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THE USE OF JAMESON CELL FLOTATION TECHNOLOGY AT CLEVELAND POTASH

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RESUME

Les études en pilote utilisant la cellule de flottation Jameson ont montré les avantages tangibles qui résulteraient du passage à une unité de production spécialisée à l'intérieur du circuit de flottation. On a constaté que deux de ces cellules auto-aspirantes seraient nécessaires pour remplacer les 28 cellules de flottation existantes avec nettoyeur et renettoyeur, suivant le principe traditionnel avec entraînement par roue motrice.

La cellule Jameson a fait la preuve d'un rapport supérieur titre/rendement à cause de son aptitude à récupérer des particules de potasse riches dans les fractions grossières (+ 850 μm).

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INTRODUCTION

Cleveland Potash Limited (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 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 +0.85mm fraction would improve overall plant efficiency by assisting concentrate debrining and drying, and reducing pressure on secondary milling. Figure 1 condenses the primary aspects of the circuit.

EXPERIMENTAL

The pilot cell had an internal diameter of 520 mm, and was approximately 5 m high.The cell was fed by a Warman slurry pump generating a flow of 10 m^3h^{-1} at 2.5 bar, as measured at the feed inlet. Residence time within the cell was calculated at 2 minutes. Figure 2 outlines cell structure.

Flotation of four different streams was undertaken with the Jameson cell, as detailed in Table 1.

Flotation of recleaner concentrate

M.I.B.C frother was added directly into the pump suction line at the required addition of 5ppm; critical in establishing and maintaining flotation. The slurry/froth interface was adjusted to a depth of 30 cm below the cell lip using 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 airflow to the cell was set to 50 l min^{-1} equating 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 airflow divided by cell cross sectional area and is critical in determining scale up parameters.

Flotation of cleaner concentrate

Cell conditions remained the same. Grade and recovery was measured over a wide range of feed grades, necessary in analysing its potential as a feasible production technology. The slurry density was maintained between 15 and 20 wt% solids to assist pumping and thereby stabilise feed inlet pressure and air flow into the cell at 2.5 bar and 50 l min^{-1} respectively. Table 2 details results.

Flotation of rougher concentrate

The state of the cell was altered; the froth bed depth was increased to 40 cm. Airflow and M.I.B.C. additions remained the same. The sampling campaigns were constructed in such a way as to compare the Jameson cell recoveries with those produced by the entire plant cleaner and recleaner circuit, as given in Table 6. At this stage froth washing was undertaken in an attempt to remove entrained gangue. Run numbers 23,24 and 27 were chosen.

For run numbers 11 to 21, Table 5, tests were conducted at froth bed depths of 30 cm and no washing was carried out. The remaining operational parameters were unchanged.

During rougher concentrate flotation the recovery path of the coarse +0.85 mm material was traced, illustrated in Figures 3 and 4, and Table 4.

Flotation of slimes float feed

Tests were carried out with the froth bed at 40 cm and no change to other variables. No dilution of the feed, however, was required as adequate feed inlet pressures and air influx were evident. The results are in Table 7.

DISCUSSION AND CONCLUSIONS

Immediately after commissioning very little manipulation of metallurgical parameters such as, air flow, frother additions, froth bed depth, levels of slurry in the downcomer, and froth washing was required in order to establish optimum performance from the cell. There was no overwhelming requirement for testwork involving the analysis of small incremental changes in cell variables. The majority of the testwork was centred around developing accurate sampling and continuous 24 hour cell operation with minimum supervision.

Table 1 details the characteristics of the streams tested; the solids content of the slurry proved to be significant throughout the pilot trials. For all streams except slimes flotation feed it was necessary to dilute the Jameson cell feed with saturated brine at a ratio of 1:1. The total mass pull from the CPL rougher flotation section is 500 m^3h^{-1}. A full scale production unit would therefore be required to accommodate an influx of 1000 m^3h^{-1}. Preliminary scale up calculations indicate that two 2.75 m diameter units would be necessary, in order to effectively replace 28 Denver No.30DR 2.8m^3 cleaner and recleaner cells.

The rougher concentrate is typically 32 wt% solids 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 less than 2.5 bar. This poor operating condition gives rise to low degrees of aspiration with subsequent loss of flotation performance. The role of the saturated brine was therefore instrumental in removing entrained air prior to pumping and not overly significant in reducing the apparent influence of viscosity. It remains to be seen if an alternative solution for reducing pressure loss at the feed inlet can be found, other than that of additional dilution brine, thereby reducing the scale and cost of a larger industrial unit.

Flotation of recleaner concentrate

Presently there is little scope for a fourth flotation step at CPL. The Jameson unit did, however, upgrade from 88.5% KCl to 91.2% KCl at a recovery of 94.7% KCl. This brief run on recleaner concentrate yielded a sound base level and reference point for ensuing testwork.

Flotation of cleaner concentrate

Table 2 and figures 5 and 6 give the performance of the Jameson cell versus CPL recleaner cell performance, with identical feeds. The Jameson cell has clearly established a superior grade/recovery at 89% KCl and 87.6% respectively; the mean values of the plant recleaners being 89.5% KCl at 78.7% recovery. This additional recovery is undoubtedly attributable to high grade coarse particles reporting to the concentrate on a scale which is not observed within plant recleaner operation, see Table 4. A students t-test on paired mean concentrate and recovery results yield values of 0.107 and 3.524 respectively. The slightly higher grade produced from the Jameson cell is not significant while the recovery is significant.

During the sampling campaign detailed in Table 4 the Jameson cell recovered 30.4 wt% + 0.85 mm material to the concentrate, compared with 5.7 wt% + 0.85 mm by plant recleaner cells. The benefits of such performance can be qualified in terms of improved concentrate debrining, centrifuging, drying, improved overall plant recovery, and less recycle to secondary milling.

