HOW TO DEVELOP A SCALABLE JAMESON CONCENTRATOR FROM CLASS 5 – CONCEPT LEVEL TESTWORK

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ABSTRACT

As a Jameson Cell and IsaMill™ supplier, Glencore Technology combined these two high-performer and well proven technologies in 2020 to produce a complete flotation/regrind circuit design designated the Jameson Concentrator. The sizing process for this concentrator can be based on the industry-leading, process-guaranteed, 1:1 scale-up bench-scale dilution cleaning test – particularly useful when sample quantity is difficult for pilot scale work. Combining this test with the IsaMill™ technology database (modified through readily available calculators) enables a pathway to design a concentrator with minimal sample investment. The authors of this paper will describe how you can execute this and include it in early project trade-off studies.

This paper will showcase the ease with which a mass balance and equipment sizing for an AACE Class 5/4 (±35%) Concept study can be generated and demonstrate the scalability of the dilution cleaning test and IsaMill™ database. This will be done using a 25 kg copper sample as a case study to illustrate how the design of a scalable Jameson Concentrator can be achieved at a bench-top laboratory level.

INTRODUCTION

As the global supply of high-grade, easily floatable ore bodies continues to decline, mining companies are increasingly forced to turn to low-grade, finely disseminated ore bodies, which are far more difficult to recover using mechanical flotation cell technology. Until recently, the solution to low-grade ore bodies has been the construction of ever larger flotation cells, which provide increasingly more residence time to compensate for the inefficiencies of the contacting environment (Anderson et al, 2022). It is counterintuitive to build larger equipment as the industry pivots towards a more carbon-reducing mindset. By leveraging the significant benefits of the Jameson Cell technology, an alternate concentrator design approach can be utilized: the Jameson Concentrator.

Anderson et al (2023) published a comparison between a conventional concentrator and Jameson Concentrator design utilizing the AACE Class 4 framework. The key findings showed improvements in overall project economics and environmental impact when choosing the Jameson Concentrator. Significant savings in concrete, steel, and power consumption were shown as the largest benefits. The findings translated into a 56% reduction in construction phase emissions and a 36% reduction in operations phase emissions per annum. These carbon footprint savings have fueled signficant interest in this technology for full flotation flowsheet development.

This paper will demonstrate how a scalable 1:1 testwork program can be included in concept-level testwork (dilution cleaning tests) with minimal sample investment to investigate the performance of the Jameson Concentrator circuit in early AACE Class 5/4 (±35%) equipment trade-off studies.

DILUTION CLEANING CURVE – BENCH SCALE

The dilution cleaning test (or “infinite dilution cleaning test”) aims to mimic a bench scale evaluation of the grade/recovery curve with no hydraulic entrainment of hydrophilic unwanted mineral particles. The results from this test show the effect of an extremely low-density flotation system (“infinite“ dilution cleaning), which is believed to approach the maximum theoretical separation.

This test uses standard small lab-scale mechanical flotation cells to make small bubbles within a high-shear environment. The test maintains a frother concentration at the critical coalescence concentration (ccc) to ensure fine bubbles are sustained (to simulate Jameson Cell bubbles). Results from these tests can be used to assess the amenability of the Jameson Cell flotation technology to improve concentrate grade in the flotation system being studied. The generated grade recovery curves from dilution cleaning testing scale 1:1 to full-scale industrial installations, as shown in Figure 1.

