

# BENEFITS OF HIGH INTENSITY FLOTATION AT THE HEAD OF BASE METAL FLOTATION CIRCUITS

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## ABSTRACT

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The Jameson Cell is a high intensity flotation device, which utilises induced air from atmosphere. It was developed jointly by Mount Isa Mines and Prof. GJ Jameson of the University of Newcastle in the 1980's. It is proven to generate fine bubbles, in the order of 300 to 500µm, in a high intensity, high shear and compact zone contained in the downcomer. This aerated mixture exits the downcomer into the pulp zone, which is the quiescent mineral and gangue separation zone.

Preflotation is the process where some of the readily floatable gangue material is recovered directly to tailing with minimal valuable mineral contamination. This can be done in a reverse flotation stage where the valuable mineral is suppressed and the naturally hydrophobic gangue material is floated off. Eliminating a portion of the gangue before it enters the downstream circuit reduces required flotation capacity and improves ease of valuable mineral recovery. It is a very effective and low cost method of expanding flotation capacity and improving overall circuit performance.

Scalping is the process where a final grade concentrate is produced in the roughing circuit. The scalper concentrate typically consists of well liberated and fast floating minerals. Valuable mineral which is not recovered in scalping is treated in the remainder of the circuit where it is floated as a lower grade concentrate and upgraded and recovered in the cleaner circuit. The removal of the liberated mineral prior to a regrinding stage allows the regrind and cleaning circuits to be designed and operated more appropriately to the middling material.

A number of Australian base metal flotation circuits feature a reverse flotation stage at the head of the circuit. Test work and plant operating data has shown that the use of a Jameson Cell in the prefloat cleaner application has further improved prefloat gangue recovery and selectivity. Operation of a Jameson Cell in a carbonaceous/pyrite prefloat cleaner duty at the Mt Isa copper concentrator increased copper recovery and reduced pyrite in the copper concentrate. Testwork at Zinifex Century Zinc Mine showed a decrease in zinc losses by the utilisation of Jameson Cell prefloat cleaner. Appraisal of a Jameson Cell in a scalping role within the Mt Isa Copper Concentrated indicated significant benefits could be achieved.

## INTRODUCTION

### The Jameson Cell

The principles of Jameson Cell operation have been discussed by numerous authors including Jameson (1998), Jameson et al (1998) and Evans et al (1995). Recent developments have been reviewed by Harbort et al (2003) and Carr et al (2003). Operation can be described with reference to Figure 1.

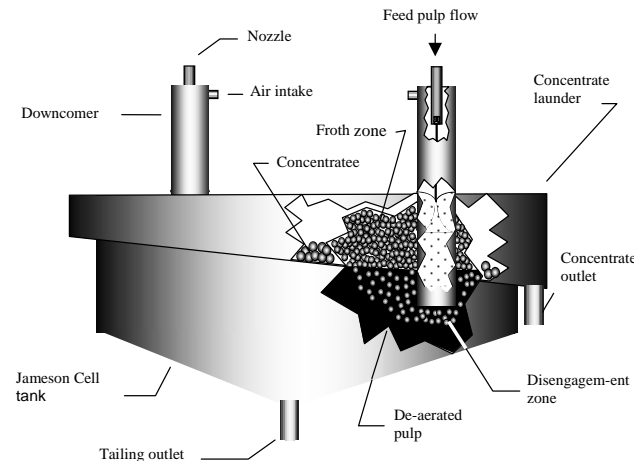


Figure 1. Jameson Cell Schematic

The operation of the Jameson Cell can be divided into three main zones:

The downcomer where primary contacting of bubbles and particles occurs. Feed slurry is pumped into the downcomer through an orifice plate, creating a high-pressure jet. The plunging jet of liquid shears and then entrains air, which has been naturally aspirated. Due to a high mixing velocity and a large interfacial area there is rapid contact and collection of particles.

