New Jameson Cell flotation of industrial minerals

by Steve Hall* and
Mark Harrison**

The efficiency of froth flotation is determined by a sequential series of probabilities (*1*). Paramount is the achievement of intimate particle-bubble contact ahead of value particle-bubble attachment, pulp-froth disengagement and finally, the transportation of concentrate froth to the product launders. Different flotation technologies utilise a variety of techniques (2,3,4) to maintain the above phenomena. An assessment of net operational savings in using any one technology is valid only for equivalent feed material. Economic assessment is then possible according to realised cost savings and any proven additional revenue from increased metallurgical performance.

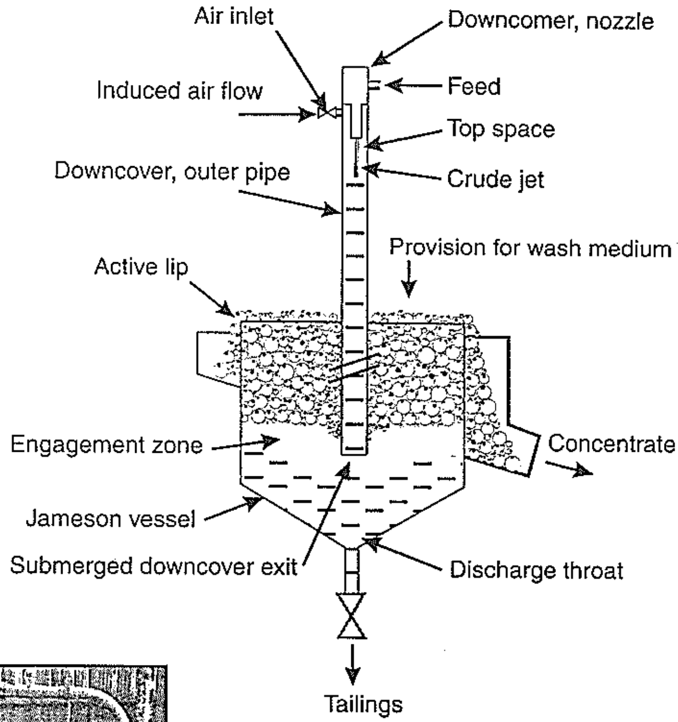
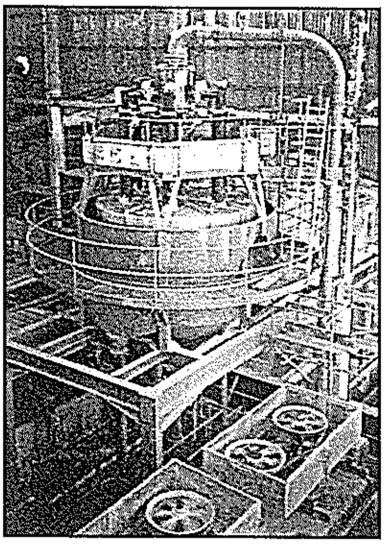


Figure 1. Section through a Jameson Cell indictating the relative location and the action of a solitary downcomer.

The Jameson Cell is an exceptional froth flotation device as it functions by hydrodynamical means. The associated technical and economic attributes of this non-mechanical technology impart revolutionary potential to commercial flotation. At present there are close to 130 commercial installations of the Jameson Cell at about 44 individual flotation sites throughout the world. On 6 September 1994, the first commercial application of the Jameson Cell to industrial mineral flotation was commissioned at Cleveland Potash Ltd in the UK.



Jameson Cell - technical operation

The heart of the Jameson Cell is the *downcomer*. The action of a solitary downcomer within a Jameson Cell is shown by *Figure 1*. A downcomer is a simple static device, comprising of a nozzle assembled to an outer pipe with a single air inlet. The downcomer is held vertically with its base positioned at a depth in an engineered Jameson Vessel.

During start up, feed enters the Jameson Vessel as a crude jet of slurry issuing from the nozzle. Quickly the base of the downcomer becomes submerged forming a liquid seal that ensures the downcomer fills up with pulp. A head of slurry is thereby elevated above the active lip inducing hydrostatic suction and thus creating a region of low vacuum in the top space of the outer pipe.