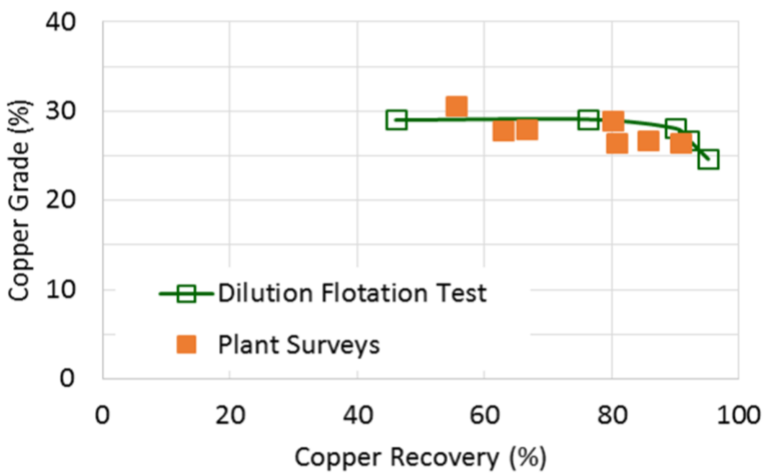


Figure 1: Cleaner Scalper Survey - Mt Isa Mines Copper Circuit

While the dilution cleaning test will forecast the potential performance of a Jameson Cell, there are limitations and considerations that need to be considered. Since bench-scale tests utilise conventional mechanical cell mechanisms, actual performance in Jameson Cells for some minerals can be higher. While the bench-scale simulation identifies the benefits of wash water and reduced entrainment to concentrate, this does not translate to demonstrating the benefits of fast flotation kinetics. Minerals such as gold etc, have surfaces that can tarnish quickly. Only technology with fast bubble-particle interaction can recover these particles, such as the Jameson Cell. This type of behaviour has been exhibited in Figure 2.

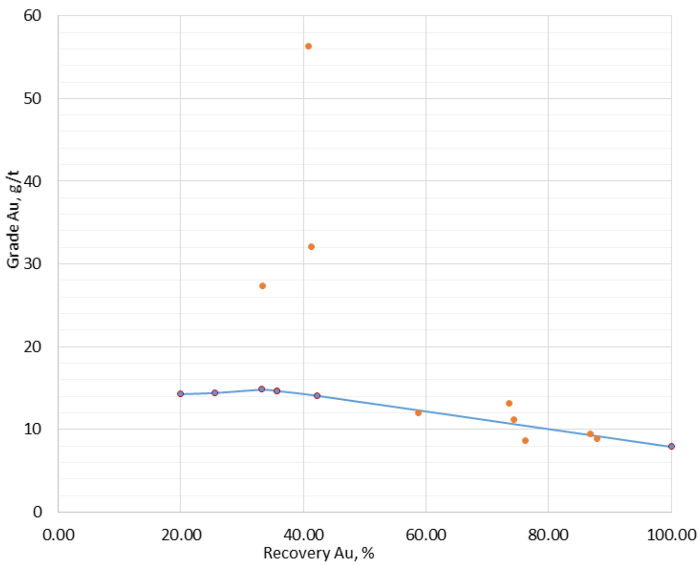


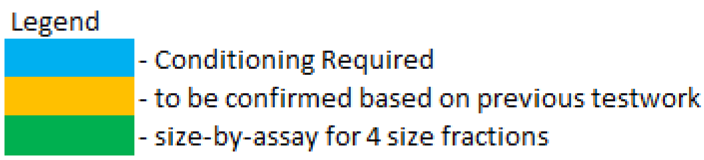
Figure 2: Gold Dilution Test (Blue Line) v Rougher Scalper Surveys (Orange)

CONDUCTING A TESTWORK PROGRAM

Typically, in a bench-scale testwork program, a series of conventional rougher tests and cleaners will be conducted as part of the initial program. Selecting the operating points from this scoping work, development of a testwork program that can be used to design a scalable Jameson Concentrator is possible. For example, initial grind size, regrind size and reagent dosing (e.g., collectors, depressants etc.) can be transferred to a full flowsheet program.

Typically, the ore selection for these tests (utilising a copper base case) would be a composite of the first seven years of the mine life. If additional sample is available, variability testing of high and/or low grade composites can be used to more accurately establish the plant operating envelope.

For the purposes of this exercise, we will assume 25 kg of sample is available, an expected ~10% mass pull is taken, and show how the data can be interpreted to size a full circuit Jameson Concentrator. When reviewing the programs, please use the following legend:



TEST 1 - ROUGHER DILUTION TESTS (1-2KG)

The rougher dilution test is typically done with 1 to 2 kg of material that is slurried to a prepared grind size (e.g 106 microns) and at a density of ~35% solids (w/w). This is then added to a lab-scale mechanical flotation vessel suitable for the sample size. The flotation is then run to sample extinction (no more concentrate being collected) whilst the time is recorded. This time is known as T1.