The tank pulp zone where secondary contacting of bubbles and particles occurs and bubbles disengage from the pulp. The aerated mixture exits the downcomer and enters the pulp zone of the flotation tank. The velocity of the mixture and large density differential between it and the remainder of pulp in the tank results in recirculating fluid patterns, keeping particles in suspension without the need for mechanical agitation.

In the froth zone, gangue material that is entrained in the froth is removed by froth drainage and/or froth washing.

### Applications at the head of base metal flotation circuits

#### *Preflotation*

Preflotation is the process where the bulk of the readily floatable gangue material is recovered directly to tailing with minimal valuable mineral contamination. Typically, the hydrophobic gangue material is floated and the entrained valuable mineral is removed by froth washing. Eliminating a portion of the gangue before it enters the downstream circuit reduces required flotation capacity and improves ease of valuable mineral recovery. It is a very effective and low cost method of expanding flotation capacity and improving overall circuit performance.

Periodically amounts of naturally floatable species of carbonaceous pyrite and talc occur in ore bodies of the northwest Mining Province of Queensland. Their presence if untreated results in contamination of final concentrate. Talc in particular has detrimental down stream affects, causing an increase in smelter slag viscosity and higher metal losses to slag. Historically, treatment has consisted of flotation, followed by depression, often with ambiguous results Hoffman et al (1965) and Lyon et al (1971). Investigation by Grano et al (1990) identified the natural floatability of carbonaceous pyrite.

Also present in northwest mining area of Queensland is a host rock of carbonaceous shale. A carbon preflotation stage is required to remove the organic carbon from downstream flotation stages.

Use of preflotation prior to roughing is increasingly considered a viable alternative to the flotation/depression route.

### *Scalping*

Scalping involves producing a final grade concentrate in the roughing circuit. Although not a new concept in flotation, the high selectivity and rapid collection kinetics of the Jameson Cell enables the separation to be achieved with enhanced economics Gray et al (1998). Following scalping the valuable mineral remaining in the circuit is floated as a lower grade concentrate that is then upgraded the cleaner circuit. The removal of the liberated mineral prior to a regrinding stage allows the regrind and cleaning circuits to be designed and operated more appropriately to the middling material. This allows a greater efficiency of separation of composite particles. Minimising the quantity of regrinding decreases slimes generation and reduces the losses that inevitably result from their presence. Also, the shorter residence time of mineral in the flotation circuit means the less likely the oxidation of the mineral surface.

## **Case Study Sites**

The Mount Isa Mines Copper Concentrator and the Zinifex Century Zinc Concentrator were used to evaluate the benefits of the Jameson Cell at the head of the flotation circuit. A brief description of the operations is given below.

### *Mount Isa Mines Copper Concentrator*

Chalcopyrite ore and converter slag are treated to produce copper concentrate at the Mount Isa Mines Copper Concentrator. The concentrator was commissioned in 1973, replacing the original No. 1 lead-zinc concentrator, for the processing of all the chalcopyrite ore coming from Mount Isa mine Lumsdaine et al (1980).

At present production ore is sourced from the southern 1100, 3000 and 3500 orebodies. Currently 50% of mill feed is from the 3000 and 3500 orebodies. Chalcopyrite is the only significant copper mineral and occurs as a replacement deposit in a silica-dolomite host rock. Sulphide gangue consists of pyrite ( $\text{FeS}_2$ ) and minor amounts of pyrrhotite and cobaltite. The ore averages 8% sulphur. The current flowsheet is shown in Figure 2.