A separate issue is made of Table 3 which highlights Jameson cell performance with very poor feed grades. It can therefore operate to high efficiencies under extreme plant conditions. Indeed recoveries are far higher with the Jameson cell, which would yield hope for 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 resulting in the drafting of Tables 5 and 6. Table 5 simply compares Jameson cell performance against plant cleaner cell performance, again with identical feed grades. Mean values of all campaigns show the Jameson cell at 89% KCl grade and 81.9% recovery. The plant cleaners produced a grade of 85.5% KCl at 83.2% recovery. The poorer Jameson cell recovery simply reflects a low froth/slurry interface. A major advantage of the Jameson cell is the ease by which the slurry/froth interface can be altered in response to altering feed grades which are seen to fluctuate quite markedly. A two sided student t-test for paired mean concentrate and recovery results, gives values of 4.9 and 0.7 respectively. This indicates that the Jameson cell grade is significant with little chance of the existing circuit matching this figure with a recovery of 83.2%. The better plant recovery of 83.2% is not significant. There is a very good chance that this could be achieved from the Jameson cell frequency distribution.

For the results detailed in Table 6 the sampling became more detailed and the Jameson cell was compared directly against the performance of the entire plant cleaner and recleaner circuit,as in Figures 3 and 4. The froth bed depth was increased from 30 cm to 40 cm. The mean values of the sampling campaigns given in Table 6 clearly shows the hiatus in performance between the Jameson cell and plant recleaners/cleaners. The Jameson cell is observed to produce acceptable final concentrate grades similar to plant recleaners with a recovery of 81.2% KCl as set against a recovery of 74.7% for the whole of the circuit. This extra recovery results from the coarse material reporting to concentrate and not to tails. Figures 7, 8, 9 and 10 yield a visual aspect to the tabulated values.

On three occasions the froth bed was washed with saturated brine; run numbers 23, 24 and 27. It is concluded that no significant benefits are to be readily found by washing the froth. This is entirely to be expected, owing to the very nature of the froths at CPL which are not prone to entrainment.

Flotation of slimes flotation feed

From Table 7 two different grade/recovery relationships are evident. The Jameson cell recovery of 82.6% would result in an additional one tonne per hour of potash being recovered, resulting in additional revenue of approximately £518,000 per year.

The argument, to achieve similar recoveries 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 is certain to suffer.

Cleveland Potash Limited have decided to purchase a full scale unit to treat slimes flotation feed. This unit will also be used to treat rougher flotation concentrate to assist in the decision to purchase further Jameson cells to entirely replace the standard cleaner and recleaner circuit. This cell would have a diameter of 3.25 m and would treat 325 m^3h^{-1} of slurry. It would effectively replace 2 banks of roughers and one bank of cleaners, totalling 16 X 2.8m^3 cells.

ENVISAGED SAVINGS

The power requirements for the motors is an obvious candidate; the electricity costs would be reduced by at least £21,000 per year. The cost in maintaining 28 Denver cells in parts alone is close to £20,000 per year (neglecting any savings in manpower). The fuel requirements to dry the final product would reduce, possibly realising savings in the order of £100,000. These estimates are based on the scenario of 28 X 2.8 m^3 cleaner and recleaner cells being replaced by 2 Jameson units. The pay-back period would be approximately one year.

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

CONTRIBUTORS

Martin Burns, member of the Institute of Mining and Metallurgy. Research and Development Engineer at Cleveland Potash. Previously worked in South Africa as Plant Metallurgist for Johannesburg Consolidated Industries, gaining experience within the realms of precious and base metal processing. Graduate of Leeds University, holding a B.Eng(Hons) in Mineral Processing and an M.Sc in Engineering Ceramics.

Garry Coates, Metallurgical Technician at Cleveland Potash for six years. Holds HND qualifications in Civil Engineering and Business Studies and Finance.

Lucy Barnard, Metallurgical Technician at Cleveland Potash for one year. Previously worked as a research assistant at the National Physical Laboratory. Graduate of Imperial College of Science Technology and Medicine, holding a B.Eng(Hons) in Material Science and Engineering.

TABLE 1
Characteristics of streams tested. Amount retained wt %

Size-mm	Rougher Conc	Cleaner Conc	Recleaner Conc	Slimes Float Conc
+0.85	12.4	6.2	2.6	0.0
- 0.85+0.6	14.3	15.4	14.6	0.3
- 0.60+0.3	39.3	45.7	51.6	3.0
- 0.30+0.1	24.6	24.8	26.7	34.6
(-0.1)	9.4	7.9	4.5	62.1
% Solids	32	33	38	18
kg m^{-3}	1.41	1.42	1.45	1.33
% KCl	70-80	80-87	87-90	70-80

TABLE 2
Cells treating cleaner concentrate. Weight % KCl present in streams

	Jameson cell performance				Plant recleaner performance			
Run	Feed	Tails	Conc	Rec	Feed	Tails	Conc	Rec
1	75.4	34.7	91.2	87.0	75.4	44.3	89.0	82.1
2	80.0	22.5	88.1	96.5	80.0	48.1	91.5	84.1
3	65.5	20.1	89.2	89.5	65.5	34.0	88.1	78.3
4	75.8	44.3	90.6	81.3	75.8	48.9	89.5	78.2
5	70.0	32.6	88.6	84.5	70.0	49.2	89.2	66.3
6	73.7	38.8	88.5	84.3	73.7	48.5	90.6	73.6
7	68.3	31.9	88.0	83.6	68.3	37.5	90.3	77.1
8	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
Cells treating low grade cleaner concentrate

	Jameson cell performance				Plant recleaner performance			
Run	Feed	Tails	Conc	Rec	Feed	Tails	Conc	Rec
9	41.3	16.5	89.7	73.6	41.3	28.1	88.6	46.8
10	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 recleaner and Jameson concentrates

