PROCEEDINGS

XVII. INTERNATIONAL COAL PREPARATION CONGRESS

1-6 OCTOBER 2013

ISTANBUL TURKEY

Edited by

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Two decades of Jameson Cell installations in coal

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ABSTRACT

Jameson Cell technology was first introduced in the late 1980s to overcome the design and operating inadequacies of column and conventional flotation cells. From the first commercial base metals installation at Mt Isa in 1989 followed by the first coal installation at Newlands in 1990, it has been continuously developed and improved to make it more robust and easier to use. There are now over 320 units installed in a wide range of applications and industries of which about 45% are employed for coal. The latest designs combine the original advantages of high productivity and small footprint with significantly reduced maintenance costs and much more operator-friendly features. This paper will describe the development of the Jameson Cell technology over two decades and drivers for changing circuit configurations from 2-stage to single stage and then back to 2-stage over the years. Although most Jameson Cell installations are currently utilised for recovery of metallurgical coal, there are a growing number of applications emerging for treating ultrafine thermal coal, many with high raw coal ash contents, predominantly clay. The paper will also describe recent pilot-scale test work and the results obtained from this to support the commercial scale project.

Keywords: Jameson Cell, Coal, Flotation, Frother

1. Introduction

The Jameson Cell is a fundamentally different flotation technology to mechanical and column cells, having been invented by Prof Graeme Jameson at the University of Newcastle in NSW. They were first tested and commercially installed in a coal washing plant at Xstrata Coal's Newlands mine (Jameson et al., 1991). The fines stream was cyclone overflow material which was previously discarded (minus 20-25 microns in particle size with 15 to 50% ash content). Pilot plant testing showed it was possible to achieve greater than 90% combustibles recovery with a product target of 10% ash. This led to the installation of the first generation full scale, Mark I Jameson Cells in 1990. These cells were in continuous operation for over 15 years until a new washing plant was built to replace the old plant in 2006. The new plant also uses Jameson Cells and has four new B6000/20 model Mark III cells installed. Following the initial Newlands installation, many sites have tested the technology which was shown to consistently produce low ash concentrates and achieve high combustibles recovery whilst being forgiving to variations in feed ash (Harbort et al., 1992; Atkinson et al., 1993; Manlapig et al., 1993). BHP Coal's (now BHP Billiton Mitsubishi Alliance - BMA) Goonyella 1,800 tph coking coal operation in Central Queensland tested the advanced flotation technologies and subsequently replaced the entire 32 mechanical (Wemco) cell circuit with 8 Jameson Cells operating in a 2-stage configuration (Caretta et al., 1997). Figure 1 compares the performance of the Jameson Cells at this plant after commissioning to the old mechanical cell circuit. The ability of the Jameson Cell to consistently deliver a low ash product at high combustibles recoveries contributed to an overall plant yield increase of ~3.5% and led to production records.

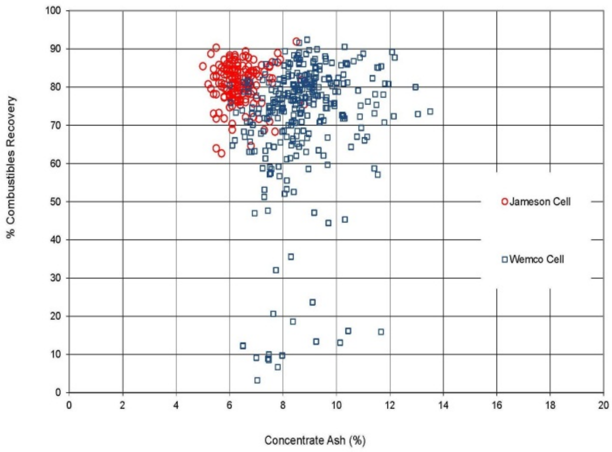

Figure 1: Full scale Jameson Cell performance at Goonyella mine compared to old mechanical (Wemco) cell circuit

Amongst the key benefits is froth washing and the simplicity afforded by the Jameson Cell, it being easy to operate and maintain; with no moving parts, and needing no auxiliary equipment except for the feed pump. Over 150 Jameson Cells are now operational on coal worldwide, the current largest installation being at Wesfarmer's Curragh Mine in the Bowen Basin of Central Queensland which treats over 5 million tonnes of coal fines per year using only twelve cells. Long-established coal producing countries like Kazakhstan are also realising the benefits of the Jameson

Cell over conventional cells and emerging coal regions such as Mozambique and Mongolia are now beginning to use the Jameson Cell for metallurgical coal applications.