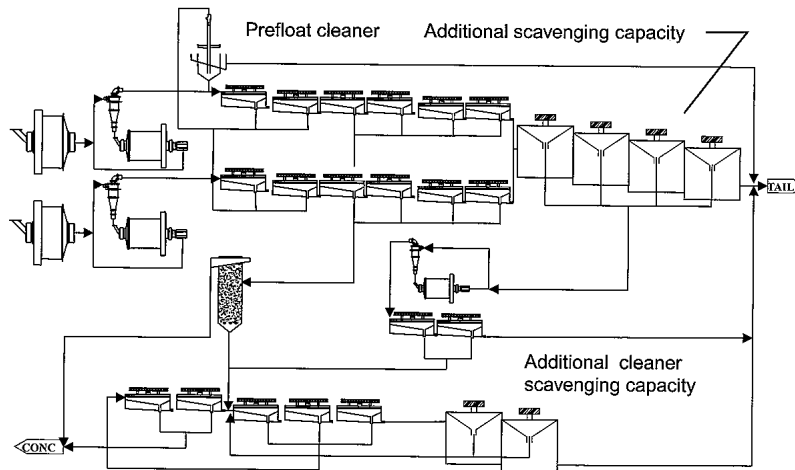


Figure 2. Mount Isa Mines Copper Concentrator Flowsheet

Future ore production will draw increasingly larger tonnages from the 3000 and 3500 orebodies. The host rock is very similar to that of the 1100 orebody but is slightly more siliceous in nature. Silica assays range from 60 to 70%  $\text{SiO}_2$  and the ore is both abrasive and hard with a current Bond Work Index of approximately 22kWh/t. Copper mineralisation is disseminated through the silica-dolomite. Mineralogical examination indicates liberation of chalcopyrite is about 75% at a  $P_{80}$  of 150 $\mu\text{m}$ . Flotation feed sizing is normally in the range 80% passing 150 $\mu\text{m}$ , depending on milling rate and ore type.

Over time there has been an increase in the amount of naturally floatable species of carbonaceous pyrite and talc in ore. This would normally decrease concentrate grade for a given recovery; however at the same time the concentrator has been required to increase concentrate grade from 25% to 27% Cu. A preflotation circuit to remove naturally floating species has been necessary to achieve this, Carr et al (2003).

### Zinifex Century Mine

The concentrator at Zinifex Century Mine produces a zinc and lead concentrate. The flotation circuit consists of carbon prefloat, lead flotation, zinc primary flotation, ultra fine milling, zinc ultra fine flotation Burgess et al (2003). Figure 3 shows the concentrator flowsheet at Century.

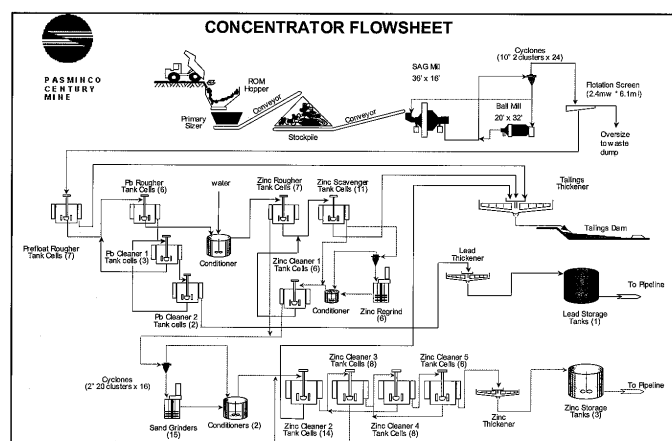


Figure 3. Zinifex Century Zinc Concentrator Flowsheet

Currently the carbon prefloat stage consists of a bank of roughers. The function of the carbon prefloat roughers is to remove a portion of carbon from the feed before it enters the remainder

of the circuit, the aim being to prevent downstream contamination of concentrates and reduce the demand for flotation reagents. Prefloat rougher concentrate is pumped to final tailing. The pfloat rougher tailing gravitates to the lead circuit. Recently zinc losses to the throwaway pfloat concentrate has been identified as an area for improvement. Research into the preflotation of circuit has shown that zinc losses are in the form of fine entrained sphalerite that is carried with water into the froth.