Initially the jet is submerged within the downcomer pulp. However, immediately upon opening the air inlet, air is drawn to the in situ vacuum from the local environment. Regulating the amount of induced air flow, stabilises the pulp at an intermediate height in the downcomer. An extent of the slurry jet plunging through the low vacuum region is thus exposed. High shear and mixing conditions are created by the impingement of the exposed jet within the pulp in the downcomer. Air is continuously entrained and dispersed as fine bubbles of diameter 300 to 600 μm (mean arithmetic) (*5*). A maximum of 50% to 60% void fraction (v/v) is attainable in the operating downcomer thereby thinning the film thickness between bubbles and increasing the interfacial area available to contact mineral particles.

Slurry is resident in the downcomer for between 8 to 10 seconds. Resultant fluid momentum ensures pipe flow of the mineral laden bubbles as they are carried downwards to the submerged downcomer exit.

In the vicinity of the exit, pulp and froth enter a disengagement zone. Froth rises forming a consistent froth bed that is washed as necessary to remove entrained gangue prior to concentrate froth overflow into product launders. Tailings flow through the discharge throat at the base of the Jameson Vessel. The resulting fluid flow characteristics satisfy all requirements for system agitation. In total, slurry is resident in a Jameson Cell for between 120 and 180 seconds.

Commercial Jameson Cells may use a number of downcomers within a froth-partitioned (FP) Jameson Vessel. Isolation of the rising mineral bearing froth produced by one or a group of

*University of Nottingham, UK.
**MIM Technology Marketing Europe, UK.

downcomers, maintains flotation performance at a fraction of the designed maximum feed volumetric flow. Aside from achieving an enhancement of metallurgical performance, the technical operation of the Jameson Cell alone contributes an innate number of unique money-saving attributes.

Jameson Cell: economic benefits

The eighteen economic attributes of the Jameson Cell are best described according to their intrinsic or extrinsic origin.

Table 1. Intrinsic attributes of the Jameson Cell

Economic attribute No.	*Definition*
1	Air aspiration
2	Bubble generation
3	Intimate particle-bubble contacting in short residence time
4	Tranquil, rising, particle loaded froth available for washing
5	System agitation
6	Rota on-line maintenance by rapid isolation of wear components
7	System turndown capability

Intrinsic attributes

The downcomer simultaneously provides seven intrinsic attributes as defined by *Table 1*.

Table 2. Conventional flotation components eliminated by Jameson Cell

System	*Description*
A	Air compressors, air blowers, and air delivery network
B	Spargers and/or sparging mechanisms
C	Agitators -: as rotor-stator assemblies, drive transmission and drive motors

Table 2 describes the mechanical systems eliminated by the intrinsic attributes of downcomers.

The removal of the mechanical entities from the flotation system leads to significant cost savings in absorbed energy, and in on-going maintenance.

Table 3. Extrinsic attributes of the Jameson Cell

Economic attribute No.	*Description*
8	Compact equipment size, ie. reduced footprint
9	Reduced numbers of cells per flotation stage
10	Simplified circuit layout
11	Simple process control and parameter monitoring
12	Effective response to changes of feed grade
13	Reduced operating manpower requirements
14	Greater operator understanding
15	Reduced total maintenance cost
16	Reduced total flotation floor area
17	Reduced spares inventory held in site stores
18	Rapid system stabilisation after start up

Extrinsic attributes.

The extrinsic attributes listed in *Table 3* occur as a consequence of a commercial Jameson Cell achieving flotation performance in a very short slurry residence time.

The purpose of this paper is to detail the new applications of the Jameson Cell to the treatment of industrial minerals. To date, commercial installations of the Jameson Cell exist in potash and graphite production. Other graphite, fluorspar and zircon duties are summarised by the conclusions of pilot study.