The remainder of this paper will describe the development of the Jameson Cell technology over two decades, the evolution of flotation circuit designs, continued challenges of fine coal processing in the coal industry; and a recent case study for the development of a thermal coal project from pilot plant to full scale is included to illustrate the recommended design approach.

2. Jameson Cell Development

The Jameson Cell development path has seen four main phases of progressive improvement (Figure 2) since its first commercial installation in 1989. Two decades of significant advances have culminated in the latest model, the Mark IV Jameson Cell, which incorporates the following features:

- Feed recycle system; to ensure stable cell operation maintaining optimum performance independent of feed fluctuations.

- Low wear, high discharge coefficient, slurry lens orifice.
- Flexible feed nozzle allowing quick and easy inspection and precise alignment of the plunging jet to maximise metallurgical performance.
- Improved above-froth or in-froth washwater system.

With the release of the Mark III downcomer in 2000, the orifice plates used for jet formation were replaced with the slurry lens orifice (Figure 3). The benefits included a shallow slurry entry angle which optimised slurry flow and maximised component wear life; a high discharge coefficient, and improved slurry jet formation resulting in more consistent air entrainment and vacuum.

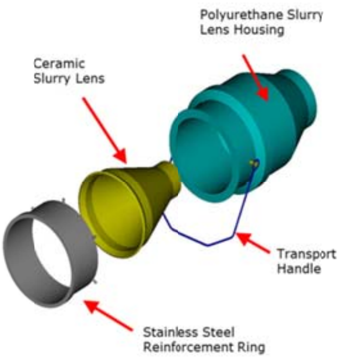

Figure 3: Mark IV Slurry Lens

For maintenance, the slurry lens is significantly easier to access compared to the old design. If a slurry lens becomes blocked or needs replacing, it is now a 10 minute job which can be done online by isolating the specific downcomer while the rest of cell (and other downcomers) remain in operation. The wear performance of the slurry lens orifice has far exceeded expectations. Since its introduction in 2000, 1,500 slurry lenses have been installed in coal applications and no site has so far needed to replace one of these items due to wear.

