

Design criteria and recent developments in large-capacity Wemco flotation cells

by P. KIND*, Ph.D. (Clausthal), B.Sc. (Visitor)

SYNOPSIS

The scaling-up of the large flotation cells that have been developed during the past few years has been based on hydrodynamic considerations and has resulted in a 500 ft³ cell unit. Plant results on a porphyry copper ore show that the 500 ft³ unit is equivalent to the previously used 300 ft³ model.

Plant tests on the use of 300 ft³ flotation cells for the recovery of phosphate, particularly from the coarse size fractions, are also described.

SAMEVATTING

Die skaalvergroting van die groot flottasieselle wat in die loop van die afgelope paar jaar ontwikkel is, is op hidrodinamiese oorwegings gegrond en het gelei tot 'n seleenheid van 500 vt³. Aanlegresultate vir porfierkopererts het getoon dat die eenheid van 500 vt³ gelyk staan met die model van 300 vt³ wat vroeër gebruik is.

Aanlegtoetse in verband met die gebruik van flottasieselle van 300 vt³ vir die herwinning van fosfaat, veral uit die growwe groottefraksies, word ook beskryf.

INTRODUCTION

The Wemco flotation cell of today started as the Fagergren flotation cell, which was invented in the early 1930's by William Fagergren in Utah, U.S.A. Up to 1948 it was marketed by Cyanamid, and since then by Wemco, now a Division of Envirotech Corporation, Menlo Park, California, U.S.A.

The Fagergren was characterized by its deep multi-piece squirrel-cage rotor and squirrel-cage shroud. In 1967/1968, Wemco developed and patented a new one-piece deep rotor and a one-piece stator (U.S. patent 3,491,880), sold under the trade mark 1+1. Fig. 1 shows the con-

ventional Fagergren impeller and the 1+1 star rotor-disperser. Until 1967, Wemco cell sizes ranged from 1 to 60 ft³.

In 1967, the 300 ft³ cell was developed and successfully compared in a parallel industrial test against the 60 ft³ cells. In 1970, the first 500 ft³ cell (no. 144) was tested in the flotation of iron ore in North America.

PRINCIPLE

The Wemco flotation cell is an open-trough type, self-aerating mechanical flotation cell, which is shown in Fig. 2. The mechanism consists of a star-like rotor, which rotates inside the shroud or disperser. When operating, the rotor creates a fluid vortex inside the standpipe and in the draft tube, this vortex being at a sufficient vacuum to induce air into the standpipe through the air inlet from above the cell surface. The induced air is mixed inside the rotor-stator zone with the pulp that has been sucked into the rotor from below. The large-capacity Wemco flotation cells have a false-bottom draft-tube system that enhances the circulation of the pulp. It permits a low rotor submergence, even for the large-capacity cells. The three-phase mixture leaves the shroud (disperser) through the disperser apertures in radial direction. The new disperser fulfils the shrouding effect perfectly, since the tangential velocity of the three-phase mixture imparted on it by the rotor is converted to an entirely radial direction. This is shown by

the flow pattern of the laboratory cell, equipped with 1+1 parts (Fig. 3). The particle-loaded air bubbles rising to the froth surface are separated outside the disperser, and the remaining pulp, which flows down the tank walls and returns to the rotors, is separated in the large cells through the false bottom and the draft tube. The conical stator hood is to quieten the cell surface and to keep any turbulence created by the rotor away from the froth layer.

The function of the mechanism in a Wemco flotation cell is therefore threefold: to circulate pulp, to mix pulp with air, and to draw in air. These functions depend on the shape and geometric dimensions of the rotor and stator, on the speed and submergence of the rotor, on the vertical distance between the rotor and the real tank bottom and, for the large cell sizes, on the engagement of the rotor in the draft tube.

As far as the pulp-circulation capacity is concerned, the following relations can be stated.

- The greater the speed of the rotor tip (by increased rotational speed or by installation of a larger-diameter rotor), the greater the circulation capacity.
- A decrease in the clearance between the rotor and the tank bottom improves the pulp-circulation capacity.
- Rotor engagement in the draft tube is essential for effective pulp circulation; otherwise, short-circuiting of the pulp occurs.
- An increase in the tip speed and

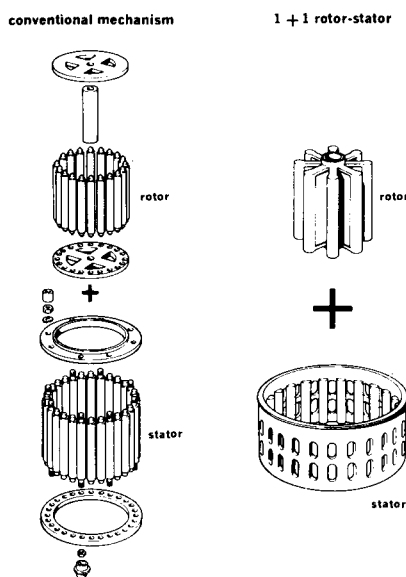


Fig. 1—Wemco mechanisms

*Wemco Europe, Division of Envirotech, France.

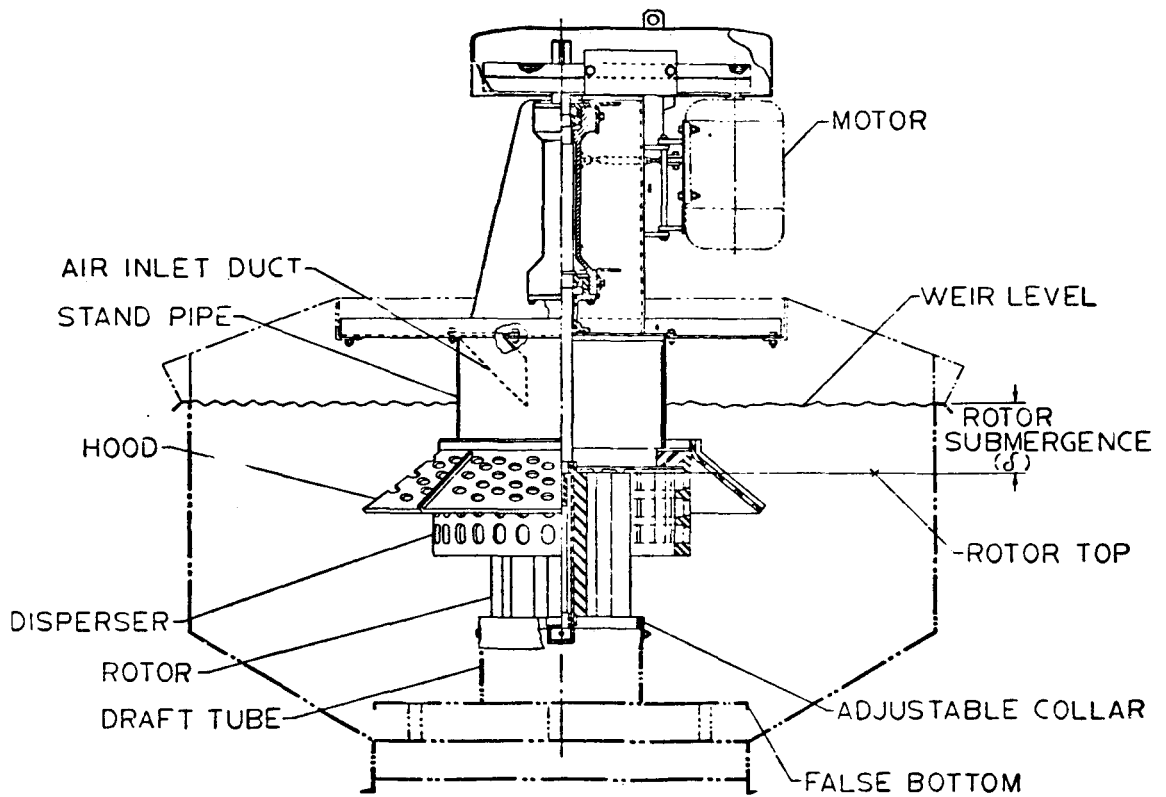


Fig. 2—Wemco I+I flotation cell

a decrease in the distance between the rotor and the tank bottom increases the power consumption.

Concerning aeration characteristics, the relations listed below can be expected.

- The greater the speed of the rotor tip, the greater the volume of induced air.
- The lower the submergence of the rotor, the greater the volume of induced air.
- The lower the specific gravity and the viscosity of the flotation pulp, the greater the quantity of induced air.

Obviously, an optimum condition is to be found for the various parameters mentioned above. This is particularly true for the flotation of coarse particles, where a greater turbulence is required to keep the coarser solids in suspension, but it is limited by the reduced stability of the particle/air-bubble unit. Further, large air bubbles would be required.