The concentrate is then collected into "Stage 1 Feed" and is diluted down to roughly 10% solids (w/w) at the ccc point and floated in a suitably sized flotation vessel. The material is then floated for 7/8ths the time of T1 and concentrate is collected ("Stage 2 Feed"). The concentrate will then be put back into the same flotation vessel as Stage 1, diluted to the lip and then floated for 6/7ths the time of T1. During this time, kinetic samples are collected. The maximum time for the first three concentrates is recommended to be collected at Conc 1- 30 secs of the total time, Conc 2 – 1 min of the total time, Conc 3- 2 min of the total time. This process of testwork is illustrated in Figure 3.

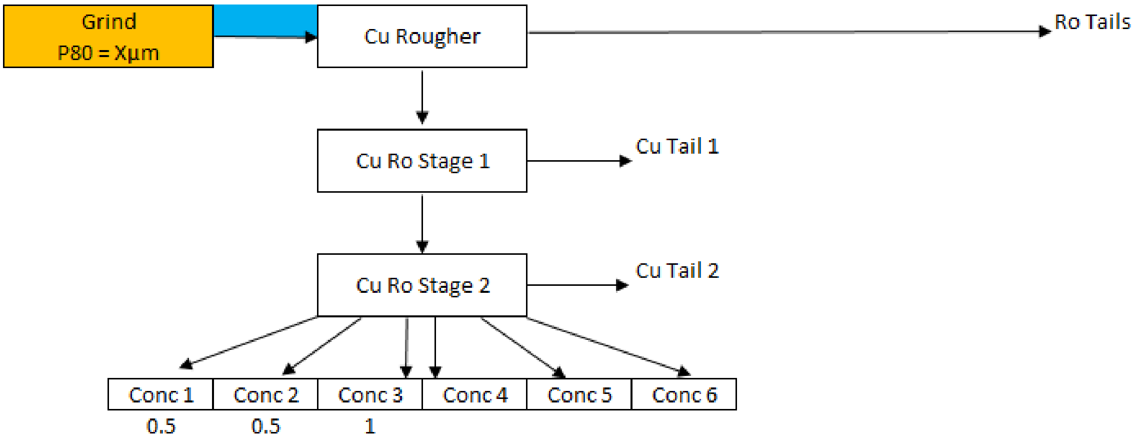


Figure 3: Dilution Test on a Rougher Feed

A grade recovery curve can be developed by assaying the kinetic and the tails samples of Cu Ro Stage 1,2 and Copper Rougher. Conducting the kinetic sampling will allow the operator to evaluate scalping opportunities (taking the concentrate directly to final product) and identify the potential influence of entrainment to the conventional tests. An important note in the dilution cleaning test is that since the test is floated to extinction (residence time does not factor into the sizing of Jameson Cells), the overall rougher recovery will always be at least the same as a standard conventional cell. Higher concentrate grades will be achieved from the simulated froth washing effect at a selected recovery point; an example of this relationship is seen in Figure 4

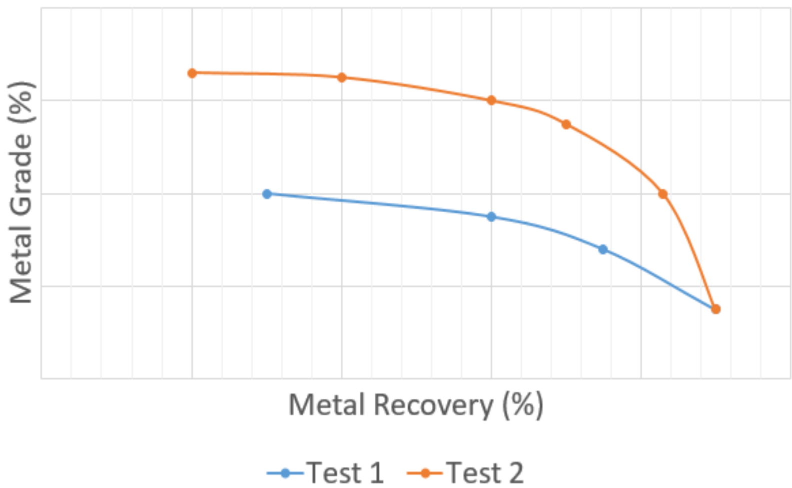


Figure 4: Conventional Test (Test 1) v Dilution Cleaning (Test 2)

