Use of Jameson cell flotation technology at Cleveland Potash, Ltd., North Yorkshire, England

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Cleveland Potash, Ltd. (CPL), is a mining company that extracts and refines sylvinite ore, primarily KCl and NaCl, from an evaporite deposit in North Yorkshire, England. The processing plant uses froth flotation to produce a KCl-rich product, which can be either a very fine concentrate (−100 μm) or a coarser concentrate (100–1100 μm). The Jameson cell is being tested in both circuits.

Although KCl is readily rendered hydrophobic by the amine collector, difficulty in recovering high-grade, coarse material is still experienced. Enhanced recovery of this slow-floating, +0.85-mm fraction would improve overall plant efficiency by assisting the debrining and drying of concentrates and by reducing pressure on secondary milling. Fig. 1 summarizes the primary aspects of the circuit.

Pilot trials

The pilot Jameson cell had an internal diameter of 520 mm and was approximately 5 m high. The cell was fed by a Warman slurry pump that generated a flow of 10 $m^3 h^{-1}$ at 2.5 bar, as measured at the feed inlet. The residence time in the cell was calculated to be 2 min. A schematic section of the cell is presented as Fig. 2.

Flotation of four different streams was undertaken with the Jameson cell; details of the streams are given in Table 1.

Flotation of recleaner concentrate

In tests on the flotation of recleaner concentrate methyl isobutyl carbinol (MIBC) frother was added directly into the pump suction line at the required addition of 5 ppm, which is critical in establishing and maintaining flotation. The slurry–froth interface was adjusted to a depth of 30 cm below the cell lip with the use of a bubble probe, relay and air-operated tails sleeve valve. At this stage no attempt was made to wash the froth with saturated brine.

The air flow to the cell was set at 50 l min^{-1}, equivalent to a superficial rise velocity factor of 0.41 cm s^{-1} and an air to pulp ratio of 1:3.33. Rise velocity is simply air flow divided by the cross-sectional area of the cell and is critical in determining scale-up parameters.

Flotation of cleaner concentrate

Cell conditions for the flotation of cleaner concentrate remained the same as those described above. Grade and recovery were measured over a wide range of feed grades, as was necessary to analyse the potential of the Jameson cell as a feasible production technology. The slurry density was maintained at 15–20 wt% solids to assist pumping and thereby stabilize feed inlet pressure and air flow into the cell at 2.5 bar and 50 l min^{-1}, respectively. Table 2 gives details of the results. The data in Table 3 illustrate how both the

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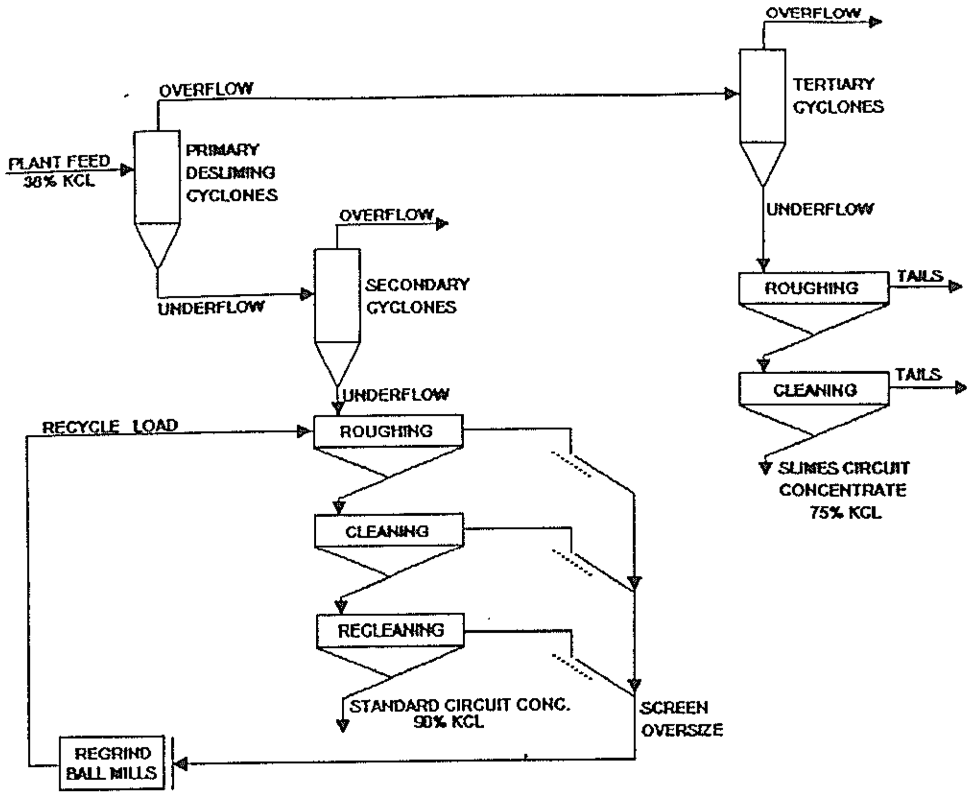

