation using a Jameson Cell.

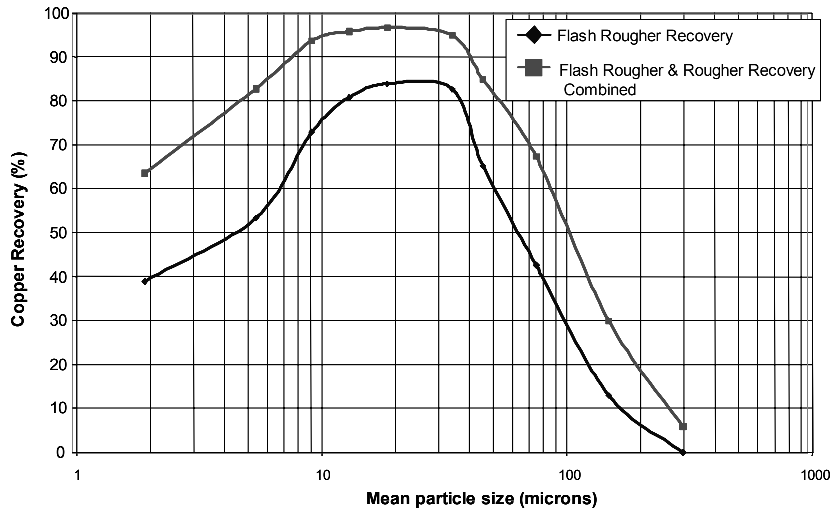

Figure 19: Size-Recovery for the Jameson Cell in copper roughing duty

The size-recovery graph of the Jameson Cells in the copper roughing duty (Figure 19) shows very high recovery of the 9 to 38 micron size fractions. These are the well-liberated fast floating size fractions that should be sent directly to final concentrate. The coarser size fractions are not well recovered as they are poorly liberated and slow floating. They cannot be recovered into a high-grade concentrate without contaminating it and reducing the concentrate grade. The finer, -6 micron, fractions are only moderately recovered as they are also slow floating. The conditions used to reject coarse composites and minimise fine gangue entrainment only allows moderate recovery of these slow floating fines.

The poorly recovered coarse composites and slow floating fines will be recovered in the scavenger circuit and sent to regrinding, where the composites will be liberated and upgraded in the cleaning circuit.

Case Study 5: Minera Alumbrera Cleaner Circuit.

Minera Alumbrera Ltd operates the Alumbrera concentrator in Argentina. Alumbrera was commissioned in 1997 treating a nominal 80,000tpd however following plant expansion in 2003 now treats a nominal 100,000tpd of porphyry gold/copper ore. The concentrator is one of the only concentrators in the world using only Jameson Cells for cleaner circuit flotation.

The original Alumbrera flow sheet (Figure 20) consisted of 2 parallel circuits. Each circuit contained a 13.4MW SAG mills discharging to 2 x 6MW ball mills to achieve a primary grind P80 of 150 microns. Each flotation train consisted of 8 x OK100 flotation tank cells acting as rougher followed by a regrind mill to reduce the cleaner feed size to P_{80} of 37 microns. Cleaning is conducted in two parallel Jameson Cell circuits.