## Discussion

### *Prefloat duty at Mount Isa Mines*

Work on a pilot scale Jameson Cell for one stage preflotation and for preflotation cleaning had been performed over a number of years. A series of pilot tests were conducted in 2000 to confirm parameters for engineering design. A full scale Jameson Cell was installed in 2002 in the copper concentrator to upgrade the rougher pfloat concentrate and minimise copper losses from the circuit Carr et al (2003).

The optimum Jameson Cell pfloat cleaning operating conditions were found to be:

- Wash water ratio between and 0.5 and 1.0
- Feed percent solids 20%
- Jg - 1.25cm/sec
- Air-to-pulp ratio between 0.44 and 0.82
- Froth depth – 150mm to 400mm

Figure 4 shows total talc recovery versus copper rejection from concentrate for the commissioning period, the original test work and for bench scale tests taken during commissioning, respectively. Target performance was to achieve a copper rejection of 90%, at a talc recovery of 70%. The upper envelope for commissioning surveys indicates a minor shortfall from this point, with an interpolated copper rejection of 90% at a talc recovery of approximately 67%. At 90% copper rejection talc recoveries of 50% and 47% were achieved in the bench scale tests and original test work respectively.

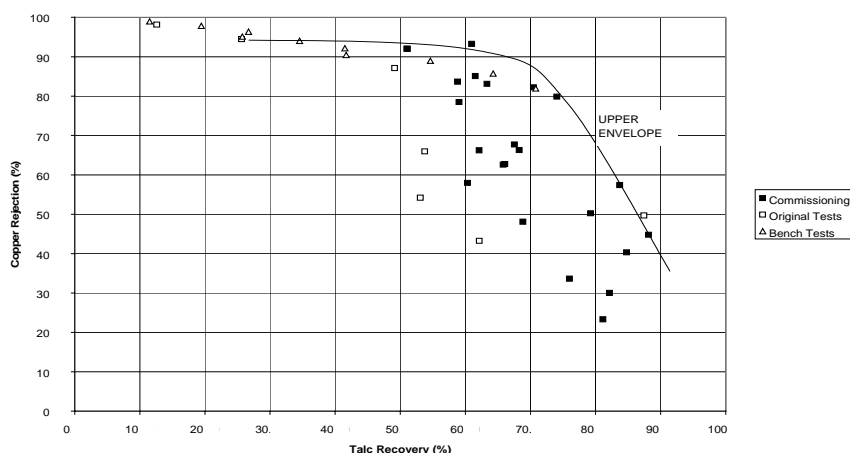


Figure 4. Talc Recovery versus Copper Rejection at Mount Isa Mines Copper Concentrator

Figure 5 shows total  $\text{FeS}_2$  recovery versus copper rejection from concentrate for the commissioning period, the original test work and for bench scale tests taken during commissioning, respectively. Targeted performance was to achieve a copper rejection of 90%, at an  $\text{FeS}_2$  recovery of 50%. The commissioning surveys indicate a shortfall from this point, with a copper rejection of 90% at an  $\text{FeS}_2$  recovery of only 17%. At 90% copper rejection  $\text{FeS}_2$  recoveries of 30% and 28% were achieved in the bench scale tests and original tests respectively. The commissioning results show a strong linear relationship between copper rejection and  $\text{FeS}_2$  recovery indicating some degree of carbonaceous chalcopyrite being present and also  $\text{FeS}_2$  recovery gains being due to entrainment rather than true flotation. There is some initial evidence that carbonaceous pyrite that did not float within

the Jameson Cell has not been refloated in the prefloat roughers and does not report to final concentrate.