Sieve size	% wt retained		% KCl		% NaCl		% Insolubles	
mm	1	2	1	2	1	2	1	2
+0.85	30.4	5.7	90.8	92.7	8.0	6.8	1.2	0.5
+0.60-0.85	31.3	21.3	85.1	89.0	10.5	8.0	4.4	3.0
+0.30-0.60	27.4	41.9	86.3	91.6	12.3	8.0	1.4	0.4
+0.10-0.30	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

TABLE 5
Cells treating rougher concentrate.
Jameson cell with 30cm froth bed depth. Weight % KCl in streams

	Jameson cell performance				Plant cleaner performance			
Run	Feed	Tails	Conc	Rec	Feed	Tails	Conc	Rec
11	67.1	24.0	88.5	88.1	67.1	33.6	79.4	86.6
12	63.9	32.8	88.5	77.3	63.9	27.7	85.8	83.7
13	69.9	29.4	90.0	6.0	69.9	32.8	87.9	84.7
14	76.7	37.4	90.0	87.7	76.7	33.9	87.4	91.2
15	74.6	36.6	87.4	87.6	74.6	40.4	86.9	85.7
16	65.5	31.1	87.4	81.5	65.5	34.5	86.3	78.8
17	61.7	30.4	88.5	77.3	61.7	28.9	83.9	81.1
18	68.3	29.6	88.5	85.1	68.3	33.8	84.4	84.2
19	71.2	36.4	89.0	82.7	71.2	40.9	85.8	81.3
20	66.4	33.8	90.1	78.6	66.4	36.4	86.9	77.7
21	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
Cells treating rougher concentrate.
Jameson cell with 40 cm froth bed depth. Weight % KCl present in streams

	Jameson cell performance				Plant cleaner and recleaner performance			
Run	Feed	Tails	Conc	Rec	Feed	Tails	Conc	Rec
22	78.8	47.0	90.0	84.5	78.8	54.5	90.2	78.0
23	80.0	52.9	90.2	82.2	80.0	63.0	92.7	67.0
24	79.9	48.1	91.7	83.7	79.9	53.0	91.8	79.6
25	74.7	47.3	89.6	77.7	74.7	50.7	89.0	74.6
26	79.4	46.5	92.8	83.0	79.4	47.2	93.9	74.0
27	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

TABLE 7
Cells treating slimes float feed. Weight % KCl present in streams

	Jameson cell performance				Combined slimes rougher and cleaner performance			
Run	Feed	Tails	Conc	Rec	Feed	Tails	Conc	Rec
28	27.8	4.9	77.4	87.9	27.8	8.5	78.4	77.9
29	18.4	6.0	75.9	73.2	18.4	6.5	77.9	70.6
30	23.3	4.6	71.8	85.8	23.3	6.6	82.3	77.9
31	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