SCALE-UP CONSIDERATION

When flotation cells are scaled up from a given size to larger units, the

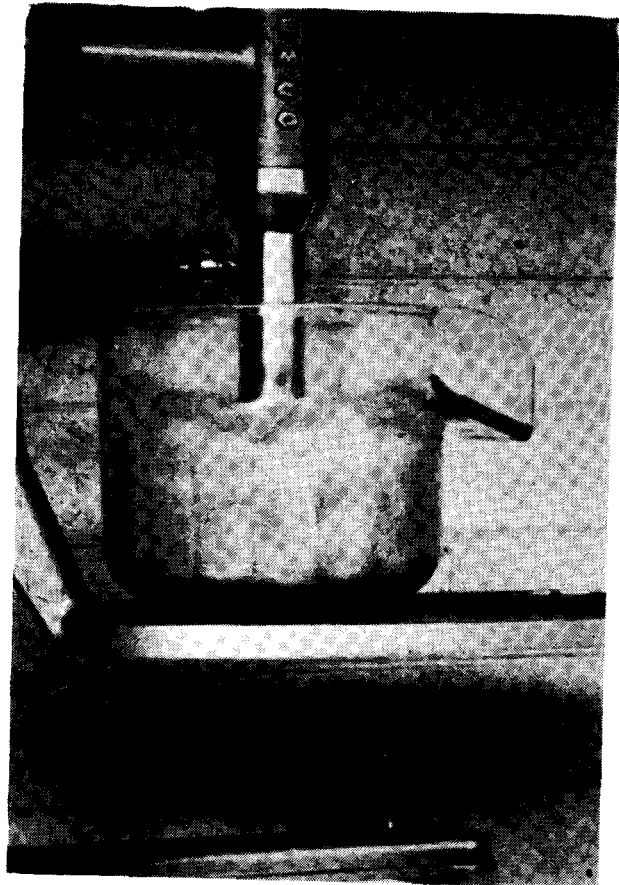


Fig. 3—Wemco laboratory cell with I+I parts

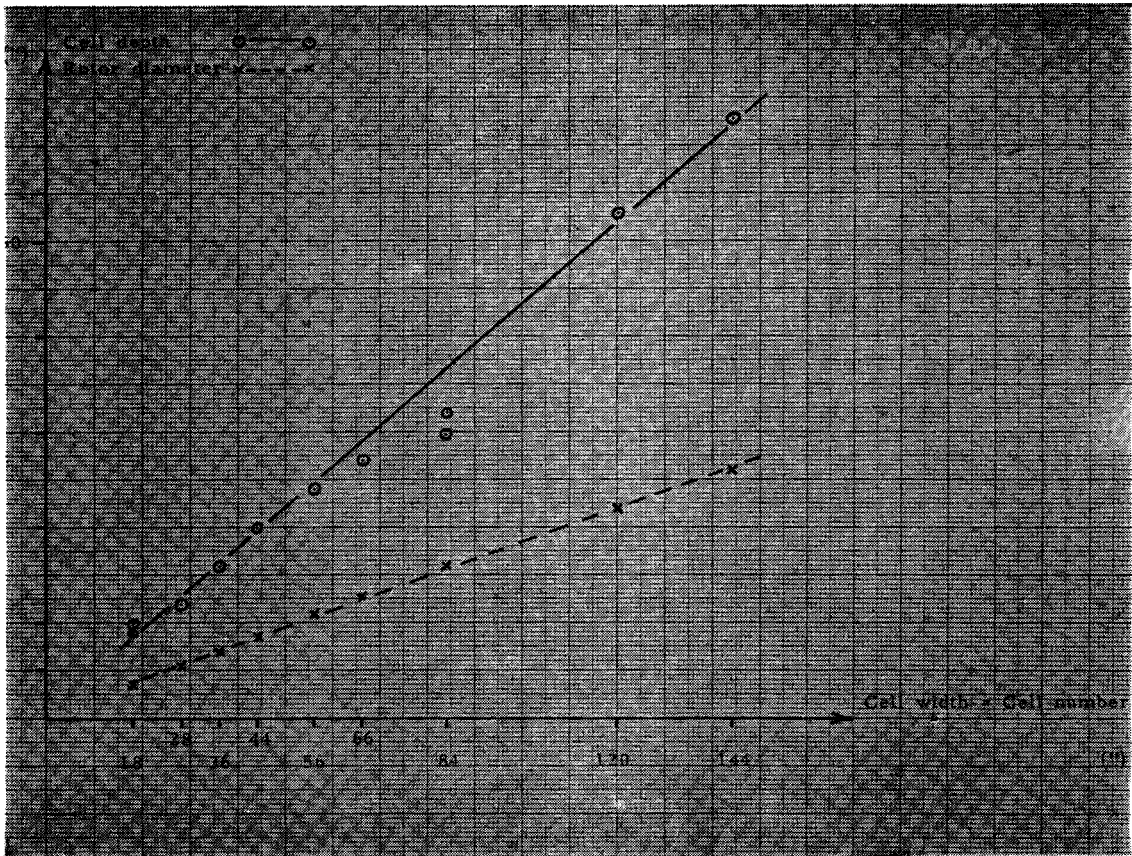


Fig. 4—Relation of cell depth and rotor diameter to cell size

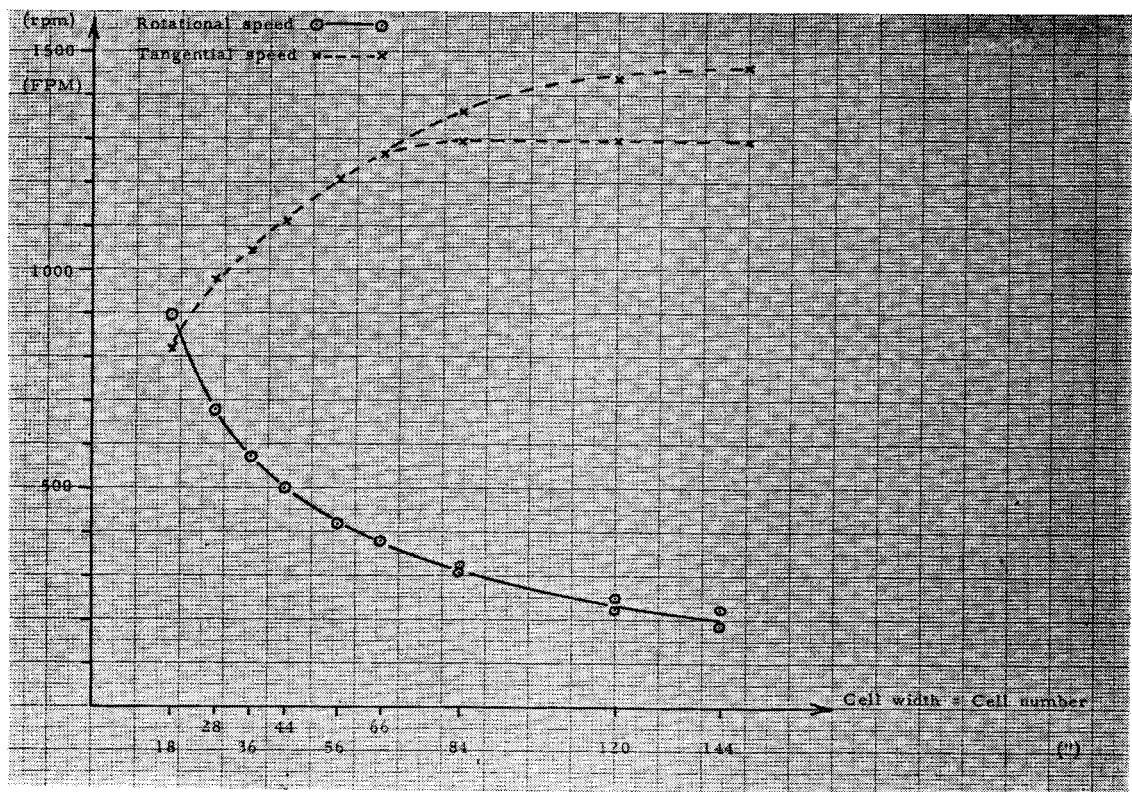


Fig. 5—Relation of rotational and tangential speed to cell size

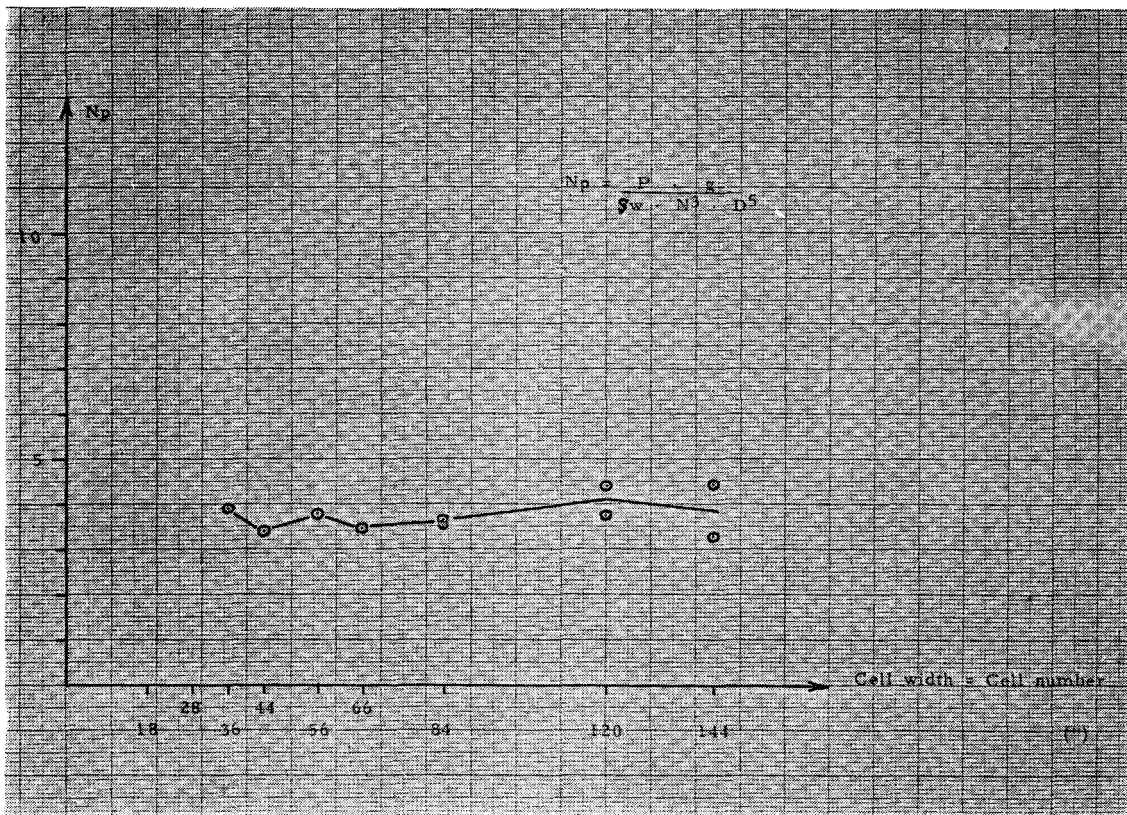


Fig. 6—Relation of power number (N_p) to cell size

specific capacities of the mechanisms with regard to pulp circulation, air dispersion, and air induction must be maintained. Only if this is done can one expect to process large quantities of a given raw material in a larger cell with the same metallurgical results.

If the width of the cell is regarded as a basic parameter of the cell tank (also being the size number of Wemco flotation cells), the depth of the cell is scaled up in a linear way (Fig. 4). This means that a bigger cell is also a deeper cell. The length of the tank, i.e., the distance between two mechanisms, can vary between 75 and 100 per cent of the tank width, depending on the application. The ratio of blade height to rotor diameter remains almost constant, with values of 1.14 and 1 for the 1 ft³ and the 500 ft³ model respectively. As shown in Fig. 4, the diameter of the star rotor increases linearly with the width of the cell, which corresponds to a constant ratio of impeller diameter to cell width.

Once the geometric parameters

have been selected, impeller speed and aeration control are the major operational parameters to be considered in the scale-up of flotation cells. For Wemco flotation cells up to 60 ft³, the speed of the rotor tip increases with one-third the power of the rotor diameter, as Arbiter and Steininger¹ and Arbiter, Harris, and Yap³ recommend. For the larger cells, a more or less constant tip speed of 1300 ft/min seems to be feasible. It should be noted that these cell sizes have the false-bottom draft-tube system (see Fig. 5). In some applications, the tip speeds of the large cells have been increased to higher values for the floating of heavy and coarse material.

Various sizes of flotation cells are fully scaled up from a hydrodynamic point of view if the power number is kept constant^{2, 3}.

$$\text{Power number } N_p = \frac{P \cdot g}{l \cdot N^3 \cdot D^5},$$

where

P = net power consumption
 g = gravitational acceleration
 l = fluid density

N = rotor speed

D = rotor diameter.

Fig. 6 and Table I show that this hydrodynamic characteristic is fully respected in all sizes of Wemco flotation cells. It should be mentioned that the change from the squirrel-cage Fagergren rotor to the 1+1 star rotor was accompanied by a higher power number due to the greater blade area of the rotor. For the no. 66 cell operating at 428 r/min in water, the power number increased from 1.38 to 3.05 (Table I). The greater blade area made it possible to reduce the diameter of the rotor and the tip speed by about 25 per cent, with the benefit of lower wear and maintenance costs.