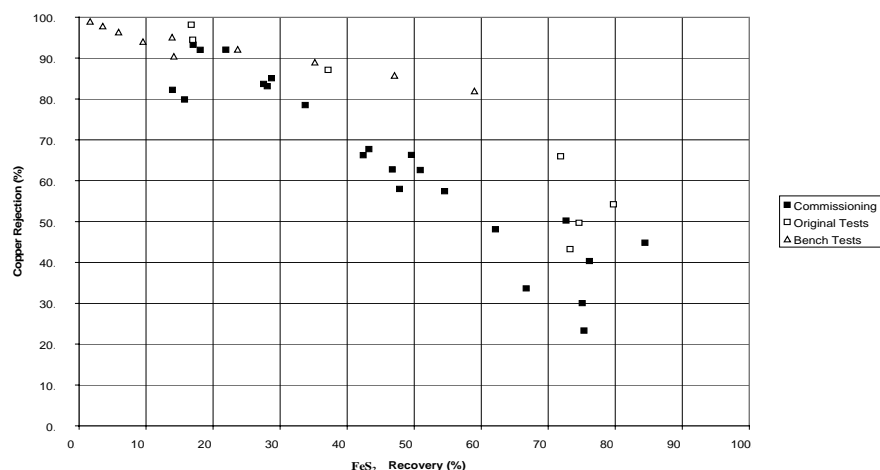


Figure 5. Pyrite Recovery versus Copper Rejection at Mine Isa Mines Copper Concentrator

A review of earlier analysis by Grano et al (1990) indicates that significant amounts of pre-aeration in bench tests results in a decrease in carbonaceous recovery and in an increase in chalcopyrite recovery. This same phenomenon is seen to be occurring within the Jameson Cell, although with the high aeration and turbulence within the downcomer it is happening in a much shorter time.

The most obvious explanation for the lack of pyrite recovery in the prefloat cleaner is surface passivation by iron hydroxides. Should this be occurring it is possible that the pyrite will not be refloated in the remainder of the circuit. A review of pyrite in feed versus pyrite in concentrate, Figure 6, indicates that even with the lower Jameson Cell pyrite recovery the amount of pyrite reporting to final concentrate has decreased following the Jameson Cell installation. This suggests that pyrite did not float in the remainder of the circuit either.

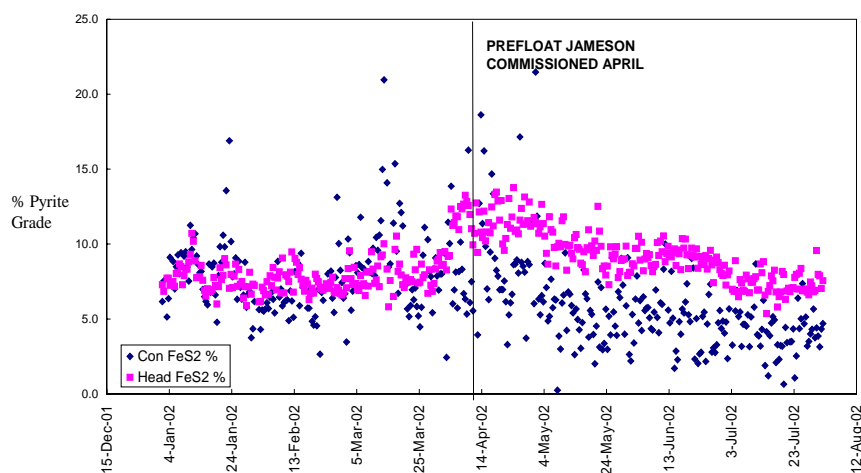


Figure 6. Pyrite Levels in Feed and Concentrate pre and post Jameson Cell installation

### *Preflotation duty at Zinifex Century Zinc Mine*

In October 2002 a L500 Jameson Cell pilot plant rig was installed in the concentrator at Zinifex Century Zinc Mine, Pokrajcic (2003). The aim of the test work was to minimise zinc losses to carbon prefloat concentrate while maximising carbon removal by using the Jameson Cell as a prefloat cleaner. The majority of zinc losses are in the form of fine sphalerite entrained in the preflotation rougher concentrate.