Commercial installations

(a) Site 1: Potash production

Cleveland Potash Ltd ("CPL"), unlocked the potential of the Jameson Cell in 1992. Initially, laboratory based potash recleaner tests were performed by the University of Nottingham as a Jameson Cell Testing Authority. A J100 pilot-scale Jameson Cell unit was used to test samples transported from CPL. The availability of a "hot floor" room enabled problems of potash recrystallisation from saturated brine slurries on temperature reduction to be avoided. Indicator tests showed that the downcomer could be applied to potash processing and that froth washing with saturated brine from a header tank was possible. These conclusions incited the development of a site based pilot plant programme.

At CPL, flotation is used to concentrate sylvite (KCl) from halite (NaCl) plus insolubles such as clays and sulphates. Stringent desliming of the all flotation feed is essential ahead of the addition of starch (clay depressant) and amine (KCl collector). Chloride mineral dissolution is minimised by the use of saturated brine as desliming and flotation media.

Two stage desliming to 100μm is achieved through primary and secondary cyclone banks. The secondary cyclone underflow (-1500+100μm) reports to the standard flotation feed pump box. Primary cyclone overflow is further deslimed to 30μm via tertiary cyclones.

Standard rougher tails are passed over DSM screens to recover middlings and any misplaced coarse potash. Rougher screen oversize (+450 μm) is distributed to three regrind ball mills. Rougher screen undersize reports to a tails centrifuge. Standard cleaner tailings are gravity fed to LH-cyclones and the cumulative bank underflow reports to the regrind mills. Standard recleaner tailings report to DSM screens. Recleaner screen oversize (+ 200μm) is also fed to the regrind.

Both LH-cyclone overflow and recleaner DSM underflow report to tertiary cyclones. The resulting total tertiary cyclone underflow (-100+30μm) is fed to the slimes flotation feed pump box. Tertiary cyclone overflow reports to a tails thickener for brine recovery from tails solids. Jameson Cell on-site pilot testing progressed by using key flotation streams of both flotation circuits (*6,7*). Results indicated that the greatest economic benefits could be gained by utilising the attributes of the downcomer as close as possible to the head of each flotation circuit.

Slimes flotation

On 6 September 1994, a single Jameson Cell 3250/6 (FP) was fully commissioned at CPL as a Total Slimes Flotation system. The single Jameson Cell replaced 16, 2.8 m^3 Denver No.30 DR flotation cells used as slimes roughers and cleaners, i.e., the entire original slimes flotation.

Client CPL

Jameson Circuit layout

Number of units	1
Number of stages	1

Feed detail

Origin	Tertiary cyclone underflow
Volumetric flow (m^3/h)	370
Solids (% (w/w)	18
Particle size specification	(-100+30) μm
Fraction of total plant product produced via Jameson, %	10

Commercial performance, mean production (30 day)

Feed, % KCl	24.5
Concentrate grade, % KCl	77.4
Tailings, % KCl	5.7
Recovery, %	82.8

A conservative economic assessment for the installation and operation of the Jameson Cell at CPL is summarised in *Table 4*.

Table 4. Conservative economic summary *(8)*

Item	*Value (£)*
Payback, days	213
Additional recovery revenue pa	201,939
Net operational saving pa	209,985

Table 5 highlights a 76.7% energy saving made by utilising the hydrodynamics of the downcomer instead of the conventional cell agitator motors of the original slimes circuit.

At CPL, the single Jameson Cell recovers fine potash from a gangue comprised of halite, clays and sulphates. The achievement of fine particle selectivity occurs at enhanced recovery leading to a conservative estimate of additional site revenue as £201,939 pa for a payback in 213 operating days.