$$N_Q (N_{Q_1} = \frac{\text{Air volume rate}}{\text{Cell area} \cdot \text{rotor tip speed}})$$

$$N_{Q_2} = \frac{QA}{D^2 \cdot N \cdot D}$$

The air-flow number, which is regarded by Arbiter² as reflecting a specific operating condition of a flotation cell, is the ratio of air

TABLE I
POWER NUMBER N_p

Size	Impeller D ft	N r/min	N r/s	N^3 r/s ³	D^5 ft ⁵	P^* h.p.	P ft lb/s	N_p $\frac{P \cdot g}{lw \cdot N^3 \cdot D^5}$
36	0,583	572	9,53	865,52	0,06735	0,8	440,19	3,889
44	0,708	500	8,33	578,01	0,177896	1,2	660,28	3,306
56	0,917	420	7,00	343,00	0,648405	3,0	1650,72	3,822
66	1,063	380	6,33	253,64	1,357270	4,2	2311,00	3,462
84	1,333	310— 325	5,16 5,42	137,39 159,22	4,208727	7,5 8,5	4126,80 4677,04	3,675 3,594
120	1,833	225— 250	3,75 4,17	52,73 72,51	20,692469	17 20	9354,08 11004,80	4,415 3,777
144	2,166	190— 225	3,17 3,75	31,86 52,73	47,675169	24 29	13205,76 15956,96	4,477 3,269
66 1+1	1,063	428	7,13	362,63	1,357271	5,3	2916,27	3,051
66 conv.	1,375	428	7,13	362,63	4,915		4728	1,384

* At 6-inch rotor submergence in water⁴
 P —Net power consumption
 g —Gravitational constant
 lw —Density of water
 N —Impeller speed
 D —Impeller diameter

Unit
ft · lb/s
32,185 ft/s²
62,4 lb/ft³
r/s
ft

TABLE II
AIR-FLOW NUMBER (N_{Q1})

Size	Impeller D ft	N r/min	$\pi \cdot N \cdot D$ ft/min	Q_A^* ft ³ /min	$\frac{Q_A}{D^2}$ ft/min	$\frac{Q_A}{\pi \cdot N \cdot D^3}$	N_{Q1} $\frac{Q_A}{N \cdot D^3}$
36	0,583	572	1045	12,5	36,8	$35,2 \times 10^{-3}$	$11,05^{-3}$
44	0,708	500	1112	23	45,88	41,25	12,95
56	0,917	420	1208	44	52,32	43,31	13,60
66	1,063	380	1265	70	61,95	48,97	15,37
84	1,333	310— 325	1295 1360	125 140	70,34 78,79	54,31 57,93	17,30 18,44
120	1,833	225— 250	1295 1439	260 310	77,38 92,26	59,75 64,11	18,76 20,13
144	2,166	190— 225	1295 1530	400 540	85,26 115,10	65,83 75,23	20,67 23,96

* At 6-inch submergence in water⁴
 N_{Q1} —Air-flow number
 Q_A —Air-flow rate
 N —Impeller speed
 D —Impeller diameter

Unit
ft³/min
r/min
ft

TABLE III
AIR-FLOW NUMBER (N_{Q2})

Size	Cell surface	A Cell surface ft ²	Air-flow rate Q_A^* ft ³ /min	Air superficial escape velocity $V_A = Q_A : A$ ft/min	Rotor-tip speed $\pi \cdot N \cdot D$ ft/min	N_{Q2} $\frac{Q_A}{A \cdot \pi \cdot N \cdot D}$
36	36 × 36	9	12,5	1,38	1045	$1,32 \times 10^{-3}$
44	44 × 44	13,44	23	1,71	1112	1,537
56	56 × 56	21,77	44	2,02	1208	1,672
66	66 × 66	30,25	70	2,31	1265	1,826
84	84 × 84	49,00	125— 140	2,55— 2,85	1295— 1360	1,969 2,096
120	120 × 90	75,00	260— 310	3,46— 4,13	1295— 1439	2,672— 2,87
144	144 × 108	108,00	400— 540	3,70— 5,0	1295— 1530	2,857— 3,26

* At 6-inch rotor submergence in water⁴
 A —Cell surface
 Q_A —Airflow rate
 V_A —Superficial escape velocity of air
 N_{Q2} —Air-flow number