Fig. 1 Layout of standard and slimes flotation circuit at Cleveland Potash, Ltd.

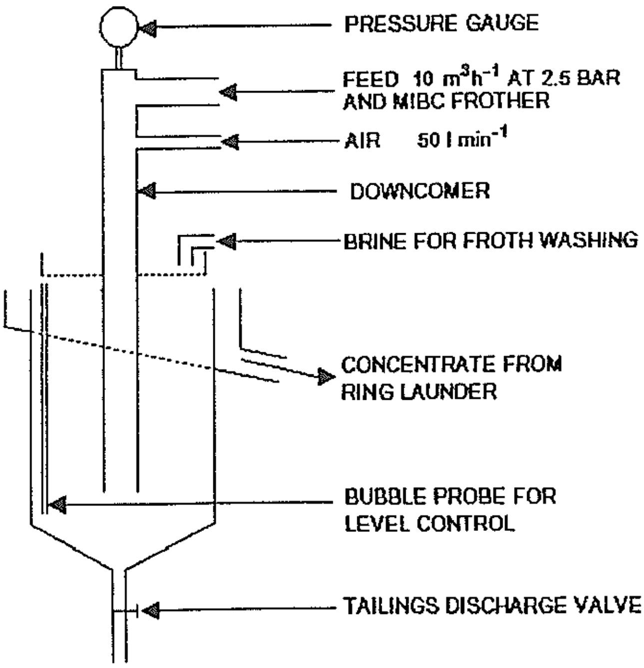

Fig. 2 Schematic diagram of Jameson cell

Jameson cell and present cleaners behave with extremely poor feed grades. Size analyses of the concentrates produced from the cells are documented in Table 4.

Flotation of rougher concentrate

In tests on the flotation of rougher concentrate the state of the cell was altered, the depth of the froth bed being increased to 40 cm. Air flow and MIBC additions remained the same. The sampling campaigns were constructed to

Table 1 Characteristics of streams tested

Size, mm	Concentrate Rougher	Cleaner	Recleaner	Slimes float feed
Amount retained, wt%				
+0.85	12.4	6.2	2.6	0.0
−0.85+0.60	14.3	15.4	14.6	0.3
−0.60+0.30	39.3	45.7	51.6	3.0
−0.30+0.10	24.6	24.8	26.7	34.6
(−0.10)	9.4	7.9	4.5	62.1
Solids, wt%	32	33	38	18
Sp. gr.	1.41	1.42	1.45	1.33
KCl, wt%	70–80	80–87	87–90	25–35

enable comparison of recoveries obtained with the Jameson cell with those produced by the entire plant cleaner and recleaner circuit (Tables 5 and 6). At this stage froth washing was undertaken (runs 23, 24 and 27) in an attempt to remove entrained gangue.

In runs 11 to 21 tests were conducted at froth bed depths of 30 cm and no washing was carried out. The remaining operational parameters were unchanged.