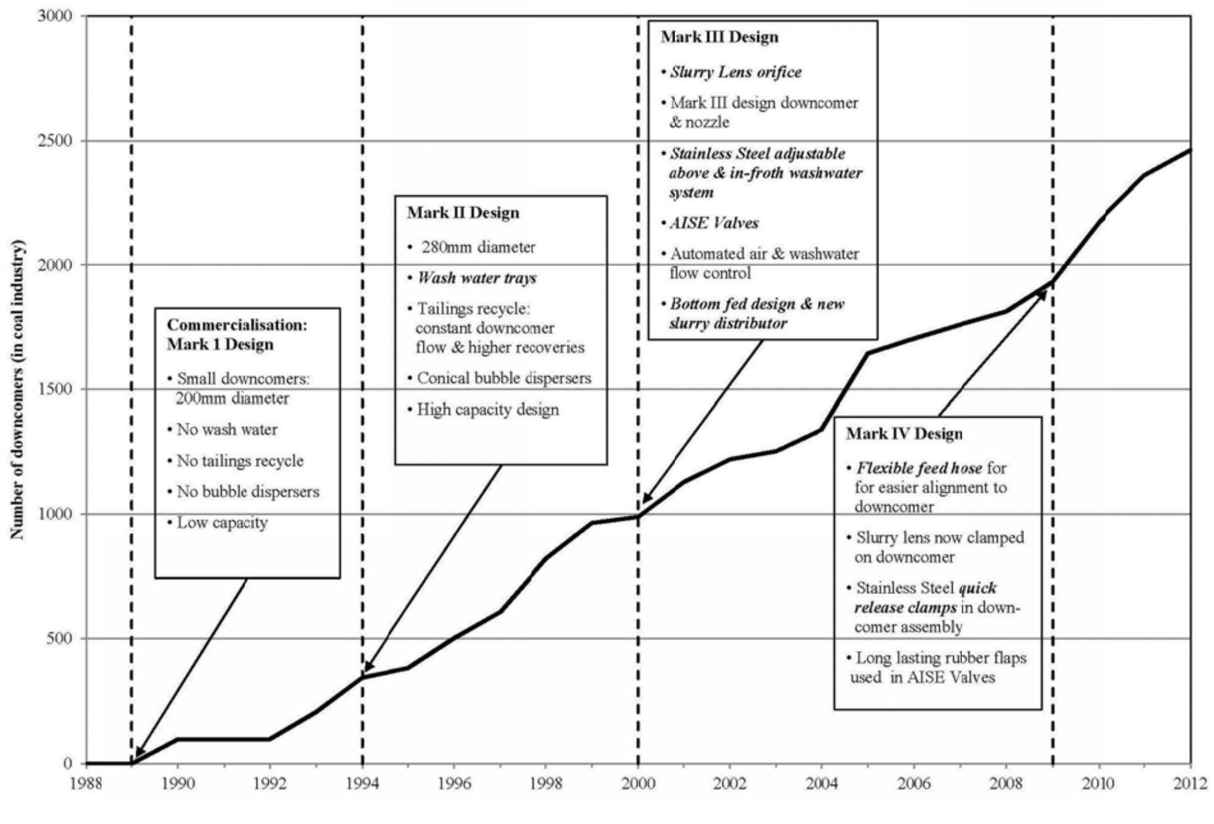

Figure 2: Jameson Cell Development Path

3 Evolution of Jameson Cell Circuit Designs

The first generation of Jameson Cell coal plant installations in Australia in the early 1990s were all 2-stage designs with primary and secondary cells producing separate concentrates that were combined to give the final product. These circuits generally operated well but flotation performance was often affected by wide variations in feed volumetric flow rate to the flotation circuit. This was usually because fluctuation in the flow rate and feed pressure resulted in inconsistent air entrainment and hydrodynamic mixing inside the downcomer. This was overcome in the mid-1990s with the incorporation of tailings recycle into the circuit design. Although originally designed to dampen feed flow fluctuations, by employing higher tailings recycle of between 40-50% and reducing the fresh feed flow rate, it was observed that cell recovery was improved which enabled a single Jameson Cell to achieve a similar level of combustibles recovery as some 2-stage circuits (Figure 4). These single stage cells are therefore typically designed to operate with a lower fresh feed flow rate and higher tailings recycle of about 40-50%. In metallurgical coal applications the number of single-stage cells required to achieve high yields (up to 85-90%) at the required quality must ensure adequate carrying capacity (bubble surface area). An equivalent 2-stage circuit would use the same number of cells as the single stage arrangement but the cells will be installed in series rather than in parallel and will operate at much lower tailings recycle (10-20%). In this type of circuit, the purpose of the tailings recycle is to simply dampen fresh feed fluctuations. The obvious attraction of the single stage flotation circuit is the reduced capital and operating cost as it can be designed using minimal feed sumps and pumps. For example, for two cells in a parallel circuit, only a single feed sump and a single feed pump are required, whereas for an equivalent 2-stage circuit, 2 sumps and 2 (smaller) pumps are required. However, the level of saving is diminished as the size of the circuit increases because 2-stage circuits with more than 2 cells can also make use of common sumps and larger feed pumps as the feed for each stage primary and secondary stage can also be split between two or more cells.