Units
ft²
ft³/min
ft/min

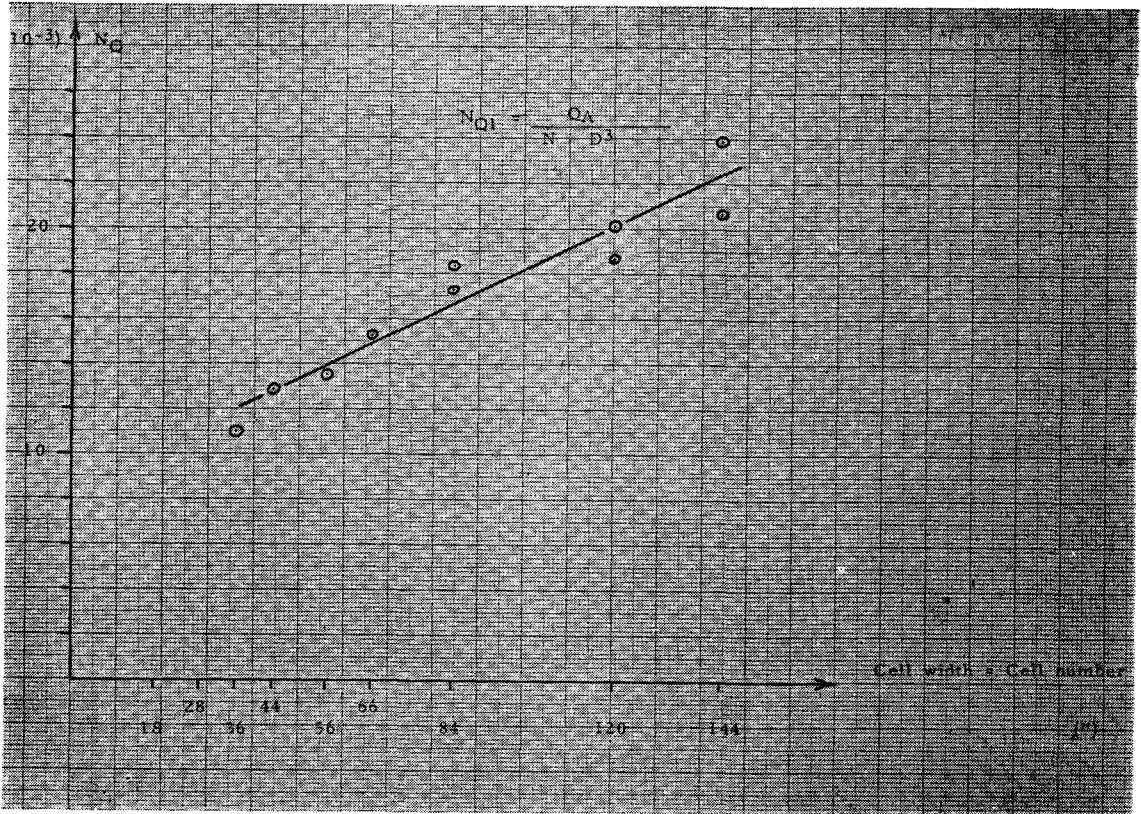


Fig. 7—Relation of air-flow number (N_Q) to cell size

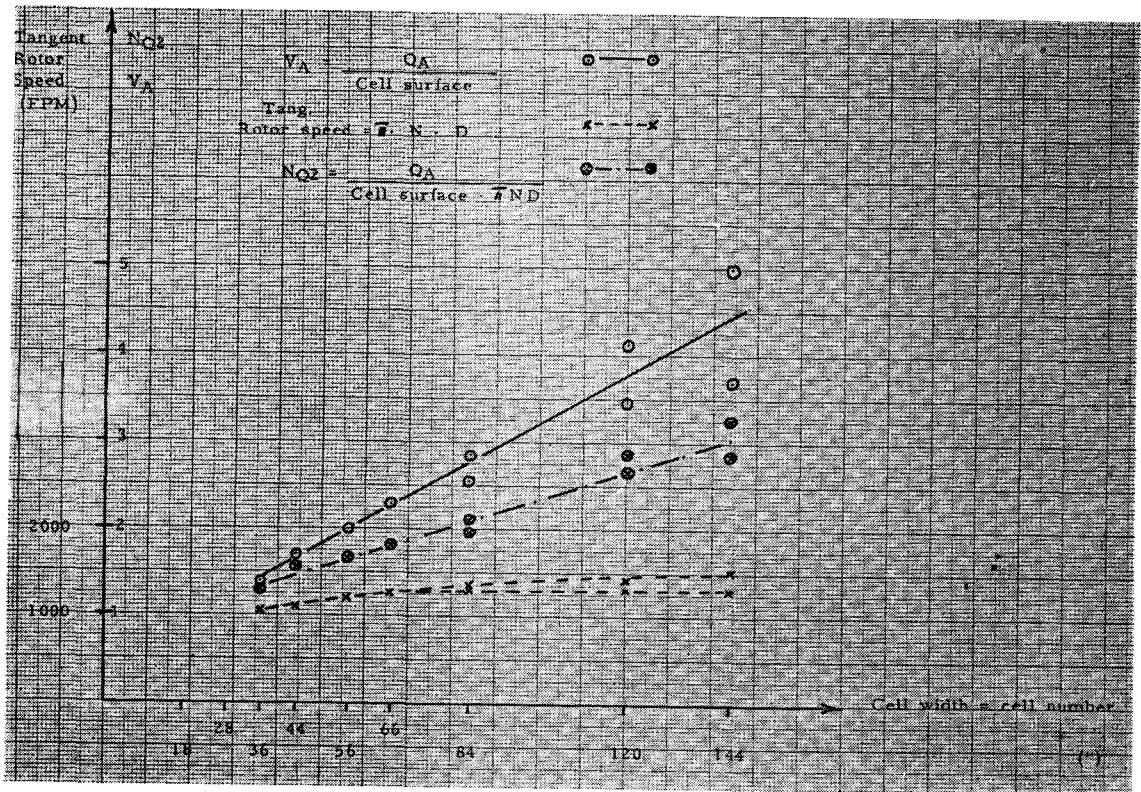


Fig. 8—Relation of air-flow number (N_{Q1}) to cell size

velocity (air volume rate to square of impeller diameter, or air volume rate to cell surface) to the tangential velocity of the impeller. Tables II and III and Figs. 7 and 8 show the various parameters.

The air-flow number increases with increasing cell size because the air velocity increases faster than the tangential speed of the rotor. This is related to the scale-up of the tank geometrics, which is characterized by a linear scale-up of the cell depth. On the other hand, constant air intensity of the cell volume is required. In other words, at natural aeration capacity, the air in a no. 120 cell would escape faster than that in a no. 66 cell.

Arbiter² has shown with Balmat flotation that, only when the aeration is restricted, can plant results be reproduced in laboratory and pilot cells. From his investigation, it also appears that the same metallurgical results can be obtained in Wemco cells having the following air-flow numbers:

2-litre laboratory cell:

$$N_Q = 1 - 2 \times 10^{-3}$$

1 ft³ pilot cell:

$$N_Q = 1,9 - 2,3 \times 10^{-3}$$

61 ft³ plant cell:

$$N_Q = 2,7 \times 10^{-3}$$

The magnitude of the N_Q values of Arbiter's investigation and those in the tables of this paper differ since the latter are related to the star rotor in water while the other data² are related to a squirrel-cage rotor in industrial flotation pulp.

RECENT DEVELOPMENTS AND TESTS

In spite of the recent progress in the hydrodynamics of flotation-cell design, major development work should still be done in industrial plants. Wemco's work during the last few years has been directed in two distinct directions.

One was the development of large-capacity flotation cells, which has now resulted in the 500 ft³ cell. It is obvious that lower primary ores need bigger installations, and consequently larger equipment. The need for automatic operation of these plants favours the trends towards bigger units. The 500 ft³ cell with a daily unit capacity of up to 830 t/d of an average porphyry copper ore

is now being used in various plants in North America. It should fulfil the requirement of even the largest mill of today to accommodate only one flotation line to one grinding circuit.

The other development was directed towards the use of large-capacity cells for the flotation of coarse particles, especially of phosphates.

Flotation Tests at Brewster Plant

At the Haynsworth Mine at Bradley, Florida, of the American Cyanamid Co., a nine-month test using three no. 120 Wemco cells was carried out to determine whether large-capacity cells can be used to up-grade fine and coarse feed of Florida phosphate, about which Custred, Degner, and Long^{5, 6} have reported.

Since the flotation feed in the size range of 20 to 150 mesh is the undersize of the preceding up-grading steps such as washing, screening, cycloning, and hydraulic classification, and since no crushing and milling steps are involved, the flotation feed is coarser than in most

other mineral applications. The minus 150 mesh fraction is discarded as slimes, and the 20 to 150 mesh fraction is classified by hydraulic sizers and vibrating screens into a coarse flotation feed (minus 20 plus 35 mesh) and into a fine flotation feed (minus 35 plus 150 mesh).

In the rougher flotation, the phosphate is floated separately in the coarse and fine circuit, using crude fatty acid, fuel oil, and ammonia for pH 9 to 9,5. The two rougher froth products are then combined, acid-washed, and subjected to a common cleaner circuit, where silica is floated with amines and where the phosphate reports to the cell underflow.