During the flotation of rougher concentrate the recovery path of the coarse, +0.85-mm material was traced (Figs. 3 and 4).

Flotation of slimes float feed

In flotation of slimes float feed tests were carried out with the froth bed at 40 cm and no alteration of other variables. No dilution of the feed, however, was required as it was evident that feed inlet pressures and air influx were adequate. The results are given in Table 7.

Table 2 Performance of cells treating cleaner KCl concentrate

Run	Date	Jameson cell Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %	Plant recleaner cells Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %
1	29/04	75.4	34.7	91.2	87.0	75.4	44.3	89.0	82.1
2	04/05	80.0	22.5	88.1	96.5	80.0	48.1	91.5	84.1
3	05/05	65.5	20.1	89.2	89.5	65.5	34.0	88.1	78.3
4	06/05	75.8	44.3	90.6	81.3	75.8	48.9	89.5	78.2
5	06/05	70.0	32.6	88.6	84.5	70.0	49.2	89.2	66.3
6	06/05	73.7	38.8	88.5	84.3	73.7	48.5	90.6	73.6
7	06/05	68.3	31.9	88.0	83.6	68.3	37.5	90.3	77.1
8	13/05	72.0	18.8	87.4	94.1	72.0	27.0	88.0	90.2
Mean		72.6	30.5	89.0	87.6	72.6	42.2	89.5	78.7

Table 3 Performance of cells treating low-grade cleaner concentrate

Run	Date	Jameson cell Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %	Plant recleaner cells Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %
9	06/05	41.3	16.5	89.7	73.6	41.3	28.1	88.6	46.8
10	06/05	43.2	20.5	88.5	68.4	43.2	26.9	88.5	54.2
Mean		42.3	18.5	89.1	71.0	42.3	27.5	88.6	50.5

Table 4 Size distribution of concentrates from Jameson cell and plant recleaner cells

Sieve size, mm	Retained, wt% 1	2	KCl, wt% 1	2	NaCl, wt% 1	2	Insolubles, wt% 1	2
+0.85	30.4	5.7	90.8	92.7	8.0	6.8	1.2	0.5
−0.85+0.60	31.3	21.3	85.1	89.0	10.5	8.0	4.4	3.0
−0.60+0.30	27.4	41.9	86.3	91.6	12.3	8.0	1.4	0.4
−0.30+0.10	9.7	26.3	91.1	92.1	8.0	7.4	0.9	0.5
(−0.10)	1.2	4.8	71.2	79.7	3.4	6.4	25.4	13.9

1, Jameson cell concentrate.
2, Plant recleaner concentrate.

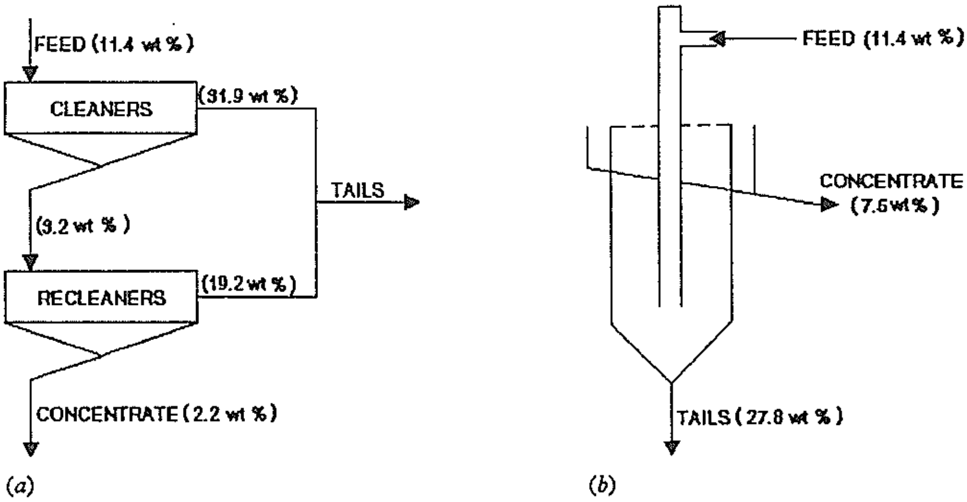

Fig. 3 Deportment of slow-floating +850-μm high-grade KCl particles to final concentrate in test run 24: (*a*) plant circuit; (*b*) Jameson cell. Data in figure refer to material retained. Total recoveries of +850-μm material to concentrate with plant circuit and Jameson cell were 14.75 and 53 wt%, respectively