Table 5. % Savings from the use of Jameson Cell vs original slimes circuit

Item	*% Saving*
Equipment footprint	80.9
Total float floor area	81.3
Absorbed power[{†}], pa	76.7
Maintenance[{ú}], pa	>79.0

[{†} Jameson Cell Additional Pumping Requirement vs. Original Slimes Flotation Circuit Cell Motors]

[{ú} Jameson Cell Maximum Maintenance vs. Original Circuit-Previous Operating Year excl. manpower]

Standard flotation

The use of flotation at CPL reflects the achievement of good liberation of KCl from NaCl at coarser particle sizes. The use of two flotation circuits stipulates a requirement of the Standard Flotation circuit equipment to recover the +850 μm particles. *Table 6* compares the performance of the pilot Jameson Cell and the standard flotation sub-aeration cells when processing the standard flotation rougher concentrate.

Results of *Table 6* indicate that the Jameson Cell could increase the standard flotation circuit recovery from 75.5% to 81.7% and maintain product grade at 90.8% KCl, if pilot results were repeated on a commercial basis. The amount of high grade +850μm material recovered from a standard flotation rougher concentrate of grade 79.9% KCl is shown in *Table 7*.

With the Jameson Cell, the weight recovery from the high grade +850μm fraction has increased from 13.4% to 46.1% thereby enhancing the recovery of KCl from the standard flotation by 4.1 percentage points. By recovering the coarse material in the Jameson Cell, the regrinding of about one third of the +850μm fraction reporting to the rougher concentrate could be eliminated. In both slimes and standard flotation

Table 6. Single stage pilot Jameson Cell vs standard circuit cells [{*}]

Feed = standard flotation rougher concentrate, no froth washing

Feed		*Single Jameson Cell*				*Standard circuit cells*			
		Concentrate		*Recovery*		*Concentrate*		*Recovery*	
% KCl	*Std*	*% KCl*	*Std*	*%*	*Std*	*% KCl*	*Std*	*%*	*Std*
70.6	3.57	89.1	0.94	85.1	3.18				
77.6	2.09	90.8	1.42	81.7	2.17	91.0	2.09	75.5	1.76

[{*} Standard Circuit Cells = (28) off 2.8 m^3 Denver No.30 DR sub-aeration cells in cleaner/recleaner configuration]

Table 7. Single stage pilot Jameson Cell vs standard circuit cells [{*}]

Feed = standard flotation rougher concentrate, (grade = 79.9% KCl)

Technology	*No. of flotation stages*	*Wt. recovery of +850 μm size fraction*	*Conc. grade, % KCl*	*Recovery %*
Single Jameson	1	46.1	91.8	83.7
Standard circuit	2	13.4	91.7	79.6

[{*} Standard Circuit Cells = (28) off 2.8 m^3 Denver No.30 DR sub-aeration cells in cleaner/recleaner configuration]

Other studies

(a) Graphite: Nottingham University Testing Authority

Client *Confidential*

The University of Nottingham was approached to study possible improvements in graphite flotation performance, particularly concentrate grade, that might arise from using Jameson Cell Technology.

The client subsequently agreed confidentiality with MIM Technology Marketing Ltd and completed a feasibility test agreement prior to testwork. The graphite ore, of Russian origin, was supplied in lump form by the client and reduced in size to -106µm. Various flotation reagent chemistries were investigated and the J100 Jameson Cell could produce equivalent grades to those obtained by conventional laboratory housed Denver cell flotation (87% to 93% C). It would appear that, in this case, the concentrate grade was not limited by flotation performance, but by lack of liberation of gangue minerals from the graphite. Detailed mineralogical work is often necessary to support flotation testwork.

(b) Graphite: Namibian site pilot plant testing

Client *Confidential*

Pilot tests on location in early 1993 appraised the use of a Jameson Cell in primary and secondary cleaning duties at a site pilot plant.

The results of a 2^4 factorial design experiment identified the significant variables of (i) air flow and (ii) froth depth. The achievement of product grade was seen to be dependent on the selected rise velocity of the concentrate froth in the Jameson Cell. Equivalent or better grades were achieved with the Jameson Cell when compared to conventional sub-aeration cells or columns. The encouraging results obtained were to lead to a detailed study of the Jameson Cell as a final product cleaner. Unfortunately the pilot site closed due to the lack of a market for the plant product.