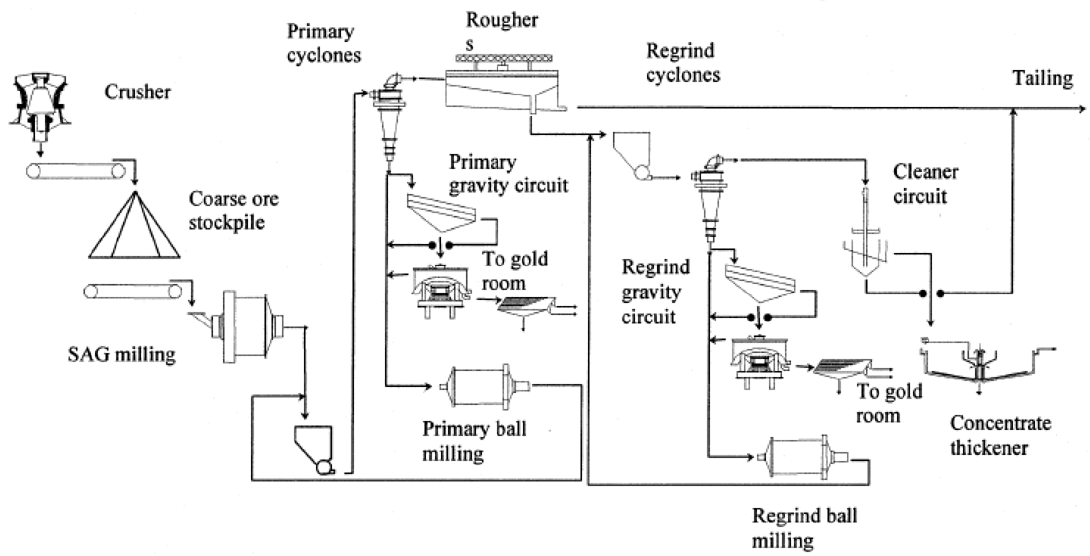

Figure 20: Minera Alumbrera process flow sheet (Harbort *et al*, 2000)

Each cleaning circuit consists of four R5233/12 first cleaners, one R5245/12 re-cleaner and two R5233/12 scavengers as shown in Figure 21. The cleaner concentrate is thickened and pumped via a 312km pipeline to a filter plant in San Miguel de Tucuman from where the filtered product is railed to port for shipment.

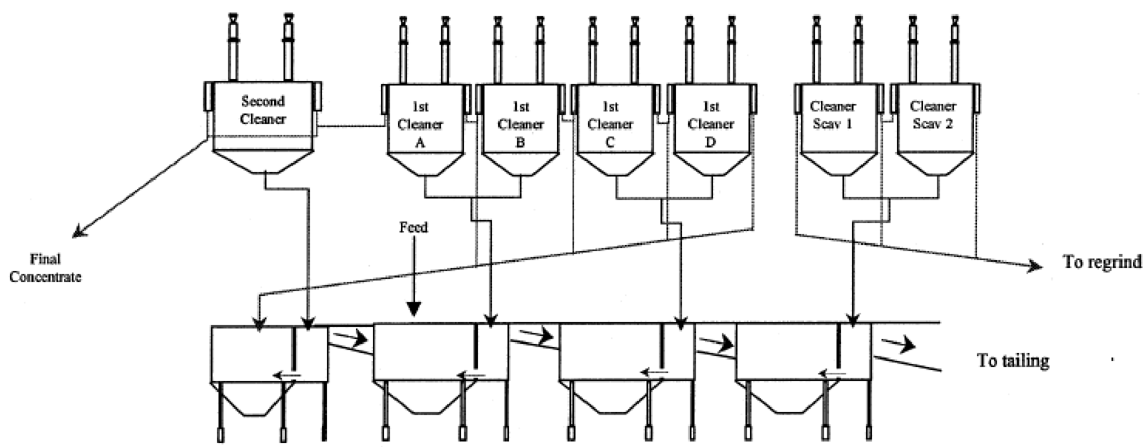

Figure 21: Minera Alumbrera cleaner circuit schematic (Harbort *et al*, 2000)

Post commissioning flotation results showed that copper recoveries from the cleaner circuit in excess of 95% were achievable at average throughputs while the first cleaner A was able to produce final concentrate grade at 70% recovery. (Harbort *et al* 2000).

The size-recovery performance of the copper cleaning circuit is shown in Figure 22. The graph shows good copper recoveries across all size fractions, especially of the coarse grained well liberated chalcopyrite. The chalcopyrite in the final concentrate is 90% liberated, due to coarse-grained mineralisation and good application of regrinding in the circuit.