The tests were conducted for roughing only, both on the fine and coarse feed. The test unit consisted of three no. 120 by 90 by 53 Wemco cells (300 ft³ unit cell volume) with double overflow and skimmers, and with feed and discharge box and automatic level control. Table IV summarizes the size distribution of the fine and coarse feed, and Table V gives the results of several months'

TABLE IV

ROUGHER FLOTATION FEED⁵ — SIZE DISTRIBUTION OF SOLIDS (% by mass — by screen fraction)

Size mesh	Rougher circuit			
	Fine feed		Coarse feed	
	Distn %	Cum. %	Distn %	Cum. %
(+)20	1,0	1,0	4,2	4,2
-20 +28	1,9	2,9	8,6	12,8
-28 +35	7,6	10,5	15,9	28,7
-35 +48	18,8	29,3	28,9	57,6
-48 +65	27,1	56,4	26,9	84,5
(-)65	43,6	100,0	15,5	100,0

TABLE V

THREE-CELL ROUGHER FLOTATION CIRCUIT⁵ — PERFORMANCE ON FINE FEED (Operating condition A)

* Rotor submergence=9 in

* Rotor speed=210 r/min

Feed rate ton/h	Solids in feed %	Phosphate (BPL*), %		BPL* recovery %
		Feed	Concentrate	
120	17	27,4	53,6	91,3
170	22	26,0	58,7	88,2
200	25	28,0	59,9	89,3
200	25	21,7	51,9	87,1
170	27	22,5	58,2	85,7

* Bone phosphate of lime

TABLE VI
THREE-CELL ROUGHER FLOTATION CIRCUIT⁵ — PERFORMANCE ON COARSE FEED

Operating condition	Rotor (top) submergence in	Rotor speed r/min	Feed rate ton/h	Solids in feed %	Phosphate (BPL*), %		Phosphate recovery %
					Feed	Concentrate	
A	9	210	120	20	26,4	58,1	85,9
B†	9	210	120	20	31,0	56,0	90,4
C	13	210	120	20	27,8	56,8	87,8
D	13	235	120	20	33,0	64,3	88,7
D	13	235	180	25	30,2	62,9	88,3

* Bone phosphate of lime
† False-bottom modification
(See text for details)

operation on the fine feed at 210 r/min (1208 ft/min, 6,14 m/s) and a rotor submergence of 9 inches. The feed rate was varied between 120 and 200 ton/h and the solids concentration between 17 and 27 per cent by mass.

The metallurgical results achieved in the test unit on fine feed were the same as obtained in the air cells operating in this plant. However, it was possible to increase the solids concentration to 27 per cent in the feed, whereas it had up to then been 17 per cent solids.

The test results obtained on the coarse feed are shown in Table VI. In the first test series on the coarse feed, the operating conditions (A) were the same as for the fine feed. The result was that the same grade of concentrate as in the plant could be obtained, but that the recovery could not be achieved (85,9 per cent for the test unit, 88,5 per cent for the plant). The 300 ft³ cells could therefore not duplicate the plant results under standard operating conditions, although the conditions were sufficient to give good results on the fine feed.

In order to improve the recovery on the coarse feed, the test cells were modified by covering the gap between the false bottom of two adjacent cells with a plate called a 'false-bottom extension plate'. This modification resulted in a continuous false bottom for the three cells and is referred to as operating condition B. The test results show an improvement in recovery, most likely because of better circulation of the pulp and better suspension of the coarse material. However, the grade of the concentrate was lower.

Then, in order to improve the grade of the concentrate, the entire

mechanisms were lowered by 4 inches, and the rotor submergence was consequently increased from 9 to 13 inches. This modification resulted in an improved grade of concentrate but lower recovery. The last modification was to increase the rotor speed from 210 to 235 r/min (1208 to 1352 f/min or 6,14 to 6,87 m/s), which brought the recovery to the plant value (88,5 per cent) while the grade of the concentrate of the test cells was the same or up to 3 per cent higher than that of the plant cells. Furthermore, the throughput could be increased without any major loss in grade and recovery by 50 per cent to 180 ton/h.

A final test consisted of feeding the fine feed into the test unit and operating at 235 r/min with the lowered mechanism and the continuous false-bottom. At a feed rate of 200 ton/h, 30 per cent solids, and 24,4 per cent phosphate in the feed, a concentrate of 58,6 per cent bone phosphate of lime (BPL) at a recovery of 86,2 per cent was obtained.

Fig. 9 shows the power and air-flow characteristics of the no. 120 Wemco cell⁵ for the four operating conditions of the test unit. An increase in the submergence of the rotor from 9 to 13 inches at the same rotational speed resulted in a decrease in the aeration and consequently in the air-flow number. At the same time, the power draw, and consequently the power intensity, rose. An increase in the speed of the rotor from 210 to 235 r/min raised the pumping capacity of the rotor and the power consumption. Since the aeration rate also increased, the power consumption increased to a lesser extent than it would have

done without an increase in aeration.

In summary, the 300 ft³ test cells achieved the same or better metallurgy than the existing air cells in the plant. The specific flotation capacity (tons of feed per hour per square foot of floor space) could be increased by 50 per cent. It went up to 0,65 ton/h per ft² with fine feed, and to 0,59 ton/h per ft² with coarse feed. The specific power consumption could be reduced to between 0,27 and 0,36 h.p. per ton/h with fine feed, and to 0,42 h.p. per ton/h with coarse feed. It was further possible to increase the solids concentration in the feed to 30 per cent for fine feed (as compared with 18 per cent solids in the plant), and to 25 per cent for coarse feed (as compared with 16 per cent solids in the plant).

Fig. 10 shows a partial view of the flotation area of the Brewster plant after reconstruction. In a total of twenty-four no. 120 Wemco cells, 1260 ton/h are treated for roughing and partial cleaning, the balance of the cleaning being done in the existing air cells.

Flotation Tests at Phosphate Development Corp. Ltd

The Phosphate Development Corp. Ltd of Phalaborwa, Transvaal, conducted parallel flotation tests to compare the metallurgical performance of 300 ft³ (8,4 m³) no. 120 Wemco cells with that of the 50 ft³ (1,4 m³) cells currently in use in the existing plant⁷.

The test unit consisted of a four-cell no. 120 Wemco machine, 120 by 90 by 53, consisting of feed box — 2 cells — connection box — 2 cells — discharge box. The cells had double froth overflow with froth skimmers. The test machine