(c) Zircon: Australian site pilot plant testing

Client *Confidential*

The application of the Jameson Cell to zircon roughing duties was briefly explored at a mineral sands pilot plant. Zircon flotation was performed under conditions of pH control in the absence of frother. Collection with an amine occurred only after effective TiO_2 depression. A target performance for zircon roughing was set as a concentrate grade 22% ZrO_2 at 90% recovery with a maximum impurity of 2% TiO_2.

From single stage tests with a feed grade of 10% ZrO_2, the Jameson Cell produced concentrate grade of >21% ZrO_2 at a 65% unit recovery (<2% TiO_2) without any pH regulation of wash medium. It appeared therefore that zircon roughing could be completed in two stages of Jameson Cell although verification of the scavenger role remained outstanding. Further, a full characterisation of SiO_2 and Fe_2O_3 concentrate impurities as entrained or co-collected entities was not undertaken.

(d) Fluorspar: European on-site testing

Client *Confidential*

The application of the downcomer to fluorspar flotation yielded the results as shown in *Table 8*. The entire flotation test results were used to develop a flotation flowsheet and metallurgical account. The circuit contemplated that for PbS flotation, one stage of single unit Jameson Cell would replace the entire Pb flotation circuit, ie. 23 conventional cells as one roughing and three cleaning stages. In CaF_2 flotation, three stages of single unit Jameson Cell cleaning were deemed necessary to ensure the final product grade and thereby replace the current plant, ie. 49 conventional cells as six cleaning stages.

Any future application of the Jameson Cell at the site relies on stabilising the current commercial chemistry, and establishing a plant operating stratagem for the evolving plant feed mineralogy.

circuits at CPL, the high ionic strength of the saturated brine medium results in (*9*):

(i) High compression of electrical double layers

(ii) A four fold decrease in surface tension by frother addition when compared to the action of an equivalent concentration of identical frother added to an aqueous system

The tranquil flow of the rising potash bearing froth produced by the commercial Jameson Cell reflects a very quick change of surface tension within the downcomer as the potash is loaded to bubbles. Hence, coarse particle recovery is probably greatly assisted by the stable provision of a required and specific rate of interfacial surface area created rapidly within the Jameson Cell.

(b) Site 2: Graphite production

Graphite recovery from the primary cyclone overflow (PCO) was deemed critical to maintain the economic viability of the Southern Africa operation. Total flotation performance was adversely affected by the presence of fine slimes gangue in the PCO stream, and also by an inefficient primary cyclone performance. Combining the product of PCO flotation with the coarse graphite float product resulted in contamination of final flotation plant product grade to less than the required 98% C.

Attempts to improve the performance of the installed conventional sub-aeration cells failed to resolve the emergency. From remote site, approximately 30kg of sample of the PCO was flown to Johannesburg for limited testing in a laboratory housed J100 Jameson Cell.

Conclusions of Jameson Cell test work led to the rapid design, installation and commissioning of a commercial Jameson Cell to process the PCO. On 26 September 1994, a single 800/1 Jameson Cell was commissioned as a fines/slimes scavenger plus cleaner.

Client *Confidential*

Jameson Circuit layout

Number of units	1
Number of stages	1

Feed detail

Origin	PCO of bulk rougher concentrate

Volumetric flow (m^3/h)	11	
Solids (% (w/w)	1.5 to 2.5	
Particle size specification	d50 = 600μm, 10% passing 150μm	

Commercial performance, single spot

Feed, % C	52
Concentrate grade, % C	90.2
Tailings, % C	25
Recovery, %	72

The incorporation of a single Jameson Cell in the graphite processing flowsheet has maintained the economic viability of the commercial operation. The Jameson Cell produces a sticky froth concentrate of fine/ultrafine graphite that is continuously fed to the tertiary cleaner feed. Plant recovery is thus critically enhanced at the required product grade of 98% C.