Monitoring Eh and pH throughout the test and ensuring frother concentrations and pH stay maintained through the test design is important. As with any bench-scale flotation test, chemistry limitations need to be considered throughout the test:

1. Highly reactive sulphides can change their kinetic performance through cleaning stages, demonstrated by a "flattening" of the grade-recovery curve. pH should be maintained throughout the dilution stages. To mitigate variations, it is suggested to pre-dose the makeup and spray water to keep the pH targets.
2. Dilution itself will affect the frother concentration in the slurry. Without sufficient frother, it won't be possible to simulate the bubble size. It is recommended to pre-dose the makeup and spray water to ensure the correct frother concentration.

TEST 2 - ROUGHER BULK RUN + CLEANER DILUTION TEST

When considering cleaner tests (particularly those in copper duties), a primary limitation is the mass pull and generation of sufficient sample mass to conduct the test. Typically, in copper applications, a concentrate mass pull of 8-10% are seen, meaning about 22 kg is required to be processed through a flotation vessel to get enough material to run the test. Since the rougher portion of this particular test is about generating concentrate through floating to extinction, a standard pilot tank cell or L150 Jameson Cell (laboratory scale) can be used.

Once a concentrate is collected, it can be reground through any laboratory scale mill (rod mill is typically preferred) to produce a flotation feed for the cleaner test (P_{80} of the Rod Mill is determined from previous work). Once the new conditioned cleaner circuit flotation feed is available, the same dilution cleaning process utilised in the rougher test (Section 2.1) is executed, utilising a feed density of less than 25% solids (w/w).

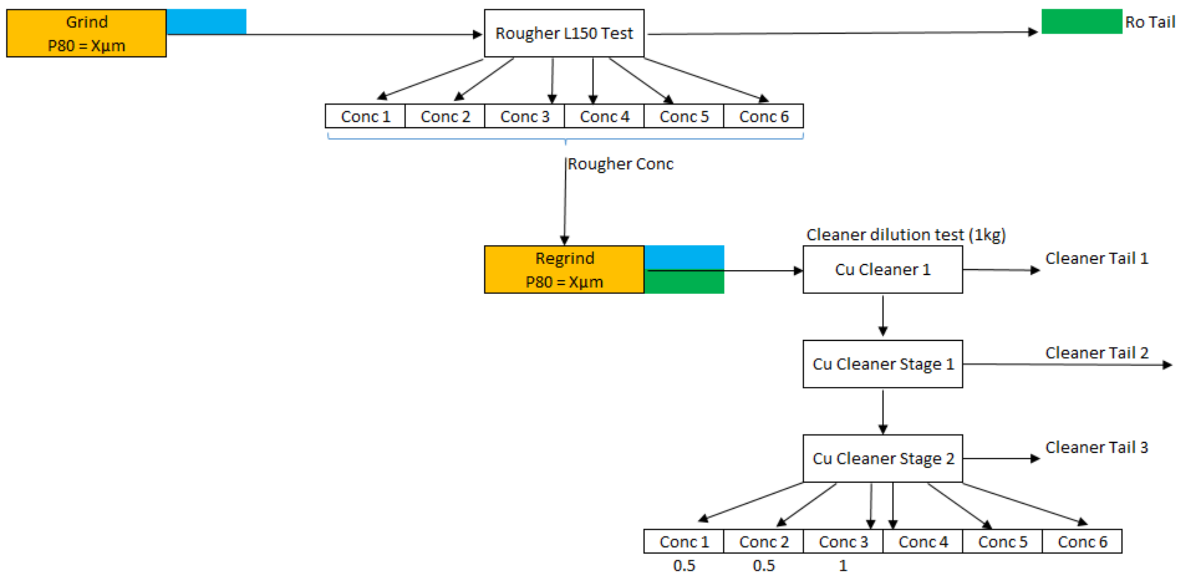


Figure 5: Dilution Test on the Cleaners

The results from this dilution test will show the true grade-recovery curve for the cleaner block and identify whether a cleaner scalper (taking the concentrate directly to final product) can be considered for the design process. For good design practices, size-by-size assays are recommended on the rougher tails and cleaner feed to validate the liberation size for the cleaner feed and determine the mechanism for rougher tails losses.