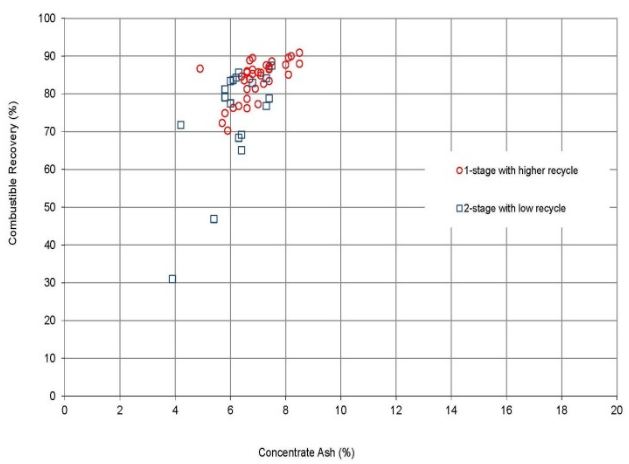

Figure 4: Flotation performance of single stage versus 2-stage Jameson Cell circuit.

From 1995 onwards, all Jameson Cell installations were single stage circuits with 40-50% tailings recycle. Over the years, many operations have experienced frothing issues in the plant caused by residual frother in the recirculated tailings thickener overflow water. This issue is complex and the effects experienced at each site are varied and often require individual solutions. The sensitivity of the overall plant to residual frother is also dependent on how quickly water is reused, the design of the water circuit and the reagent combinations used throughout the plant. Common problems experienced include instability in dense medium circuits through air entrainment, dewatering limitation due to froth handling constraints and water clarification issues.

However, the impact of lowering frother dosage to the flotation recovery in single stage circuits is severe as demonstrated in Figure 5. At this metallurgical coal operation, combustibles recovery was poor at 35-45% and well below the knee of the curve generated from a standard coal characterisation test (black line) when the frother concentration was 9 ppm. Altering froth depth, air flow rate and washwater flow rate had negligible impact on the recovery. However, when the frother dosage was increased to 14 ppm, the combustibles recovery dramatically increased to 75 to 82%, reaching the maximum at the knee of the curve.

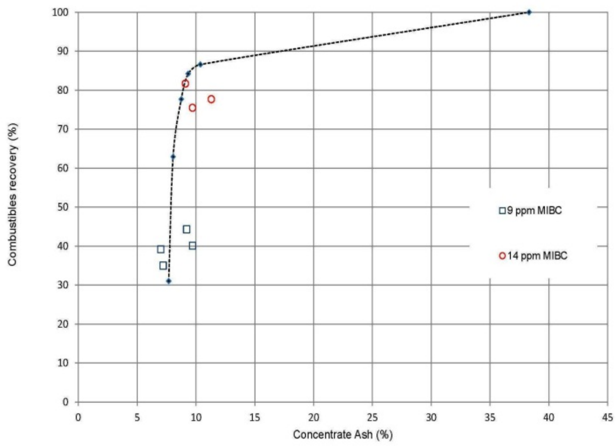

Figure 5: Effect of frother dosage on flotation performance

The reason for the dramatic change in combustibles recovery shown in Figure 5 can be explained as follows. In single stage circuits, whether a Jameson Cell or a column cell is used, the carrying capacity of the cell is entirely dependent on that cell being able to produce sufficient bubble surface area required to float all the coal. For any type of flotation machine, maximum bubble surface area can only be achieved if sufficient frother is added to prevent coalescence. The minimum concentration required for this is called the Critical Concentration of Coalescence (CCC) and is characteristic for each type of frother. Figure 6 shows the change in bubble size with frother dosage for MIBC, the most commonly used frother in coal flotation. The CCC for MIBC is around 15 ppm.