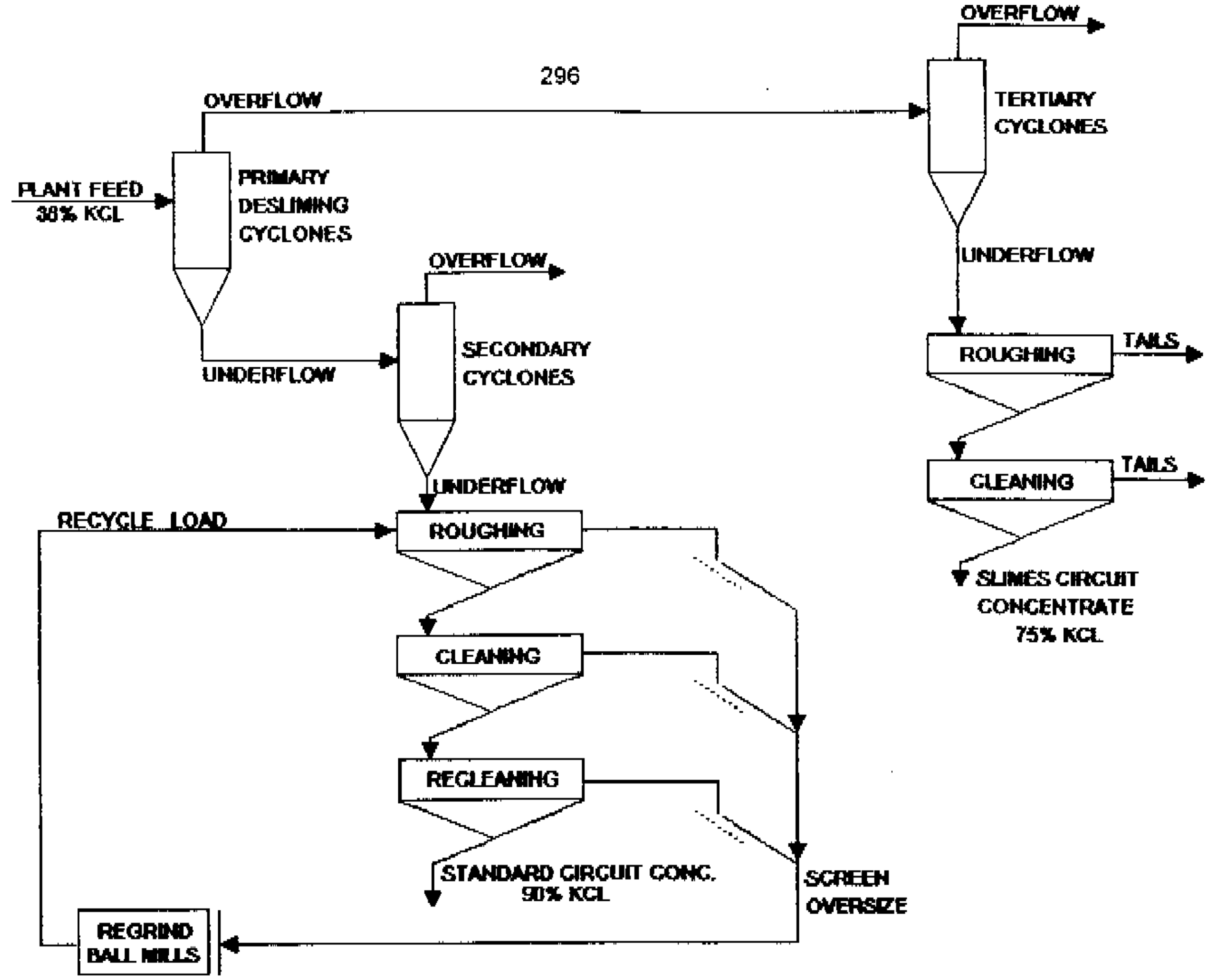


FIGURE 1. LAYOUT OF STANDARD AND SLIMES FLOTATION CIRCUIT AT CLEVELAND POTASH LTD.

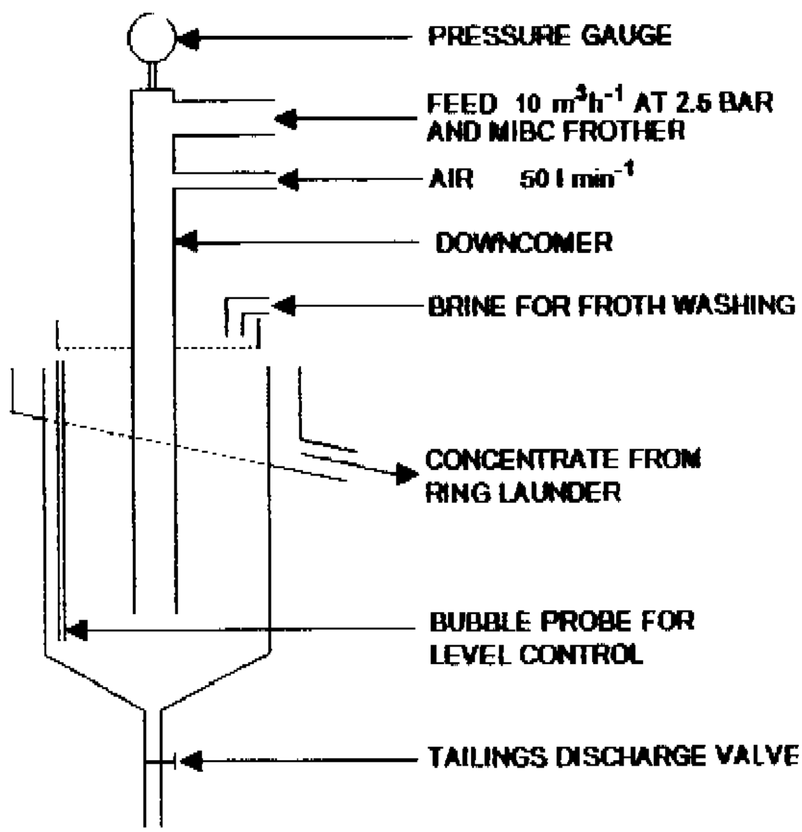
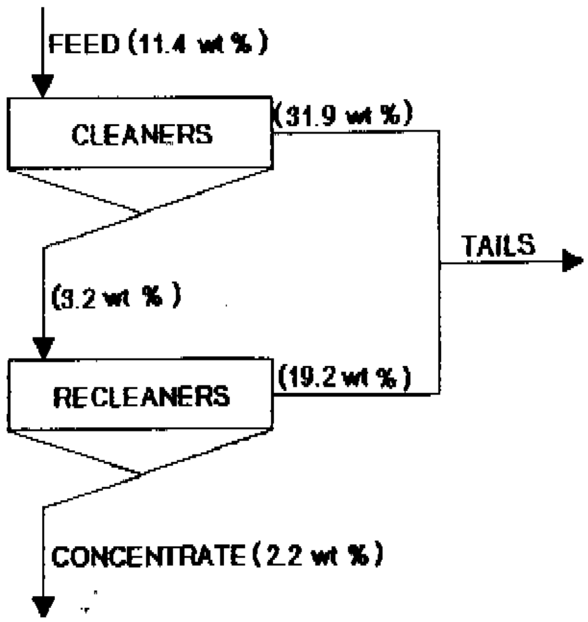
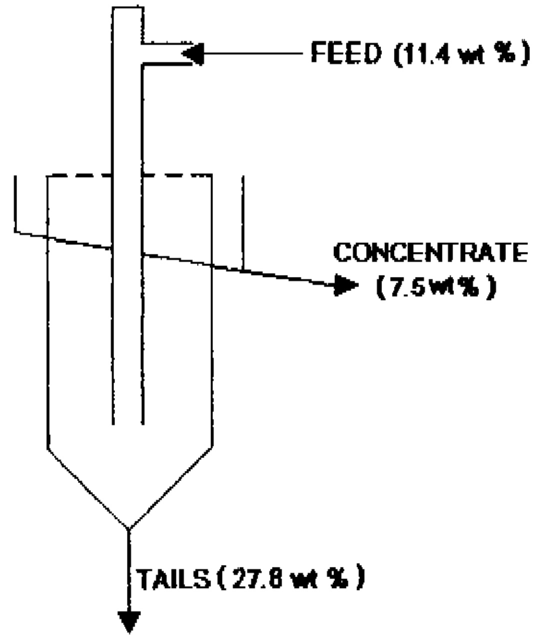