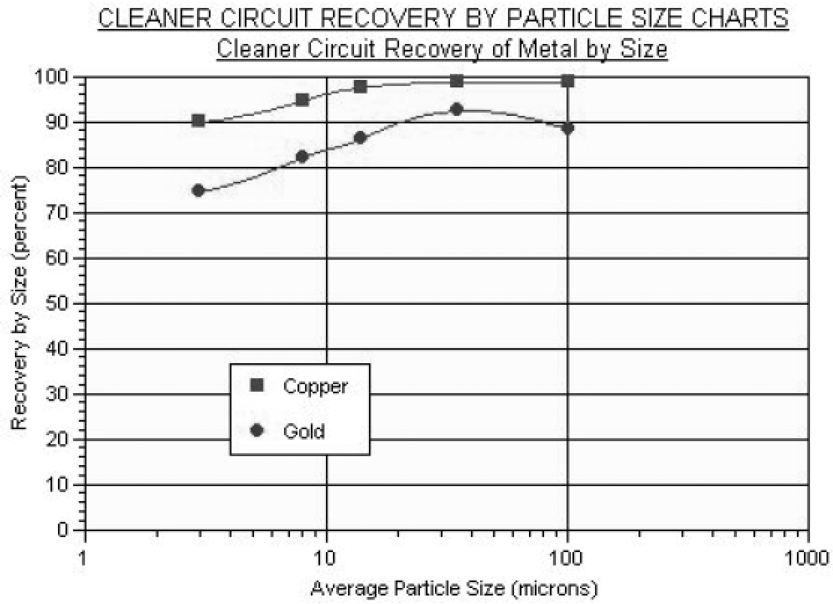

Figure 22: Minera Alumbrera cleaner circuit size-recovery (G&T, 2002)

Since commissioning, throughput in the Alumbrera Concentrator has been increased to over 100,000tpd. This increase in throughput has been facilitated through the addition of a third grinding line and a 50% increase in rougher – scavenger flotation capacity. This upgrade has been completed without any increase in cleaner circuit capacity.

Since start-up the run-of-mine head grade has decreased from 1% copper to 0.5% copper, and consequently the rougher concentrate grade has decreased from 10% copper to 5% copper. The Jameson Cell are achieving double the upgrading ratio compared to the original design showingthe strength of the Jameson Cell to produce high grade concentrate and achieve large upgrading ratios.

The current operating conditions demonstrate the robustness of the Jameson Cell design, as all of Alumbrera's concentrate is being produced by the original Jameson Cells. This does however not mean that there is no room for improvement. With our current understanding of the Jameson Cells and our appreciation of the strengths and weaknesses of conventional and Jameson Cell technology we believe the ideal solution for Alumbrera would have been to back up the Jameson Cells with a few conventional scavenger cells to get the "best of both worlds" and to have a lower cost hybrid circuit. Current proposals are for a new circuit configuration, which will use the existing equipment, to reduce the circulating loads required to achieve the high upgrading ratios to make final concentrate quality. Also proposed is an upgrade of the existing downcomers to reduce wear and improve cell efficiency.

CONCLUSIONS

Since the early 1990s Jameson Cells have had great success in coal and SXEW circuits; however, their application to the base metal industry was hindered by early design features and a lack of understanding of the best way to apply them to the base metal flotation circuit. Over the last decade developments in design and understanding of the strengths, weaknesses and operability of the Jameson Cell have allowed circuits to be designed to make them a very robust choice for base metals.

Jameson Cells can achieve good collection of the high kinetic minerals and achieve exceptionally concentrated grades while minimising entrainment. They are a high intensity flotation machine, where the high shear rates generate small bubbles that selectively collect high kinetic minerals. The small footprint allows economic application of froth washing reducing entrainment and producing high concentrate grades in a single pass. The moderate flotation recoveries generally seen with one Jameson Cell in base metal flotation can be addressed by adding increasing recycle ratios, introducing additional Jameson Cells or backing up the Jameson Cell with conventional flotation cells.

The ideal application for Jameson Cells is often in a hybrid circuit with conventional Cells, delivering better performance at lower cost and in smaller space than either technology can by itself.

While Jameson Cells are ideal for inclusion into new process flow sheets their small footprint and installation height also make them the perfect candidate for plant expansions and retrofits to existing plants. Jameson Cells can be used to improve the flotation performance in an existing plant and are a cheap expansion option.

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