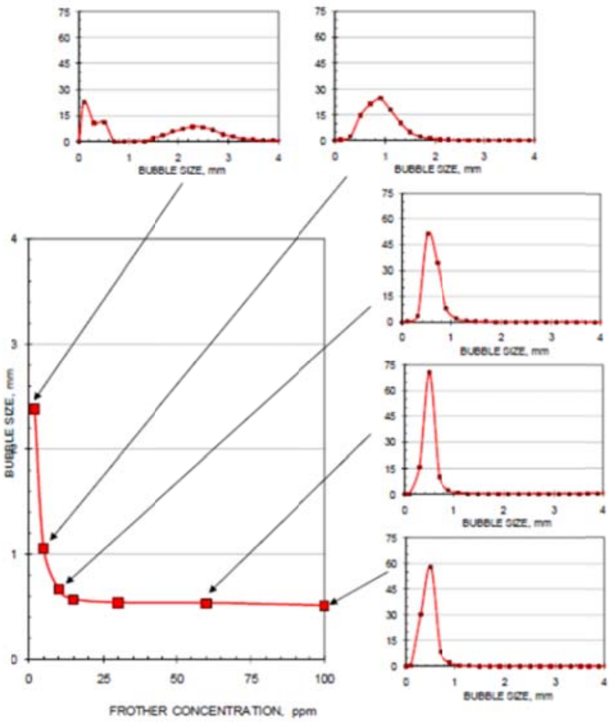

Figure 6: Bubble size as a function of frother concentration (Zou, 2010)

While the frother dictates the concentration it must be used in the flotation process; it is the flotation machine that controls the minimum bubble that can be generated. Figure 7 compares the bubble size of different technologies: Jameson, mechanical and column cells, are included as a function of the superficial gas velocity, J_g (a measure of air flow rate). The fine bubbles generated by the Jameson Cell (300-600 microns) explain why it can achieve faster flotation kinetics and has higher carrying capacity, and therefore productivity, when compared with the other cell types.

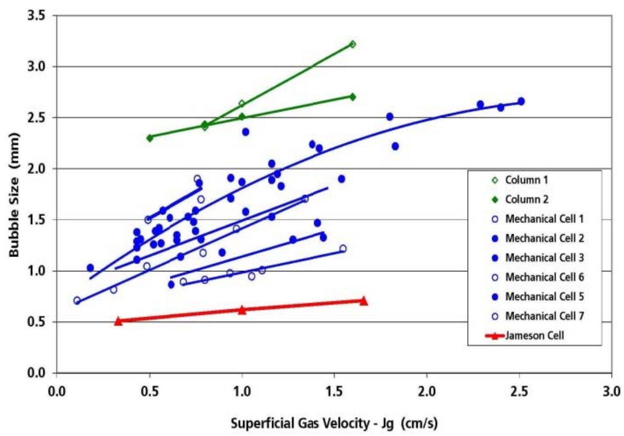

Figure 7: Bubble size as a function of J_g (measure of air flow rate) for different flotation technologies (Nesset et al., 2007; Gomez, 2012, Zou, 2010)

An impractical solution to the frother problem might be to design the entire washing plant to incorporate separate water circuits for the coarse and fines circuits. Perhaps the only practical solution that can be made is to reconfigure the flotation circuit and revert to a 2-stage design. The 2-stage circuit may provide a more robust operation because the primary and secondary stages can be operated separately to optimise performance. Higher frother dosage added upfront would enhance the performance of the primary cells and then the remaining frother in the tailings of this cell can be used to float additional coal in the secondary cells. RTCA's[1] Warkworth operations in NSW, Australia have reconfigured the Jameson Cells to operate in 2-stages and have reported an improvement in yield and higher concentrations of frother can be used without excessive frothing occurring (Lambert and Revell, 2008). New installations such as Yancoal's Moolarben plant (NSW) and RTCA's Kestrel (QLD) have also chosen 2-stage flotation circuits.

There are opportunities for washing plants operating with single stage flotation circuits to be retrofitted to become 2-stage circuits. AAMC's[2] German Creek operations (QLD) recently installed a single Jameson Cell as a secondary stage to treat the tails from two Microcel units operating in parallel (Figure 8). The footprint was small and installation was straightforward because of the simple tie-ins and no other auxiliary equipment was required other than the feed pump.