FIGURE 2. SCHEMATIC DIAGRAM OF JAMESON CELL

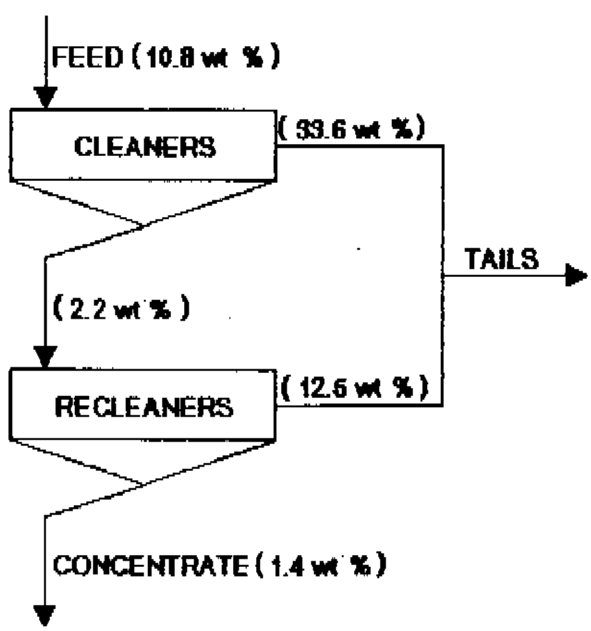


(i) PLANT CIRCUIT
TOTAL RECOVERY OF +850 μm
MATERIAL TO THE CONCENTRATE WAS 14.75 wt %

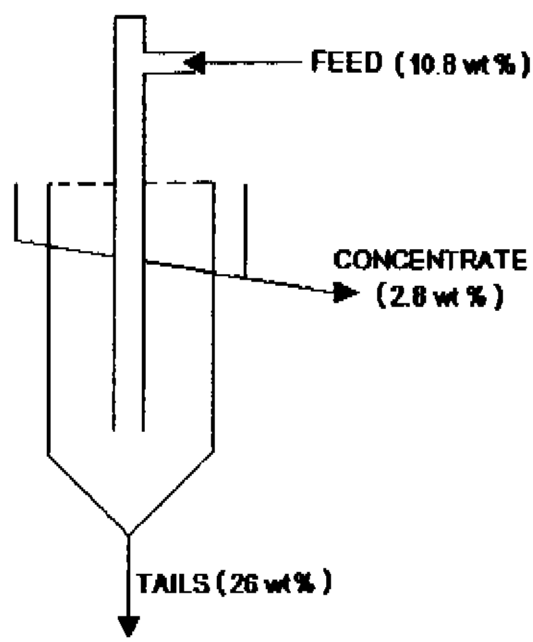


(ii) JAMESON CELL
TOTAL RECOVERY OF +850 μm
MATERIAL TO THE CONCENTRATE WAS 53 wt %

FIGURE 3. THE DEPORTMENT OF THE SLOW FLOATING +850 μm HIGH GRADE KCL PARTICLES TO FINAL CONCENTRATE IN TEST RUN NUMBER 24 (FIGURES DISPLAYED AS RETAINED wt %)



(i) PLANT CIRCUIT
TOTAL RECOVERY OF +850 μm
MATERIAL TO THE CONCENTRATE WAS 8.74 wt %



(ii) JAMESON CELL
TOTAL RECOVERY OF +850 μm
MATERIAL TO THE CONCENTRATE WAS 17 wt %

FIGURE 4. THE DEPORTMENT OF THE SLOW FLOATING +850 μm HIGH GRADE KCL PARTICLES TO FINAL CONCENTRATE IN TEST RUN NUMBER 26 (FIGURES DISPLAYED AS RETAINED wt %)