CIRCUIT SIZING CONSIDERATIONS

With the testwork completed, the dilution tests produce a grade recovery curve for the rougher-scavenger and cleaner circuits. It is possible to take this data and size a circuit comprised of Jameson Cells and IsaMill™s. There are some key considerations when selecting the equipment:

- Jameson Cells are sized on two areas, carrying capacity and volumetric flow.
- Since particle bubble contact occurs within the downcomer (the tank is simply a device to allow separation of air bubbles from gangue slurry), there is no need to size based on the probability of particle/bubble collisions, and residence time does not need to be considered.

- The IsaMill™ (regrind mill of choice for the Jameson Concentrator) is also sized on two areas; specific energy (kWh/t) and volumetric capacity.

JAMESON CELL - CARRYING CAPACITY

Carrying capacity refers to the mass of concentrate (tph) a Jameson Cell (or any other flotation equipment) can recover based on the concentrate surface area available (m^2). Typically, Jameson Cells are sized such that the duty of the cell is between 40-80% of the carrying capacity model limitation. If lower than 40%, the use of froth crowders may need to be considered.

The carrying capacity model applied to the Jameson Cell is:

$$C_a = 522.54\, d_{50}^{-0.542} \sigma^{0.2} \frac{n_p\, d_{50}^3\, \rho_p}{d_b^3} J_g \,,$$

Figure 6: Carry Capacity Model (Patwardhan and Honaker, 2000)

Where d_{50} is the mean particle size, n_p is the number of particles covering the bubble of size d_{50}, σ is the size distribution modulus, d_b is the bubble diameter, and J_g is the superficial gas velocity in cm/s.

Jameson Cells are renowned for high carrying capacities and have been reported to be considerably higher than columns and conventional flotation cells, which in industry are typically designed in the range 0.8-1.2 t/h/m^2. The greater carrying capacity in the Jameson Cell is from a combination of smaller bubble size, high contact efficiency and high froth recoveries due to a quiescent zone for froth recovery and small tank volumes and residence time (Lawson, 2016). Carrying capacity is the most important consideration when designing a flotation circuit. It is also important to note that ultra-fine bubble sizes can cause viscosity issues, which results in poor froth washing performance, the removal of tenacious froth from the launders, and pumping challenges. The Jameson Cell purposely generates bubble sizes that maximises carry capacity and recovery, without sacrificing grade and plant operability.

JAMESON CELL - VOLUMETRIC FLOW

The cell sizing is done based on satisfying a tailings recycle constraint for plant stability. As a portion of the tails is recycled as part of the design, cell sizings are typically done to ensure that recycle rates sit in the following regions:

- 10-20% for roughers and scavengers.
- 30-80% for cleaners/scalpers

ISAMILLS™ – SPECIFIC ENERGY

The IsaMill™ Signature Plot generates the specific energy for a defined reduction in particle size on a given sample. Typically, a Signature Plot™ is done with a 4-litre lab scale IsaMill™ by an accredited laboratory. Results scale up 1:1 with full-scale installations, as demonstrated in Figure 7, as power input is measured (rather than inferred from torque measurements), and conditions are kept the same (same ore type, size, media size/density, operating density).