Table 8. Results of Jameson cell fluorspar flotation

Application	*No. of Jameson Cell stages*	*Feed*	*Concentrate*	
Lead		% Pb	% Pb	Recovery, %
PbS total system	1	6.5	69.8	93.4
Fluorspar:		% CaF_2	% CaF_2	Recovery, %
Cleaner 1	1	78.2	94.0	86.3
Cleaner 2	1	93.8	97.8	52.0

Summary

The hydrodynamic Jameson Cell uses static *downcomers* to eliminate the mechanical systems of conventional flotation equipment, and increase the reliability of the flotation circuit. The commercially operating Jameson Cell at Cleveland Potash achieves efficient fine particle selectivity from tertiary cyclone underflow. The single stage Jameson Cell replaces the entire original 370 m^3/h Slimes Flotation circuit; equipment footprint is thereby reduced by 80%. Net operational savings of £ 209,985 pa are verified by the additional site revenue gained from increased potash recovery and by the 80% cost savings in both the ongoing maintenance and the energy drawn.

Coarse potash +850 μm recovery from standard flotation rougher concentrate is achievable in a pilot Jameson Cell indicating a future possible potential of increasing the plant recovery at a premium product size. Associated improvements of concentrate debrining, centrifuging, and drying are envisaged whilst simultaneously reducing the mass load to regrinding. Fine graphite selectivity is commercially achieved from an inefficiently classified primary cyclone overflow thereby enhancing plant recovery of 98% C and ensuring an entire operation's economic viability.

Pilot tests have shown positive application of the downcomer to zircon roughing, galena flotation from fluorspar, and fluorspar cleaning. For galena and fluorspar duties, high grade concentrates are produced by the Jameson Cell in a greatly reduced number of stages when compared with the conventional equipment in current operating use. Further site work is essential to clarify the application of the Jameson Cell to zircon and fluorspar duties. The numerous intrinsic and extrinsic attributes of the Jameson Cell lend themselves to the consistent production of a rising, non-turbulent, mineral loaded froth available for continuous washing. This significant froth characteristic should greatly assist the profitable achievement of product grade for many other industrial mineral applications.

References

1. Atkinson B.W., Conway C.J. and Jameson G.J. High Efficiency Flotation of Coarse and Fine Coal, paper presented at: High Efficiency Coal Preparation Symposium, SME Annual Meeting, AIME 124th Annual Meeting, March 6-9, Denver, Colorado, USA (1995).
2. Couch G.R., Flotation, p38-45, section 5.1 in: Advanced Coal Cleaning Technology IEACR/44, pp96, IEA Coal Research, London, England (1991).
3. Hall S.T., Developing Flotation Technologies, p(1.1.1-1.1.5) in: Proceedings of Minprep '91 Symposium, Minerals Engineering the Challenges for the '90s, 9-11 April, Doncaster, UK, 09-11 April 1991, pp81, Mining Industry Promotions Ltd, Rickmansworth, England (1991).
4. Skillen A., Froth Flotation: New Technologies Bubbling Under, Industrial Minerals, No.305, February, p47-59 (1993).
5. Evans G.M., Atkinson B.W. and Jameson G.J. The Jameson Cell, p331-363 in Flotation Science and Engineering, pp576, Marcel Dekker, New York, USA (1995).
6. Burns M.J., Coates G. and Barnard L., Use of Jameson Cell Flotation Technology at Cleveland Potash Ltd., North Yorkshire, England, Trans IMM, Sect. C, Vol. 103, C162-167 (1994).
7. Burns M.J., Coates G., Barnard L., The Use of Jameson Cell Flotation Technology at Cleveland Potash, p290-300 in: Proceedings of International Fertilizer Association (IFA) Technical Conference, Amman, Jordan, 2-6 October 1994, pp492, IFA, Paris, France (1994).
8. Burns M.J, Pearson J. and Harrison M.E. Operating Experience and Savings with Jameson Cell Technology at Cleveland Potash, paper in press.
9. Nemedy L., Factors Influencing Froth Stability in Potash Processing, p605-609 in: Proceedings of First International Potash Technology Conference, Saskatoon, Saskatechwan, Canada, 3-5 October 1983, pp887, Pergammon Press, Oxford, England (1984).

IM