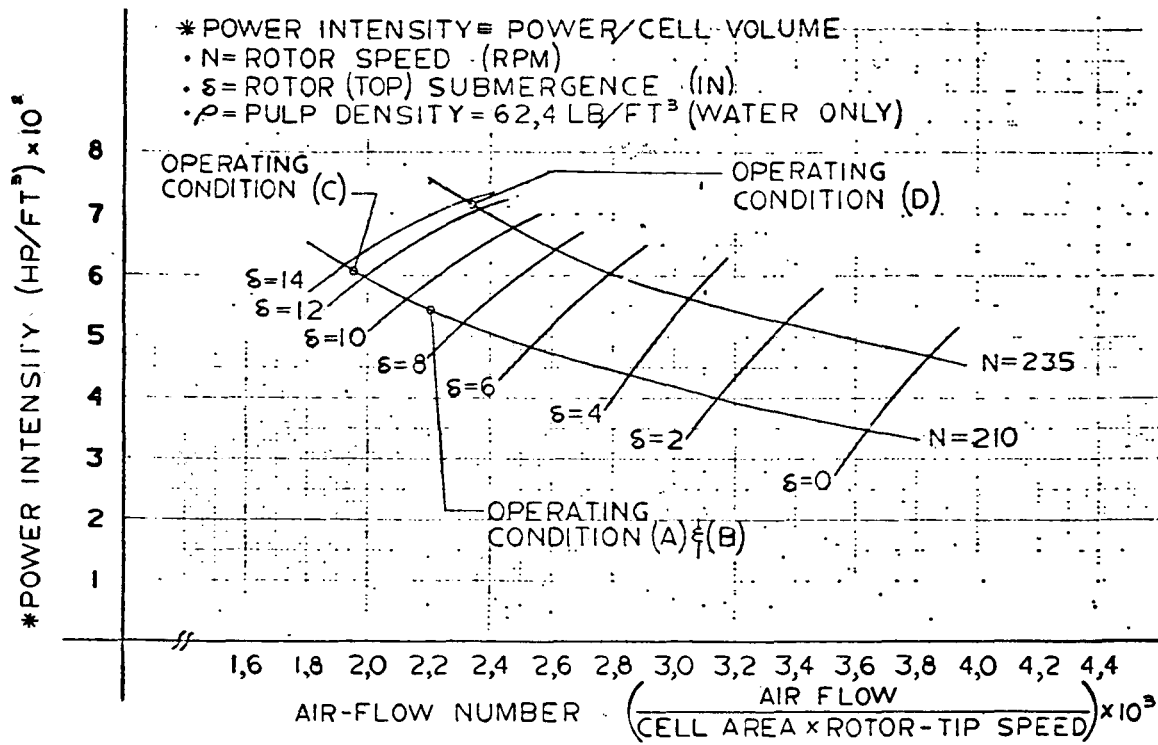


Fig. 9—Power and air-flow characteristics of the Wemco no. 120 flotation cell

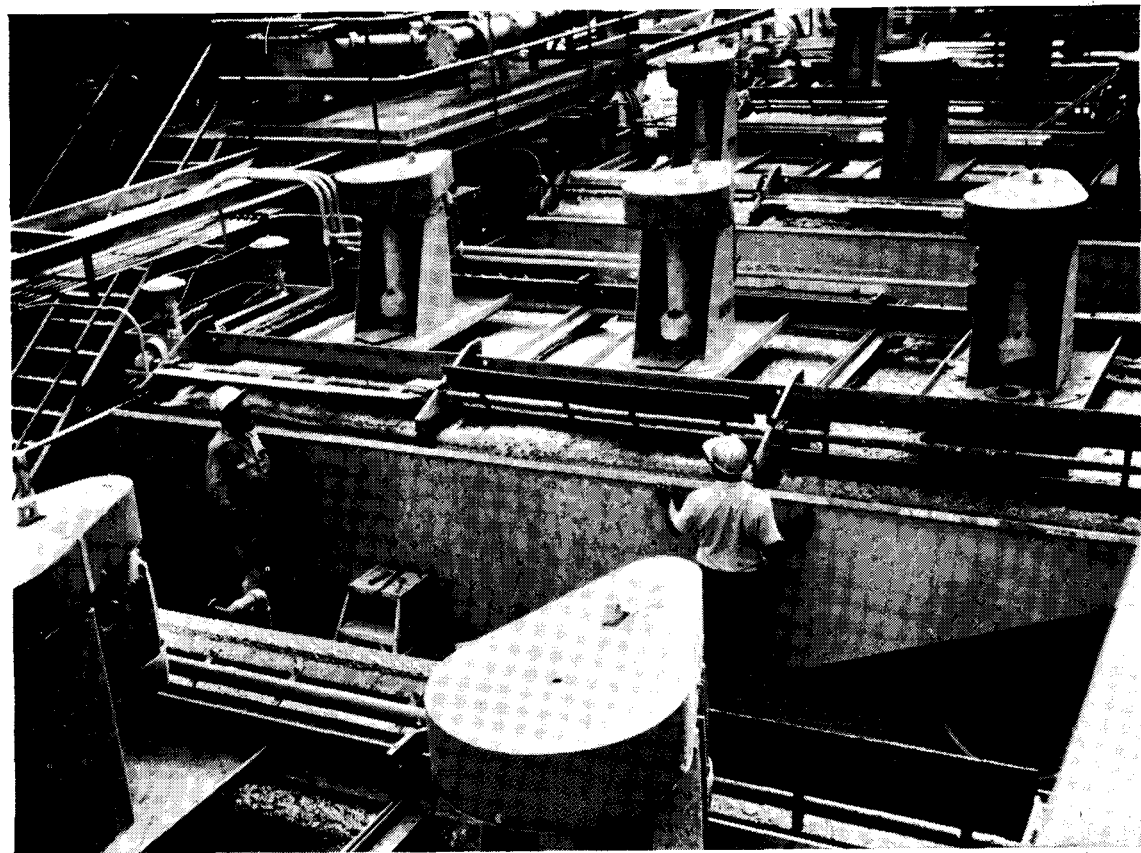


Fig. 10—Partial view of the Brewster flotation section

TABLE VII
ROUGHER FLOTATION TESTS⁷

Test no.	Condition of four 300 ft ³ Wemco cells	Four 300 ft ³ Wemco cells				Two rows of 12 50 ft ³ cells				Difference in recovery 300 ft ³ cells—50 ft ³ cells
		P ₂ O ₅ , %			P ₂ O ₅ recovered %	P ₂ O ₅ , %			P ₂ O ₅ recovered %	
		Feed	Conc.	Tail.		Feed	Conc.	Tail.		
2F	Standard no. 120 rotor, 220 r/min, 1300 f/min, 9 in rotor submergence	14,7	25,7	8,7	61,7	14,7	26,6	7,4	68,8	-7,1
3F	No. 144 A rotor, 220 r/min, 1500 f/min, 13½ in rotor submergence	17,6	29,2	10,7	61,9	17,6	28,7	10,5	63,6	-1,7
6F	As in 3F plus additional small-hole diffuser cylinder	12,4	24,9	6,4	65,1	12,3	23,9	6,7	63,6	+1,5

was operated in parallel with two rows of twelve 50 ft³ cells each in the Foskorite plant on roughing. Rougher feed was split after the point of middling addition and sent half to the test machine and the other half to the two rows of 50 ft³ cells. The rest of the flotation circuit (scavenging, cleaning, and recleaning) was unchanged for the test machine and the control unit. Reagent conditions were the same. Since the test unit had only four mechanisms as compared with the twelve mechanisms of the control unit, there was a greater danger of pulp short-circuiting for the large-capacity machine. To reduce this risk, a connection was installed after two cells.

Samples were taken around the rougher cells (rougher feed, concentrate, and tailings) so that the 300 ft³ and 50 ft³ cells could be compared operating under identical conditions for the same total volume of rougher cells. The recoveries were determined by the three-product formula. Table VII summarizes the results of three of the most relevant tests.

In the first tests (no. 2F), the mechanisms were equipped with the standard no. 120 rotor operating under standard conditions, i.e., 220 r/min or 1300 f/min. The test unit showed a lower grade and a 7,1 per cent lower recovery, and was therefore not able to achieve the same metallurgical results as those achieved by the 50 ft³ cells.

To improve the results, the standard rotor was replaced by the bigger rotor—no. 144A (test no. 3F), resulting in the same rotation

speed and a tip speed of 1500 ft/min. At the same time, the whole mechanism was lowered by 4½ inches and the submergence of the rotor was increased by the same amount. This largely improved the recovery of the test unit since the difference in recovery dropped to 1,7 per cent. The grade of concentrate from the test unit was still lower than that of the control unit.

A final modification consisted in the installation of a so-called small-hole diffuser cylinder around the disperser in order to improve the air dispersion (test no. 6F). The results of the modification appear to be an improvement both in grade and recovery, since the test unit exceeded the control unit in both. It is to be noted that the slightly better metallurgical results were achieved by the 300 ft³ test cells, in spite of the fact that only four mechanisms were available as compared with twelve units for the control sections. It was therefore felt that at least the same, if not better results, especially in recovery, can be expected of a twelve-cell 300 ft³ machine.

The overall test results were related to the size fractions to ascertain which size fraction required improvement during the testing period. The results of the analyses for the above three tests are given in Tables VIII to X. Because of the obvious changes in the rougher feed during the various test periods, only the results during the same period should be compared.

It appears that the standard no. 120 impeller resulted in an insufficient recovery in all size

fractions, which might be due to insufficient agitation and aeration. After the large rotor was installed, the recoveries of the medium and the finer size fraction improved more than that of the coarser sizes. This seems to coincide with the practice in other mineral flotation, for example potash, where a higher rotor speed is required for the finer particles than for the coarse particles. The modification of test 6F, in which the feed is coarser and lower than that of the preceding tests, seems to have been more favourable to the recovery of the coarser size. The quieter cell surface might have been a major reason for this result.

Copper Concentrator at McGill

The 21 500 ton/d copper concentrator of the Nevada Mines Division of Kennecott Copper Corporation at McGill, Nevada, U.S.A., was converted to 300 and 500 ft³ Wemco flotation cells in September 1974. Anderson, Wilmot, and Jackson⁸ have reported on the reasons for the use of large-capacity cells.

The mill used modified Forrester air cells throughout, with the exception of twenty-four 200 ft³ Booth cells. The ore treated was a porphyry copper ore with chalcocite as the main copper mineral. The ore fed to the mill had started to change to a limestone ore with chalcocite and tarnished chalcocite, which had reduced the efficiency of flotation.

Laboratory and pilot investigation had shown that the recovery of copper could be increased by about 7 to 88,7 per cent under the same

300 ft³ cells

TABLE VIII
ROUGHER FLOTATION — TEST 2F⁷

Mesh	Feed, %		Concentrate, %		Tailings, %		P ₂ O ₅ recovery %	Difference in recovery 300 ft ³ —50 ft ³ cells
	Mass	P ₂ O ₅	Mass	P ₂ O ₅	Mass	P ₂ O ₅		
+48	25,7	13,7	10,5	38,6	33,6	9,8	38,14	— 0,83
48—100	17,0	22,1	15,4	38,9	15,0	13,0	61,83	— 7,81
100—200	14,1	19,5	14,3	33,9	13,3	9,8	69,95	—11,00
200—400	13,4	12,3	12,5	20,8	12,1	5,2	76,95	— 6,85
—400	29,8	10,1	47,3	16,6	26,0	6,4	59,61	— 6,63
Total (assay)	100,0	14,7	100,0	25,7	100,0	8,7	61,70	— 7,1
Total (recalc.)		(14,69)		(25,35)		(8,83)		

50 ft³ cells

+48	28,2	13,54	12,8	37,88	37,7	9,60	38,97	
48—100	16,8	21,58	18,0	39,20	17,0	10,62	69,64	
100—200	14,1	20,29	16,0	34,78	12,9	7,32	80,95	
200—400	12,7	11,87	13,4	19,06	10,1	4,02	83,80	
—400	28,2	9,9	39,8	17,20	22,3	5,4	66,24	
Total (assay)	100,0	14,7	100,0	26,6	100,0	7,4	68,8	
Total (recalc.)		(14,6)		(26,9)		(7,98)		