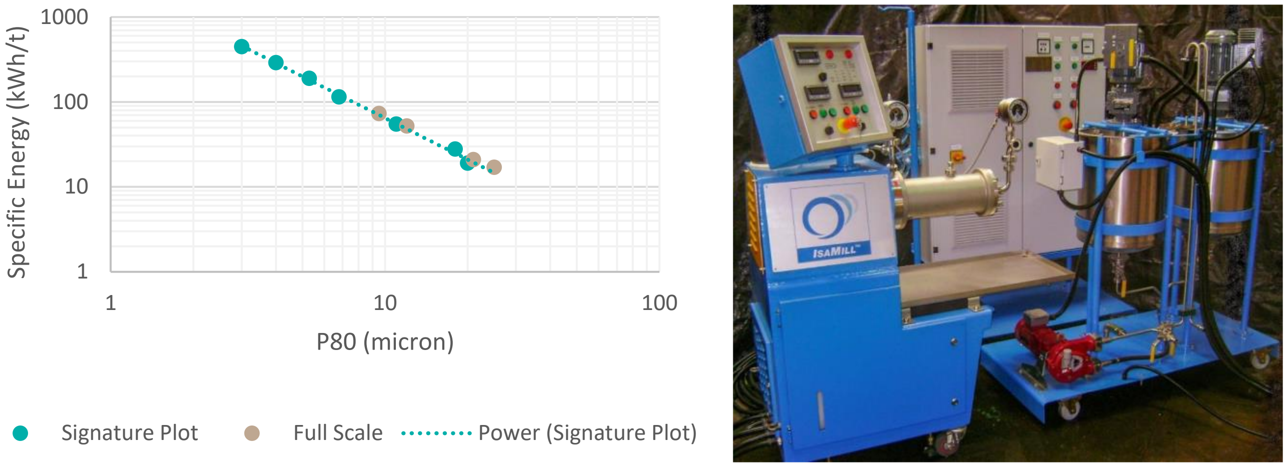


Figure 7: IsaMill™ Signature Plot - Mount Isa and M4 IsaMill™ (Gurnett et al, 2022)

The test typically requires 15 kg of material to ensure steady state is achieved and avoid coarse particle buildup. The authors understand, that for a AACE Class 5 Concept level testwork program, generating 15 kg of concentrate can be unfeasible. For AACE Class 4/5 estimates (+/- 30/45%), we do not recommend that the specific energy be determined via a Bond Work (factorised or not) approach. Glencore Technology have both an internal database and publicly available online database estimation tool that provide a higher degree of accuracy. Comparisons between these two approaches are identified in Figure 8. A significant underestimation of power can be seen by applying a Bond Work Index approach – especially as the particle size target becomes finer

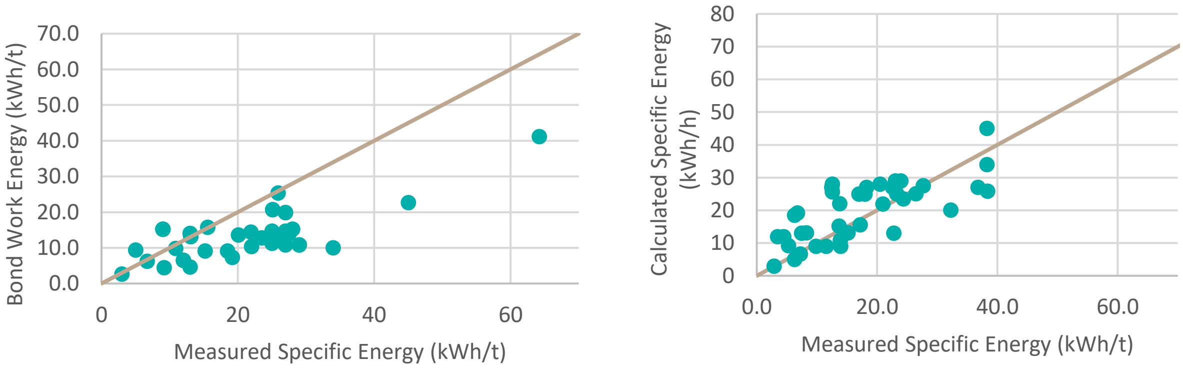


Figure 8: Bond Work Estimate versus Measured Specific Energy in an IsaMill™ (Left) and an Online Calculator Comparison to Measured Specific Energy (Right)

ISAMILL™ S – VOLUMETRIC FLOW

Volumetric flow on the IsaMill™ is an easy consideration. Since the IsaMill™ is a fixed-sized vessel with an internal classifier, there is a high and low flow limitation. The high flow exists on the basis of how much can physically go through the vessel, and the low flow limitation exists to manage the effect of the rotor to ensure that the wear is manageable on the non-drive end of the mill.