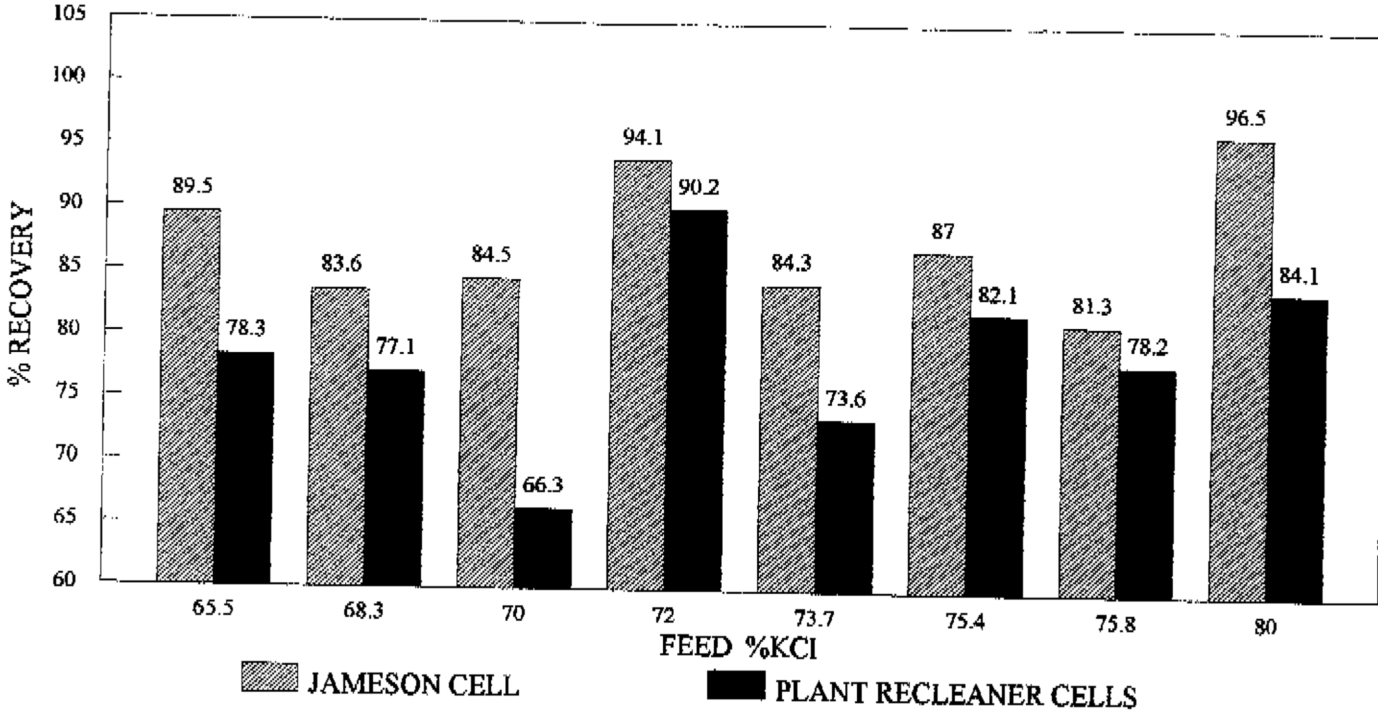


Fig.5 Cells treating cleaner concentrate-Recoveries

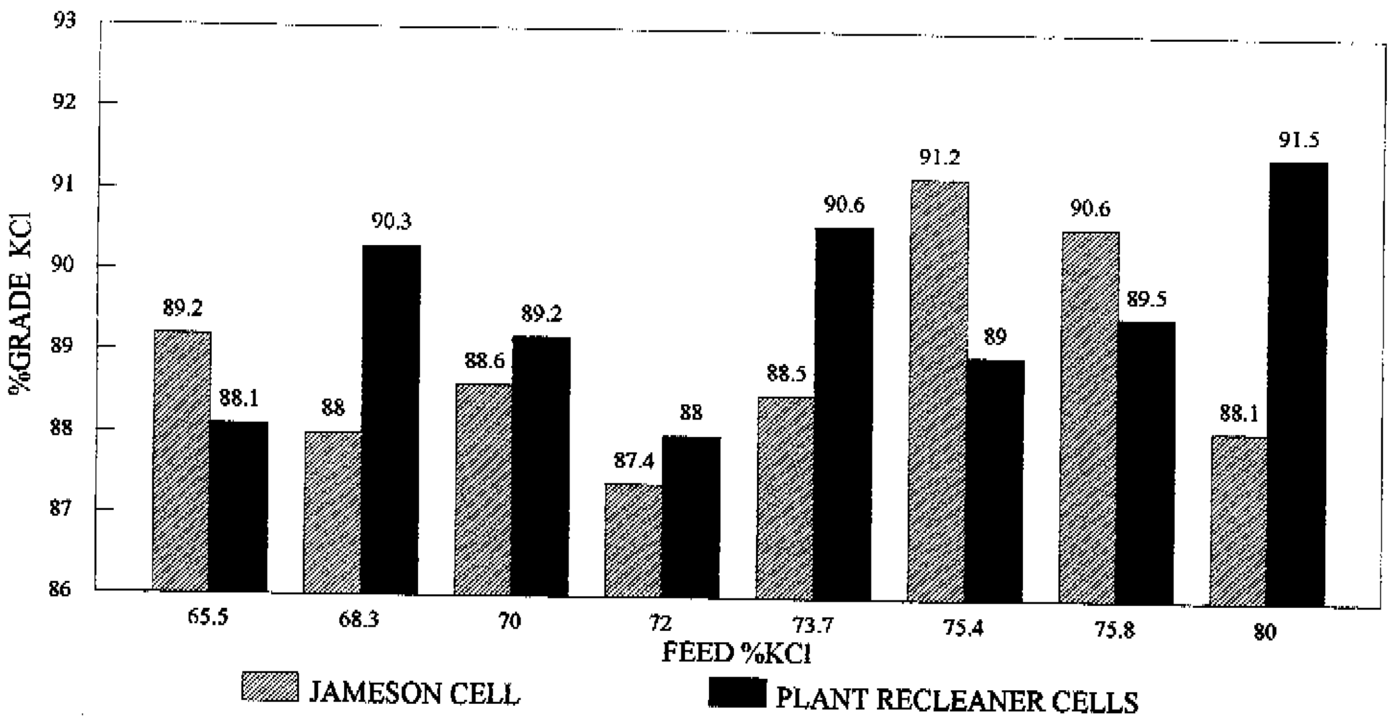


Fig.6 Cells treating cleaner concentrate-Grades

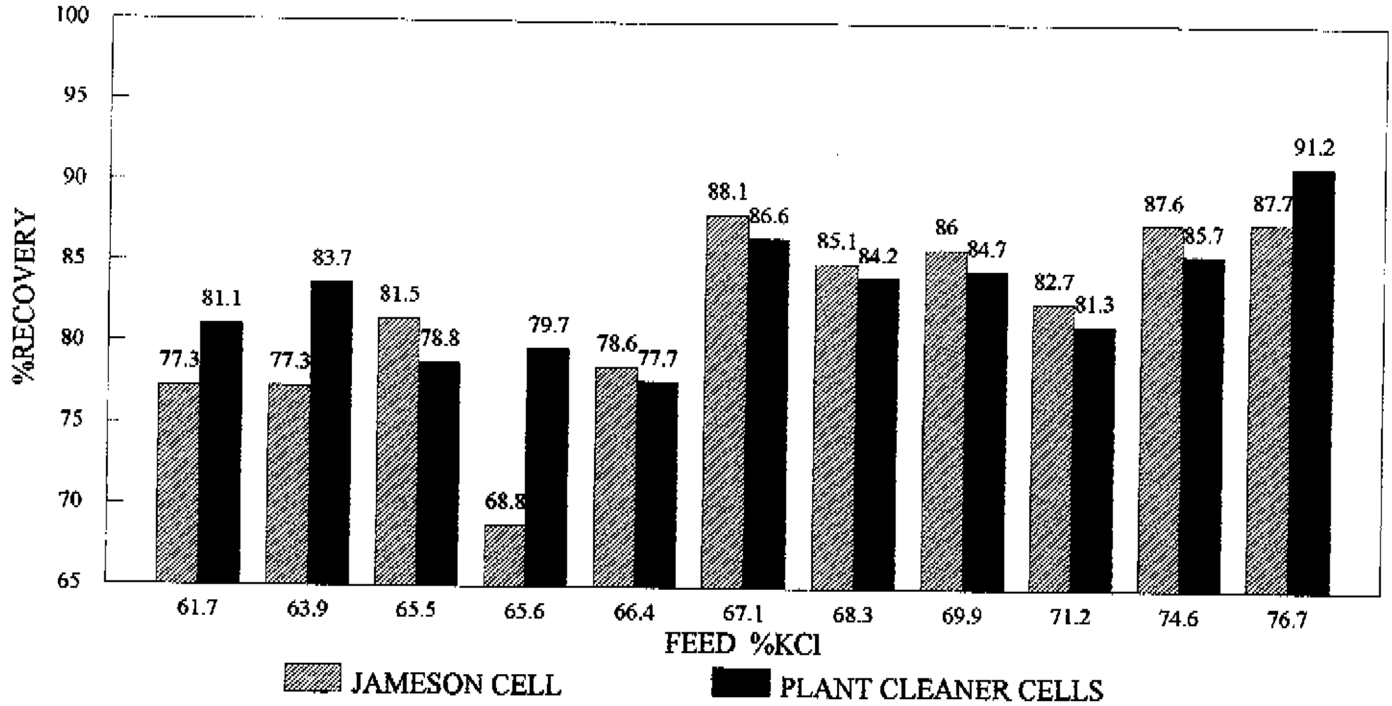