Figure 8: Recently installed Jameson Cell (left) next to two column cells at AAMC's German Creek operation

4. Challenges in coal flotation and fine coal processing

Flotation is a physio-chemical separation process and is different to other unit operations in a coal washing plant which all employ gravity based techniques to effect separation. Flotation is a complex 3-phase system that is controlled by many factors which can be categorised into

[1] RTCA is Rio Tinto Coal Australia

[2] AAMC is Anglo American Metallurgical Coal

three facets: coal characteristics, chemistry impacts and machine characteristics (Figure 9).

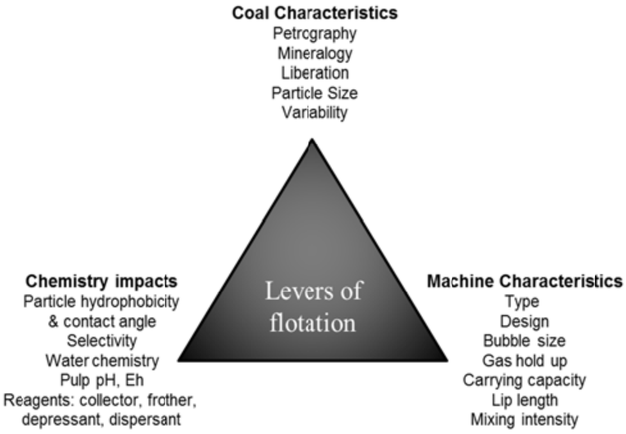

Figure 9: Flotation 'triangle' showing the factors affecting performance

The flotation machine is only one facet important to the overall process, but seems to get the most attention and is often blamed when performance of the fines circuit is poor. However, the variability of the coal and flotation reagent control are two factors which perhaps is surprisingly often overlooked. The greater the number of different coal seams and sources that are treated, the more challenging is the task of achieving effective flotation and the targeted qualities and recoveries. Operators must therefore be trained to respond to changes in tonnage, particle size distribution and flotation behaviour of the different coal types and make the necessary adjustments to reagent dosages and process variables to optimise performance.

In many plants, monitoring of flotation performance is irregular and often a 'knee-jerk' change is made when performance has clearly deteriorated. Furthermore, in many plants it may be impossible to conduct surveys because sample points do not exist for the feed, concentrate and tailings. Even in the more modern (recently built) plants, the flotation feed cannot be easily collected as it usually consists of more than one stream which gravity flows into a large collecting sump. In Jameson Cell installations, many operations unknowingly collect the downcomer feed, and use the result from a "rapid ash" analysis and the two-product formula to calculate yield and combustibles recovery. This is erroneous as the downcomer feed is an internal stream. Sampling points are therefore an essential part of good design of the fines circuit.

Even though flotation is the separation process, the overall fines circuit performance is often dictated by concentrate dewatering capacity as this often proves to be the bottleneck in the process. Many flotation circuits have to be 'scaled back' to suit the capacity of the dewatering device leading to large losses in coal fines which then cause issues in the tailings thickener. Another area to address is the type of dewatering device used for concentrate dewatering. The technology chosen needs to carefully consider the particle size and type of coal treated and not use capital cost as the driver for decisions.

5. Bulga Pilot Plant

Flotation has been traditionally used as a beneficiation process for treating coal fines but in the past it has been mainly used for metallurgical coal. However, in South Africa there has been a number of flotation installations aimed at recovering saleable thermal coal from raw tailings that would otherwise be discharged as waste. These have had mixed success because coals from this region are not readily floated, but they have also demonstrated the parallel need for selecting effective dewatering circuits for treating the clean coal concentrates (Power, 2010).

Xstrata Technology together with Xstrata Coal has been developing the flowsheet for a Jameson Cell installation to treat thermal coal at Bulga mine near Broke in NSW. This plant will eventually treat natural raw coal tailings and also tailings recovered from nearby tailings ponds that contain an estimated 3Mt of recoverable coal.