PUTTING THE RESULTS TOGETHER

By generating the grade recovery curves through the dilution cleaning and/or L150 testwork campaigns, the operating points for each section of the plant can be defined to develop the overall flowsheet. Figure 9 is a rougher dilution test that scaled up to a full-scale Jameson Cell installation. From a design perspective, 70% of the Copper units are available at the final concentrate grade (green circle). A Rougher Scalper can be used to target and remove this high grade concentrate and then decrease the subsequent downstream circuit sizing. The rest of the grade recovery curve can be recovered via the use of a scavenger (yellow circle). If a nominated throughput is known, it is possible to size the cells if the carrying capacity and volumetric flow constraints are satisfied.

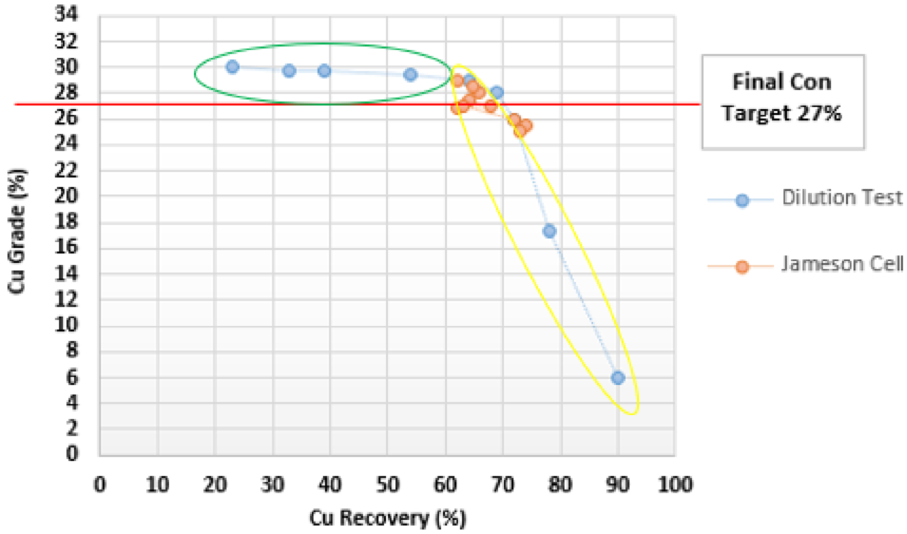


Figure 9: Rougher Dilution Test

The mass balance of the plant throughout would then define the volume of concentrate to be processed through regrinding and cleaning. Scavenger concentrate then reports to a regrind step. Using the IsaMill™ database, an IsaMill™ can be sized to satisfy the volumetric and specific energy limitations. The cleaner circuit would then be sized to operate off a single point on the grade recovery curve. In Figure 10 below, this would be roughly at the 92% recovery point.