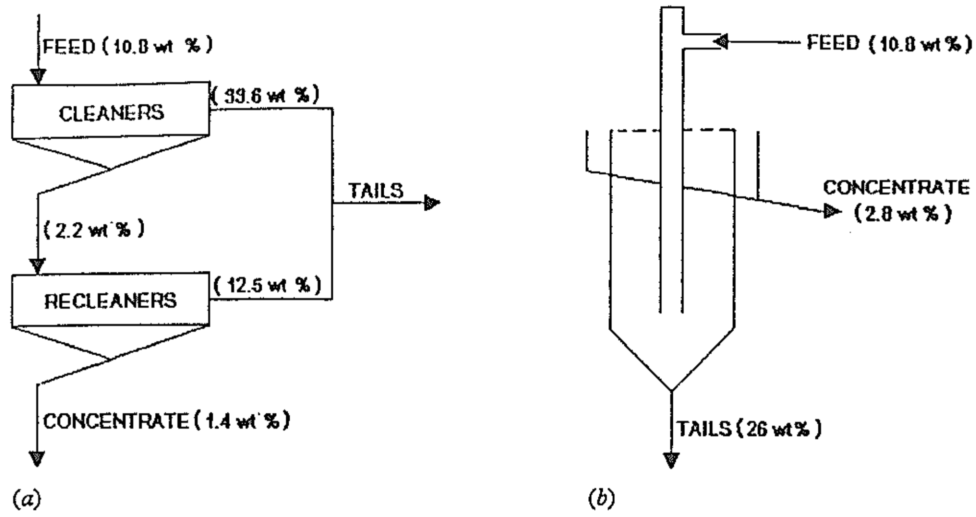

Fig. 4 Deportment of slow-floating +850-μm high-grade KCl particles to final concentrate in test run 25: (*a*) plant circuit; (*b*) Jameson cell. Data in figure refer to material retained. Total recoveries of +850-μm material to concentrate with plant circuit and Jameson cell were 8.74 and 17 wt%, respectively

Discussion and conclusions

Immediately after commissioning very little manipulation of metallurgical parameters—such as air flow, frother addition, depth of froth bed, levels of slurry in the downcomer and froth washing—was required to establish optimum performance from the cell. Neither was there any onerous requirement for testwork involving the analysis of small, incremental changes in cell variables. Most of the testwork was centred on the development of accurate sampling methods and continuous 24-h cell operation with minimum supervision.

Table 1 gives the characteristics of the streams that were tested; the solids content of the slurry proved to be significant throughout the pilot trials. For all streams except the slimes flotation feed it was necessary to dilute the feed to the Jameson cell with saturated brine at a ratio of 1:1. The total volumetric recovery from the CPL rougher flotation section is 500 $m^3 h^{-1}$. A full-scale production unit would, therefore, be required to accommodate an influx of 1000 $m^3 h^{-1}$. Preliminary scale-up calculations indicate that two units with diameters of 2.75 m would be needed to provide an effective replacement for 28 Denver no. 30DR 2.8-m^3 cleaner and recleaner cells.

The solids content of the rougher concentrate is, typically, 32 wt%, which does not produce an unduly viscous slurry. The concentrate, however, contains an appreciable amount of entrained air that does not easily escape from the pump box feeding the cell, resulting in low and surging feed inlet pressures of less than 2.5 bar. This poor operating condition gives rise to low degrees of aspiration, with subsequent loss of flotation performance. The prime role of the saturated brine diluent was, therefore, the removal of entrained air prior to pumping, its effect in reducing the apparent influence of viscosity not being overly significant. It remains to be seen if a method other than that of further dilution with brine can be found to reduce pressure loss at the feed inlet, thereby reducing the scale and cost of a larger industrial unit.