300 ft³ cells

TABLE IX
ROUGHER FLOTATION — TEST 3F⁷

Mesh	Feed, %		Concentrate, %		Tailings, %		P ₂ O ₅ recovery %	Difference in recovery 300 ft ³ —50 ft ³ cells
	Mass	P ₂ O ₅	Mass	P ₂ O ₅	Mass	P ₂ O ₅		
+48	23,1	15,4	11,5	38,9	28,1	11,5	35,2	—0,6
48—100	19,7	23,7	21,2	39,6	18,4	15,2	58,2	—6,8
100—200	14,5	23,6	17,3	37,0	13,2	11,9	73,1	—2,3
200—400	11,9	17,3	14,6	26,9	10,1	7,4	78,9	—3,0
—400	30,8	13,6	35,4	19,7	30,2	8,6	65,2	—2,4
Total (assay)	100,0	17,6	100,0	29,2	100,0	10,7	61,9	—1,7
Total (recalc.)		(17,89)		(30,17)		(10,94)		

50 ft³ cells

+48	23,1	15,4	0,7	39,4	31,1	11,5	35,8	
48—100	19,7	23,7	21,0	39,0	20,2	13,7	65,0	
100—200	14,5	23,6	18,2	35,6	13,2	11,6	75,4	
200—400	11,9	17,3	16,1	24,1	9,3	7,6	81,9	
—400	30,8	13,6	35,0	18,4	26,2	8,8	67,6	
Total (assay)	100,0	17,60	100,0	28,7	100,0	10,5	63,6	
Total (recalc.)		(17,89)		(28,81)		(10,89)		

300 ft³ cells

TABLE X
ROUGHER FLOTATION — TEST 6F⁷

Mesh	Feed, %		Concentrate, %		Tailings, %		P ₂ O ₅ recovery %	Difference in recovery 300 ft ³ —50 ft ³ cells
	Mass	P ₂ O ₅	Mass	P ₂ O ₅	Mass	P ₂ O ₅		
+48	28,8	10,70	11,9	35,81	32,9	6,68	46,18	+13,91
48—100	19,9	15,49	21,5	34,84	19,2	7,46	65,94	+ 4,98
100—200	18,7	14,61	22,3	25,26	14,1	8,15	65,26	—10,00
200—400	11,3	12,95	16,3	19,37	18,8	5,35	81,06	— 4,90
—400	21,3	10,6	28,0	15,90	15,0	5,9	70,5	— 5,18
Total (assay)	100,0	12,4	100,0	24,9	100,0	6,4	65,1	+ 1,5
Total (recalc.)		(12,62)		(24,99)		(6,67)		

50 ft³ cells

+48	28,8	10,40	8,6	38,27	34,9	7,72	32,27	
48—100	20,6	15,61	18,0	35,79	21,7	8,30	60,96	
100—200	17,5	14,25	22,2	26,23	15,9	5,96	75,26	
200—400	10,2	13,37	16,6	19,71	8,1	4,50	85,96	
—400	22,9	10,6	34,6	15,9	19,4	5,2	75,68	
Total (assay)	100,0	12,3	100,0	23,9	100,0	6,7	63,6	
Total (recalc.)		(12,49)		(24,33)		(6,82)		

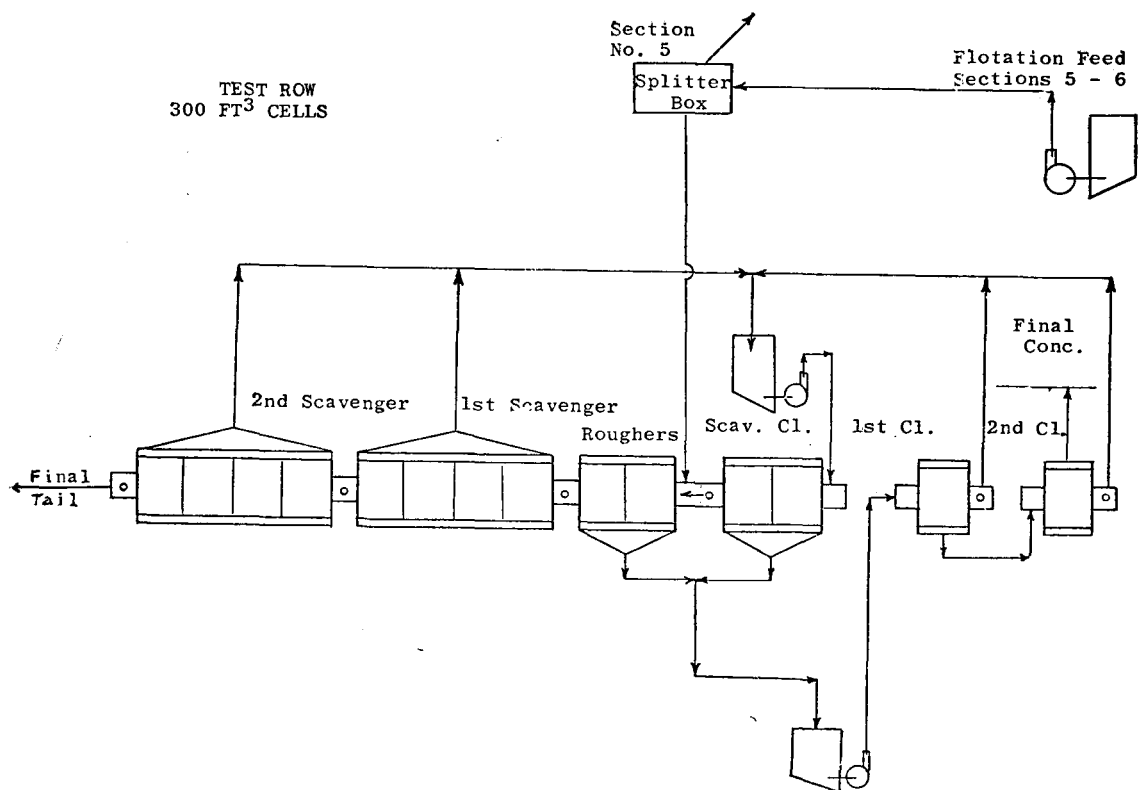


Fig. 11—Flowsheet and cell arrangement of no. 120 Wemco test row, McGill

milling conditions by the following steps:

- (1) increased agitation of the pulp by the use of mechanical flotation cells, and
- (2) an increase in the volume of the flotation cell by approximately 50 per cent to result in 17 minutes for roughing and scavenging. (The total volume for roughing and scavenging in the old plant was 15 768 ft³.)

In May 1972, a test unit consisting of fourteen no. 120 Wemco cells was installed to treat 3000 ton/d. Fig. 11 shows the flowsheet of the test unit. The flotation feed was 25.9 per cent plus 100 mesh, 50 per cent minus 200 mesh, and 28 per cent solids by mass. The test unit was compared with mill section V, both units receiving identical flotation feed from a splitter box.

Table XI summarizes the average results of 92 shifts of the test unit, control section 5, and the general mill, and shows an increase in recovery of about 6 per cent of the no. 120 test unit. The higher grade of concentrate in control section 5 was caused by the impossibility of pumping the froth of the last

scavengers back into the first cleaning.

Since the 300 ft³ cell test unit had proved that the same increase in recovery as predicted in laboratory and pilot flotation could be achieved, it was decided to convert the whole flotation section to mechanical flotation cells. For roughing and scavenging, a total cell volume of 24 000 ft³ was projected. To install the flotation cells in the existing building under full production and to reduce the costs of modifications to the building, only cell sizes of 300 ft³ unit cell volume or larger were considered. Because it was not possible to test

machines under identical conditions, the selection of machines was based on local experience with cells from three different manufacturers and corporate experience with a fourth machine. The selection was based mainly on maintenance repairs, lifting height for removal of the mechanisms, and purchase costs. Forty-eight 500 ft³ Wemco cells were chosen for the required volume of flotation cells for roughing and scavenging (24 000 ft³). The 500 ft³ no. 144 Wemco cell has the tank dimensions 144 by 108 by 63. The forty-eight cells are in the form of four machines with twelve cells each: feed box —

TABLE XI
COMPARATIVE TEST RESULTS OF NO. 120 WEMCO⁸ CELLS AT MCGILL (92 SHIFTS)

	Control section 5	No. 120 Wemco test row	General mill
Operating rate, ton/d*	2750	2750	22000
Copper in feed, %	0,988	0,988	0,988
Copper in tailing, %	0,305	0,239	0,300
Copper in concentrate, %	24,640	23,420	21,630
Copper recovery, %	69,1	75,8	69,6
+100 mesh, %	32,8	31,6	32,0
Concentrate, ton/d	36,2	37,9	N/A†
Copper lb/d	37,549	41,190	N/A
Additional copper, lb/d		3,641	

* 7 day operating rate (22 000 ton/d)

† Not applicable



Fig. 12—No. 144 Wemco cells at McGill (temporary installation)