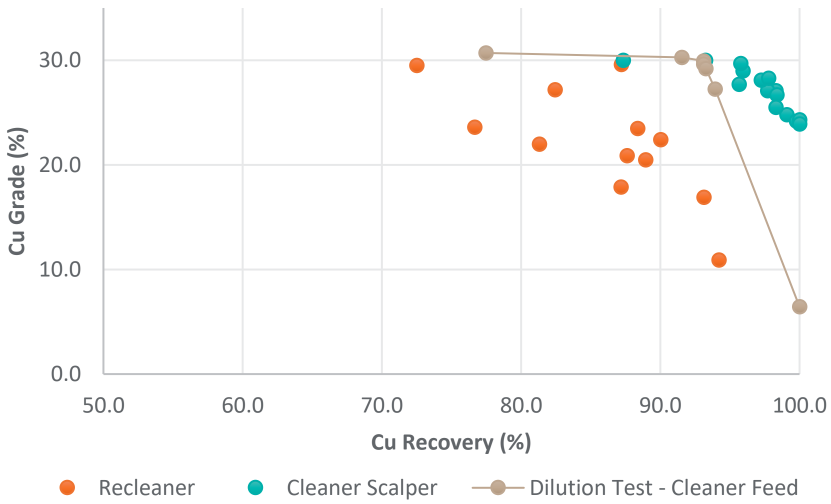


Figure 10: Dilution Test v Cleaner Scalper and Recleaner Surveys

In the cleaner circuit, mass flows are balanced internally to achieve the designated overall grade and recovery. The recommended cleaner arrangement is a Cleaner Scalper (operating at about 70% recovery), Cleaner Scavenger, and Recleaner. The Recleaner and Cleaner Scavengers are balanced to achieve the correct operating point. Overall, cleaner performance will even out to the operating point on the dilution cleaning grade recovery curve -since the surveys identified that the cleaner scalper will produce a higher grade recovery curve relative to the recleaner.

These sizings then allow you to develop a flotation circuit comprising of the following cells (Figure 11). In certain applications, the number of cells can be reduced to a single cell in each duty. Glencore Technology can supply sizing and equipment costs, and a factorised capital estimate at a AACE Class 5/4 (±35% accuracy) level, to determine the feasibility of the Jameson Concentrator.

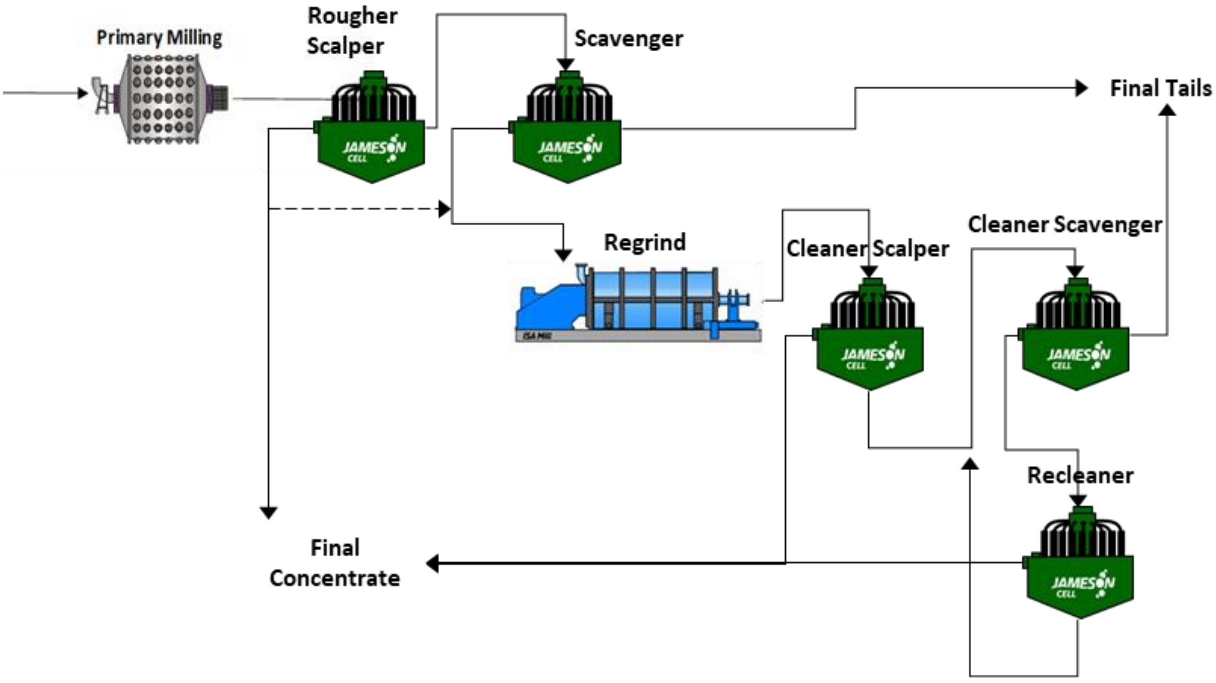


Figure 11: Circuit Layout Arrangement

SUMMARY

Using the Jameson Concentrator approach has been demonstrated to result in power savings of up to 50% and footprint savings of up to 70% in other applications. This results in significant CAPEX and OPEX savings. By following the testwork outlined within this paper, it is possible to conduct a scalable evaluation of the Jameson Concentrator at a very early stage in a project providing an easy technology trade off option.

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