Flotation of recleaner concentrate

At present there is little scope for a fourth flotation step at CPL. Use of the Jameson unit did, however, result in an upgrade of the recleaner concentrate from 88.5 wt% KCl to 91.2 wt% KCl at a recovery of 94.7% KCl. This brief run yielded a sound base level and reference point for ensuing testwork.

Flotation of cleaner concentrate

Table 2 provides a comparison of the performances of the

Table 5 Performance of cells treating rougher concentrate

Run	Date	Jameson cell (with 30 cm froth-bed depth) Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %	Plant recleaner cells Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %
11	18/05	67.1	24.0	88.5	88.1	67.1	33.6	79.4	86.6
12	19/05	63.9	32.8	88.5	77.3	63.9	27.7	85.8	83.7
13	19/05	69.9	29.4	90.0	86.0	69.9	32.8	87.9	84.7
14	19/05	76.7	37.4	90.0	87.7	76.7	33.9	87.4	91.2
15	19/05	74.6	36.6	87.4	87.6	74.6	40.4	86.9	85.7
16	20/05	65.5	31.1	87.4	81.5	65.5	34.5	86.3	78.8
17	20/05	61.7	30.4	88.5	77.3	61.7	28.9	83.9	81.1
18	20/05	68.3	29.6	88.5	85.1	68.3	33.8	84.4	84.2
19	20/05	71.2	36.4	89.0	82.7	71.2	40.9	85.8	81.3
20	20/05	66.4	33.8	90.1	78.6	66.4	36.4	86.9	77.7
21	20/05	65.6	40.5	91.2	68.8	65.6	33.8	86.3	79.7
Mean		68.3	32.9	89.0	81.9	68.3	34.2	85.5	83.2

Table 6 Performance of cells treating rougher concentrate

Run	Date	Jameson cell (with 40 cm froth-bed depth)				Plant recleaner and cleaner cells			
		Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %	Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %
22	11/06	78.8	47.0	90.0	84.5	78.8	54.5	90.2	78.0
23*	15/06	80.0	52.9	90.2	82.2	80.0	63.0	92.7	67.0
24*	15/06	79.9	48.1	91.7	83.7	79.9	53.0	91.8	79.6
25	16/06	74.7	47.3	89.6	77.7	74.7	50.7	89.0	74.6
26	16/06	79.4	46.5	92.8	83.0	79.4	47.2	93.9	74.0
27*	24/06	77.5	52.6	91.1	76.0	77.5	53.5	91.1	75.0
Mean		78.4	49.1	90.9	81.2	78.4	53.6	91.4	74.7

*Froth bed was washed with saturated brine to minimize entrainment.

Table 7 Performance of cells treating slimes float feed

Run	Date	Jameson cell				Plant recleaner cells			
		Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %	Feed, wt% KCl	Tails, wt% KCl	Concentrate, wt% KCl	Recovery, %
28	07/07	27.8	4.9	77.4	87.9	27.8	8.5	78.4	77.9
29	08/07	18.4	6.0	75.9	73.2	18.4	6.5	77.9	70.6
30	09/07	23.3	4.6	71.8	85.8	23.3	6.6	82.3	77.9
31	12/07	21.8	4.9	70.0	83.4	21.8	4.3	78.5	84.9
Mean		22.8	5.1	73.8	82.6	22.8	6.5	79.3	77.8

Jameson cell and CPL recleaner cell with identical feeds. It is clear that the former achieved a superior grade and recovery of KCl at 89 wt% and 87.6%, respectively, the mean values of the plant recleaners being 89.5 wt% KCl at 78.7% recovery. The additional recovery is undoubtedly attributable to the reporting of high-grade, coarse particles to the concentrate on a scale that is not observed in plant recleaner operation (Table 4).