The plant washes as many as 12 coal seams and coal sourced from both open-pit and underground mining operations with a flotation feed ash varying from 30-65%. It is challenging for any technology to make a consistent quality product with such a large variation in feed.

A Jameson Cell flotation pilot plant was operated on-site to provide the necessary design information for the plant extension. The pilot plant flotation testwork showed consistently high recoveries from the thermal coal feed, achieving 70 to 90% combustible recovery with 8 to 12% ash in the product. The more oxidised coal types required increased collector additions to achieve acceptably high recoveries.

The pilot plant was configured with two L500 Jameson cell units arranged in series to simulate full scale design of the flotation circuit to be installed in future. A layout of a proposed full scale Jameson Cell installation is shown below in Figure 10. This compact design allows for installation of the flotation plant efficiently in a brownfield expansion. Various dewatering and other treatment options have been considered for this plant including the combination of screen-bowl and Centribaric units with subsequent briquetting of the higher value products. These equipment items will also be tested with the pilot-plant to ascertain their suitability and once this work is completed this flotation circuit will be designed as a "standard" for future Xstrata Coal washing plants treating both metallurgical and thermal coal types.

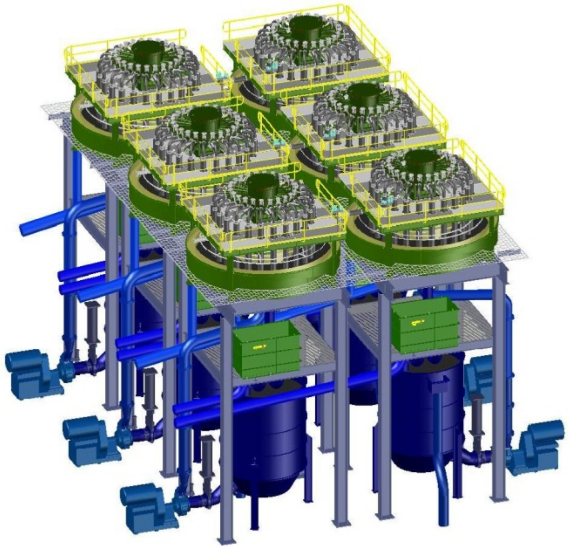

Figure 10: Layout of six B6500/24 model Jameson Cells (Footprint = 22 x 26m; Height = 17m)

6. Concluding Comments

Over little more than a decade Jameson Cells have become a standard flotation technology in the Australian coal industry. With over 110 installations, this industry represents a substantial knowledge base for operating, maintaining and improving installations in the future. There are also a growing number of coal installations worldwide in every major coal region including emerging regions such as Mongolia and Mozambique. Users have long-since recognised the major advantages, i.e. simplicity, excellent availability and low maintenance in addition to proven robust and consistent process performance.

Much of the progress that has occurred in Jameson Cell evolution is owed to improvements in the materials used in components as previously designed, but other factors clearly affect the overall performance of the flotation circuit. Some of these have also been addressed, i.e. dewatering, sampling, process control, etc. Future plants will need to be designed to incorporate further innovations in each of these areas especially where operators can be provided with reliable monitoring and control features that enable changes to be made to operating conditions and early indications of deviations from quality and recovery targets.

Xstrata Technology (XT) has built up a strong team of designers, engineers and process specialists and as a result, has continuously improved the technology over two decades whilst still maintaining close association with its inventor and his team of scientists. Such relationships are rare in process engineering and in addition XT is not just an equipment supplier, their modus operandi being to develop technology 'partnerships' with clients which include not only coal users, but process engineers and designers working in base metals, industrial minerals and a variety of other applications. Therefore, this is a unique situation where knowledge transfer from all sources is passed on to all users. There is little doubt that further improvements will result in more new models and circuit designs and the incorporation of desirable features such as on-line analysis, designed-in slurry samplers, reagent sensors, etc.

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