Fig.7 Cells treating rougher concentrate-Recoveries-30cm froth depth

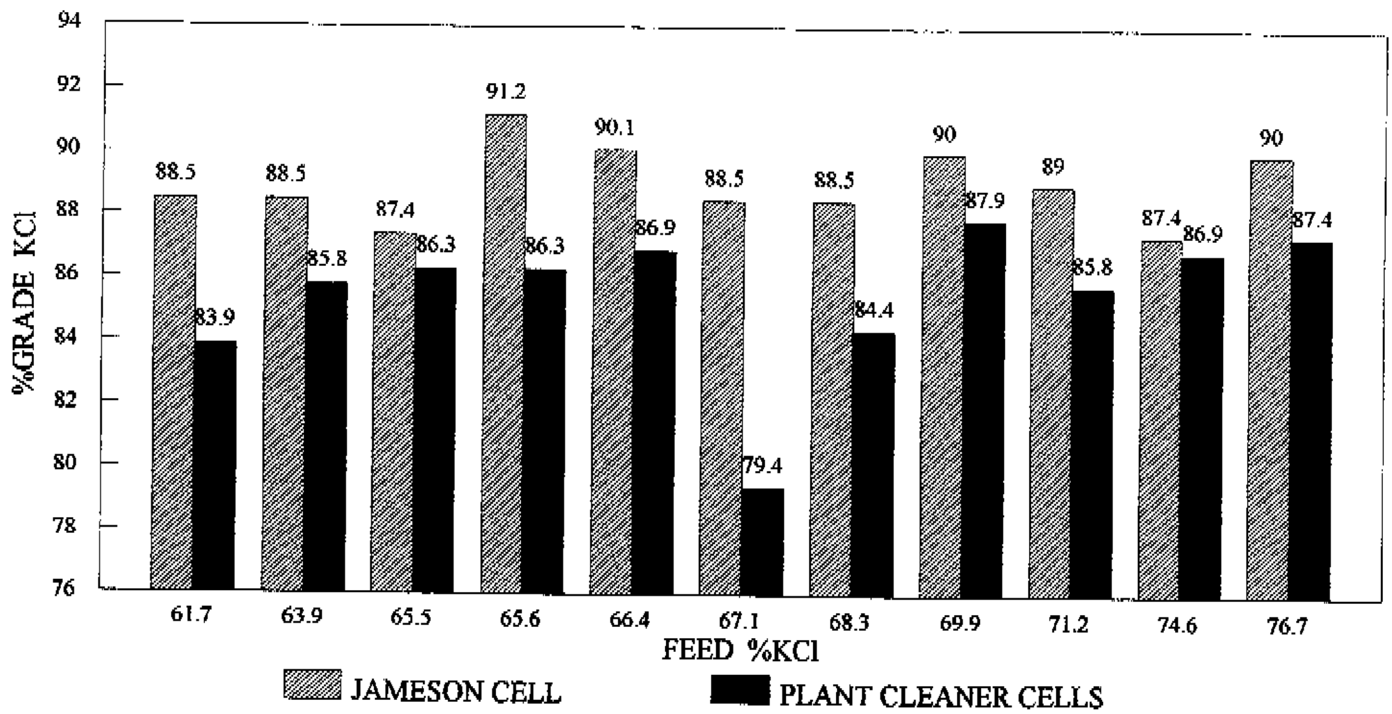


Fig.8 Cells treating rougher concentrate-Grades-30cm froth depth