During the sampling campaign for which details are given in Table 4 the Jameson cell recovered 30.4 wt% +0.85-mm material to the concentrate compared to 5.7 wt% of the same fraction achieved by the plant recleaner cells. The benefits of such performance can be seen in terms of improved debrining, centrifuging and drying of concentrate, improved overall plant recovery and less recycle to secondary milling.

The results in Table 3 highlight the performance of the Jameson cell with very poor feed grades. It is apparent that it can operate at high efficiencies under extreme plant conditions. Indeed, recoveries are far higher with the Jameson cell, which would offer hope of a large reduction in recycle back to rougher flotation during times when the plant is required to process low head grades.

Flotation of rougher concentrate

Two distinct sampling campaigns were undertaken during the flotation of rougher concentrate, results for which are given in Tables 5 and 6. Table 5 compares the performance of the Jameson cell with that of the plant cleaner cell—again, with identical feed grades. The mean values of all campaigns show that the Jameson cell achieved a KCl grade of 89 wt% with 81.9% recovery. The plant cleaners produced a grade of 85.5 wt% KCl at 83.2% recovery. The poorer Jameson cell recovery simply reflects a high froth–slurry interface. A major advantage of the Jameson cell is the ease with which the slurry–froth interface can be altered in response to changing feed grades, which are seen to fluctuate quite markedly.

The results given in Table 6 are for more detailed sampling that was undertaken to allow direct comparison of the performance of the Jameson cell with that of the entire plant cleaner and recleaner circuit, as shown in Figs. 3 and 4. The mean values of the sampling campaigns given in Table 6 clearly show the difference in performance between the Jameson cell and the plant recleaners and cleaners. The Jameson cell produced acceptable final concentrate grades, similar to those achieved by the plant recleaners, with a recovery of 81.2% KCl—as opposed to a recovery of 74.7% for the whole of the circuit illustrated in Figs. 3 and 4. The extra recovery results from the fact that coarse material reports to concentrate and not to tails.

On three occasions the froth bed was washed with saturated brine (run numbers 23, 24 and 27), but no significant benefits were readily apparent. This is entirely to be expected owing to the nature of the froths at CPL, which are not prone to entrainment.

Flotation of slimes flotation feed

Two different grade/recovery relationships are evident from the data in Table 7, which gives results that were obtained in the treatment of slimes flotation feed. The recovery by the Jameson cell of 82.6% would result in the production of an additional 1 t h^{-1} potash, representing additional revenue of approximately £518 000 per year.

The argument that similar recoveries could be achieved with present plant cells by pulling the concentrate forward at a quickened pace is flawed owing to the practicalities of dealing with higher volumetric flows of pulp at low densities. The final slimes concentrate would be certain to suffer.

CPL has decided to purchase a production unit to treat slimes flotation feed. The unit will also be used to treat rougher flotation concentrate to assist in the decision to purchase further Jameson cells to replace the standard cleaner and recleaner circuit entirely. The cell would have a diameter of 3.25 m and would treat 325 m^3 h^{-1} slurry. Effectively, it would replace two banks of roughers and one bank of cleaners, a total of 16 2.8-m^3 cells.

Envisaged savings

The power requirement of the motors of the present cells is an obvious area for savings; electricity costs would be reduced by at least £21 000 per year. The cost of maintaining 28 Denver cells in parts alone is close to £20 000 per year (not including the cost of manpower requirements). The fuel requirements for drying the final product would be reduced, possibly realizing savings of the order of £100 000. These estimates are based on the replacement of 28 2.8-m^3 cleaner and recleaner cells by two Jameson units. The payback period would be approximately one year. It should be noted that if the cells were replaced by traditional agitated units, there would be no savings and no payback period as there would be no metallurgical benefits.

It is readily apparent that Jameson cell flotation offers lower capital and running costs in addition to improved metallurgical performance.

Authors

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