Periodic test work conducted from October 2002 to January 2003, concentrated on appraising the Jameson Cell in a carbon prefloat cleaning duty.

Optimum Jameson Cell operating conditions in a prefloat cleaner duty were found to be:

- Feed percent solids between 7% and 8.5%
- Tailing Recycle at 55%
- Air to pulp ratio (APR) between 0.58 and 0.85
- Superficial air velocity (Jg) between 0.65 and 0.9 cm/s
- Jet Velocity of 13.0 m/s
- Zero wash water

When optimised the Jameson Cell in a prefloat cleaning duty reduced the overall zinc recovery to final tailing from approximately 4.5% to less than 2.0% while maintaining a carbon recovery to final tailing close to 10%. Figure 7 shows all the data generated in the test program, highlighted is the data showing best performance.

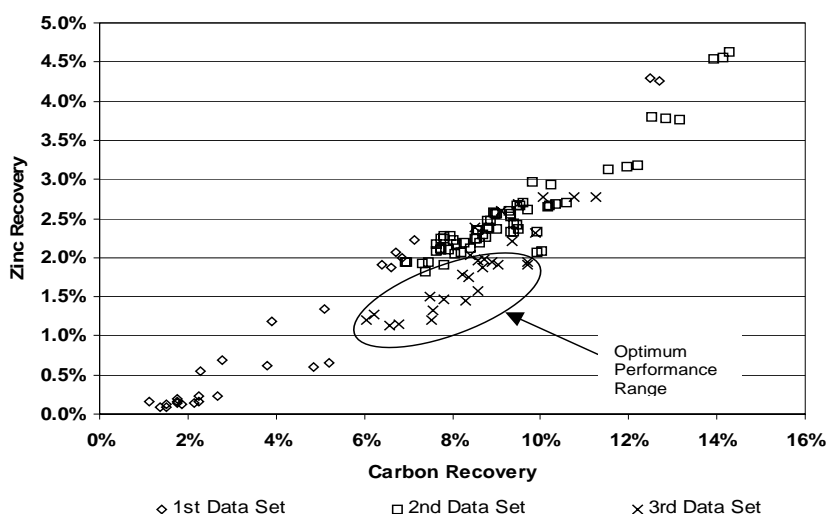


Figure 7. Overall Carbon and Zinc Recovery for the carbon Prefloat Circuit when using a Jameson Cell as prefloat cleaner.

Reducing the feed density from approximately 18% solids about 8% solids and increasing the tailing recycle had the most significant effect on selectivity without compromising rejection. This is due to the effect of reducing entrained sphalerite losses. Hence a significant reduction in zinc losses to the throwaway concentrate can be achieved with a small reduction in carbon recovery by the addition of a Jameson Cell prefloat cleaner.

### *Scalper duty at Mount Isa Mines*

In February 2000 an L500 Jameson Cell pilot plant rig was installed in the copper concentrator at Mount Isa Mines to assess the Jameson Cell performance in prefloat and slag cleaning duties. Results from the slag cleaning work on converter slag produced high mass recovery per flotation surface area and indicated that some potential existed for the Jameson Cell in a chalcopyrite roughing role.

In July 2000 a series of sighter tests which were not optimised were conducted on rougher feed material to determine if similar production rates were achievable with a chalcopyrite ore feed. The chalcopyrite tests were extended to produce a comprehensive Jameson Cell grade recovery curve. This work showed that the potential did exist to operate the Jameson Cell as a scalper, producing final concentrate from rougher feed. In late 2002 the pilot unit was continuously operated at optimised conditions to check stability of operation and reproducibility of results under variable feed conditions. A second Jameson Cell was installed in series as a scavenger to determine whether scalping would have a detrimental effect at the higher recovery section of the grade recovery curve.