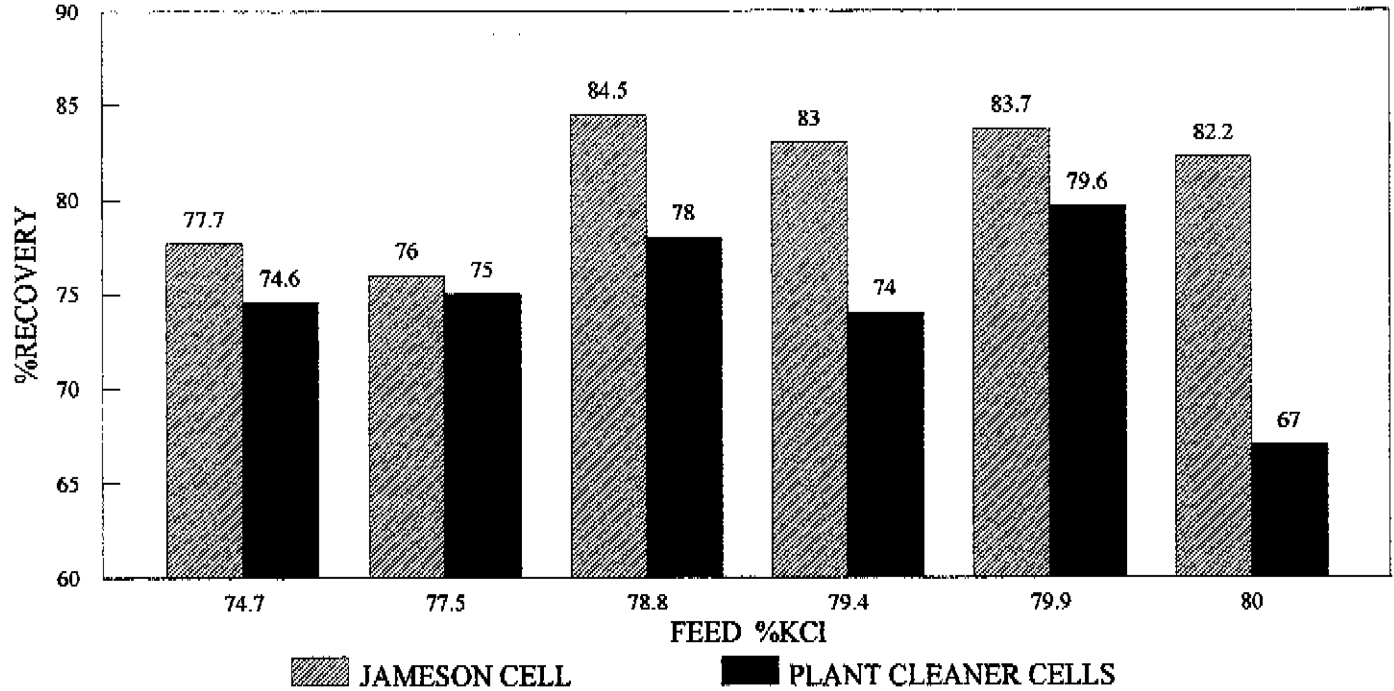


FIG. 9 Cells treating rougher concentrate-Recoveries-40cm froth depth

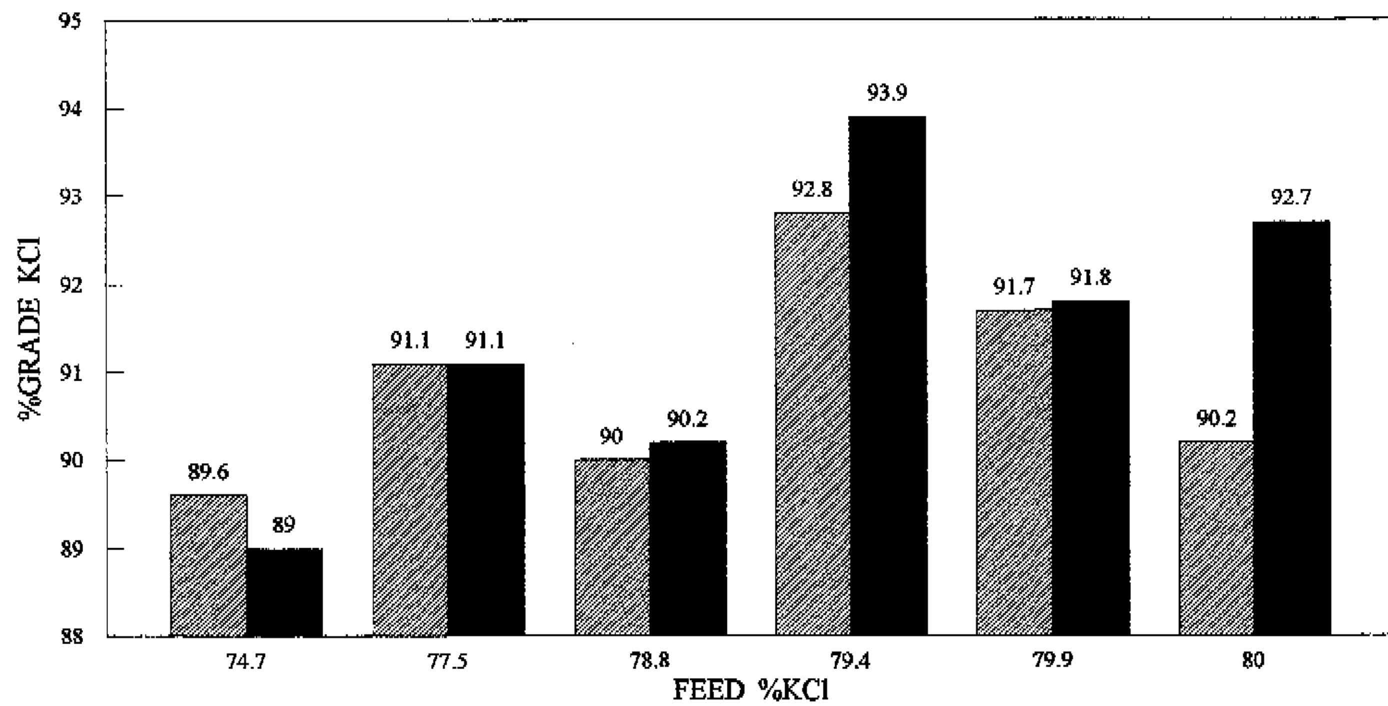


Fig.10 Cells treating rougher concentrate-Grades-40cm froth depth