Optimum operating conditions for the Jameson Cell in a scalper duty were found to be:

- Wash water ratio between 0.5 and 1.5
- Feed percent solids between 35% and 45%
- Jg between 0.7 and 0.8cm/sec
- Air-to-pulp ratio between 0.32 and 0.38
- Froth depth – 150mm

An interesting point to note is that the residence time in the Jameson is approximately 1 minute.

An overview of the scalping grade recovery curve is shown in Figure 8. These results include all tests undertaken, including non-optimised tests. Operation of the Jameson Cell in a chalcopyrite scalping role produced a concentrate grade of 29.6%Cu at up to 80% copper recovery.

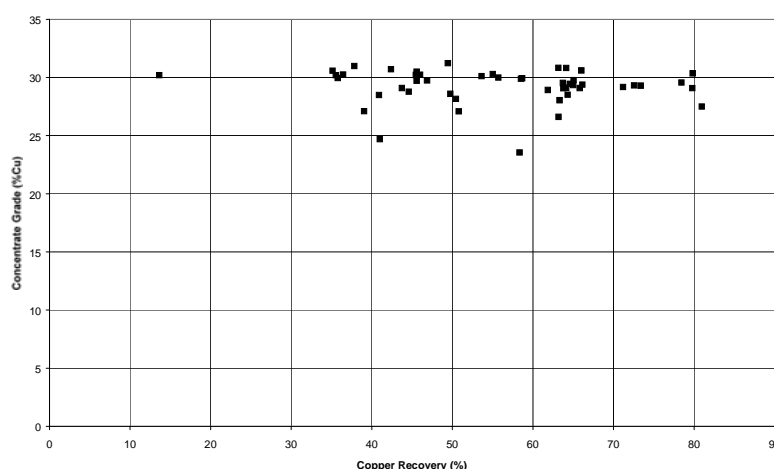


Figure 8. Scalper Testwork at Mount Isa Mines Copper Recovery verses Copper Grade

For the reproducibility tests a copper recovery of 60% with a concentrate grade of 30%Cu was considered an acceptable target. The reproducibility tests achieved an average copper recovery of 63.37%, with an average concentrate grade of 29.4%Cu. Eighty percent of tests achieved results better than the targeted recovery although at a slightly lower concentrate grade.

High mass recovery is another benefit of the Jameson Cell in a scalper duty. At 800tph at a feed grade of 3.5%Cu as mentioned previously the Jameson Cell produced an average copper recovery of 63.37%, with an average concentrate grade of 29.4%Cu, meaning 56tph of final concentrate is recovered in one stage of flotation using a Jameson Cell.

## Conclusion

Preflotation is the process where the bulk of the readily floatable gangue material is recovered directly to tailing with minimal valuable mineral contamination.

Scalping is the process where a final grade concentrate is produced in the roughing circuit.

Both of these steps exploit the fast kinetics and well liberated properties of the gangue or valuable mineral. The Jameson Cell is particularly suited to such a duties because of it high intensity mixing of bubbles and slurry and relatively low tank residence time.

The addition of a prefloat and/or scalping stage is a very effective and low cost method of expanding flotation capacity and improving overall flotation circuit performance. For instance:



1. Eliminating a portion of the gangue before it enters the remainder of the downstream circuit reduces required flotation capacity.
2. Removal of liberated mineral prior to regrind allows the regrind and cleaning circuits to be designed and operated more appropriately for the middling material.
3. Reducing the amount of material going to regrind minimises slimes generation and the losses that result from their presence. It also decreases the mineral residence time in the flotation circuit, thereby decreasing the likelihood of mineral oxidation.

Test work and plant operating data has shown that the use of a Jameson Cell in a prefloat and/or scalper duty has improved the performance and efficiency of the flotation circuit. At Mount Isa Mines a Jameson Cell in a prefloat cleaner application increased copper recovery and reduced pyrite in the copper concentrate. Test work at Zinifex Century Zinc Mine showed a decrease in zinc losses by the application of a Jameson Cell as a prefloat cleaner.

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