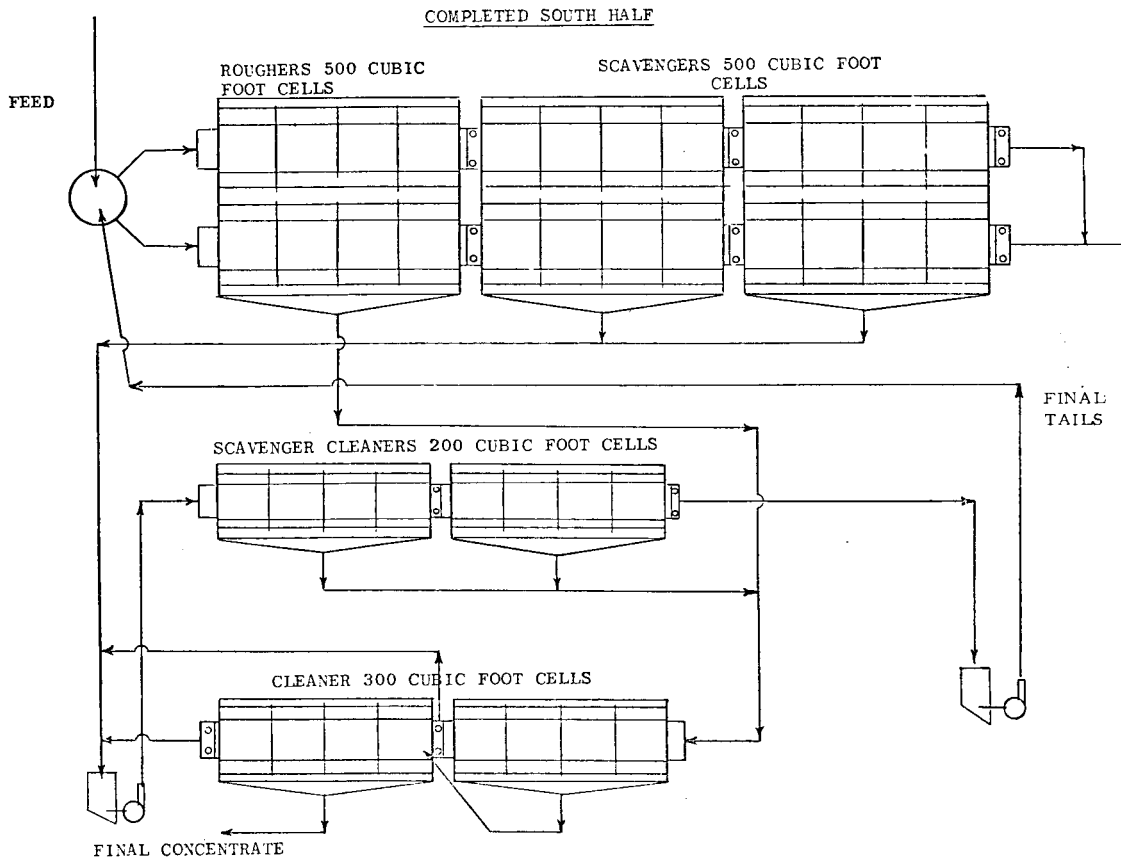


Fig. 13—Flowsheet and cell arrangement of no. 144 cells (south half) at McGill

TABLE XII

COMPARATIVE RESULTS OF NO. 144 WEMCO⁸ — CELL SECTION AND FORRESTER AIR-CELL SECTION

	South half of plant No. 144 Wemco cells	North half of plant Forrester air cells
<i>Head</i>		
Copper, %	0,594	0,594
Insoluble copper, %	0,04	0,04
<i>Concentrate</i>		
Copper, %	16,39	14,03
MoS ₂ , %	0,58	0,48
Insolubles, %	16,9	21,0
<i>Tailing</i>		
Copper, %	0,108	0,146
+100 mesh, %	35,5	35,9
<i>Recovery</i>		
Copper, %	82,4	76,2
MoS ₂ , %	41,0	40,1

4 cells — connection box — 4 cells — connection box — 4 cells — discharge box.

Fig. 12 shows no. 144 Wemco cells on a temporary installation during the construction period. Fig. 13 shows the flowsheet and cell arrangement for one half of the new flotation plant. The rougher concentrate is cleaned twice in open circuits of four 300 ft³ cells each. The scavenger concentrate is cleaned in eight 200 ft³ cells and is then subjected to the same two-stage cleaning as the rougher concentrate.

As shown in Fig. 13, the two parallel rows have one common central froth launder 3 ft wide and one outer launder 2 ft wide with a depth of from 4 to 8 ft. The walkways are above the cell surface and the froth launder, and permit a substantial saving in floor space. All cells have slide-gate air control to throttle air back both for the 300 and the 500 ft³ cells.

Table XII compares the results of the completed half of the plant with the old half of the plant. These results confirm the findings of the no. 120 300 ft³ test row, i.e., an improvement in the recovery of copper by about 6 per cent and in the grade of concentrate by about 2 per cent.

Hydrometallurgy

A recent development is the possible use of flotation machines in the field of hydrometallurgy. The leach reactors used in Anaconda's Arbiter process at Anaconda, Montana, for the ammonium leaching of copper concentrate will be equipped with Wemco no. 144 mechan-

isms. More details are expected to be reported elsewhere at a later date.

CONCLUSIONS

The following conclusions can be drawn.

1. The plant results now available indicate that the metallurgy and specific flotation capacity on a porphyry copper ore are the same for the 500 ft³ Wemco no. 144 flotation cell as for the 300 ft³ Wemco no. 120 flotation cell. Other units of the 500 ft³ size are in operation in North America on the flotation of iron ore (reverse silica float). It might be expected that 500 ft³ will soon be the favourite cell size for roughing and scavenging in new large-capacity concentrators. The 300 ft³ model might be used more extensively as a cleaner in future big mills.
2. It has become possible to float coarse phosphate in 300 ft³ cells by modification of the standard cell. In one case, the design impeller speed was increased by 10 per cent; in another case, a higher tip speed was achieved by the use of an oversize impeller. In both cases, the submergence of the rotor was increased. These results might be of interest to flotation plants with modern grinding-cyclone circuits. In cases of difficulties with classification when the grinding-mill product is discharged direct into the flotation cell, the increased suspension capacity of the lowered mechanism could help to trans-

port this coarse material through the flotation cell. It is to be noted that the rotor still operates above the cell bottom and above the trash material. Dangerous rotor impacts are still avoided, and this is further facilitated by the flexible, all-polymer 1+1 rotor—stator, which has no metallic core.

3. The example of the McGill copper concentrator, where the walkways are installed above the froth launders, might be of general interest in the saving of floor space.
4. To avoid the manual operation of flotation machines, there is, at least in North America, an increased tendency to equip both dart valves of flotation cells with automatic level controls. When there is a power failure, the level controls automatically shut off the cell discharge and avoid emptying of the flotation cells.

ACKNOWLEDGEMENTS

The author wishes to thank the Brewster Phosphate Company, the Kennecott Copper Corporation, the Nevada Mines Division, and the Phosphate Development Corporation Ltd for permission to use material for this paper.

REFERENCES

1. ARBITER, N., and STEININGER, J. Hydrodynamiques des machines de flottation. *Congres de Cannes*, 40J.
2. ARBITER, N., and WEISS, N. L. Design of flotation cells and circuits. *SME preprint 70-B-89*.
3. ARBITER, N., HARRIS, C. C., and YAP, R. F. A hydrodynamic approach to flotation scale-up. *Paper D-19*, 8th International Mineral Processing Congress, Leningrad, 1968.
4. DEGNER, V. R. Internal Company Reports. *Final Report R-73-004*—Wemco (1+1) mechanism air transfer and rotor power. 23rd Aug., 1973.
5. CUSTRED, U. K., DEGNER, V. R., and LONG, E. W. Recent advances in coarse particle recovery utilizing large capacity flotation machines. S.M.E. Fall Meeting. 22nd-25th Sep., 1974. Acapulco, Mexico.
6. Wemco on the job. *G9 S1-16*.
7. PHOSPHATE DEVELOPMENT CORPORATION LTD. Phalaborwa, Transvaal. Research Dept., *Research report no. 83*.
8. ANDERSON, M. A., WILMOT, C. I., and JACKSON, C. E. A concentrator improvement and modernisation programme utilizing large-volume flotation machines. S.M.E. Upper Peninsula Section, Houghton, Michigan, U.S.A. 3rd May, 1974.
9. Wemco on the job. *G8 S1-25*.

Discussion of the above paper

D. A. Ireland*

The design of the Impala Concentrator incorporates sixteen identical run-of-mine milling units in parallel, each with its own independent flotation circuit. The flow in all the flotation circuits is identical, consisting simply of roughing and cleaning. However, in the first four units installed, the rougher sections each consist of three parallel banks of 16 Wemco no. 66 cells whilst, from No. 5 unit onwards, a single row of ten no. 120 rougher cells was installed for each unit. In all other respects the circuits are the same. The roughing is followed by cleaning in no. 44 cells.

Initially, the no. 66 units were all equipped with squirrel-cage mechanisms, but these have now largely been replaced with 1+1 mechanisms.

This design of independent parallel flotation circuits is obviously well suited to the testing of reagents, circuits, and cell performance since classical statistical methods of comparison are easily applied.

As soon as the first circuit was installed with the no. 120 roughers, comparative tests were made of these units with and without froth skimmers, and against the no. 66 cells with squirrel-cage mechanisms and with 1+1 mechanisms.

A study of the metallurgical results obtained on Impala ore revealed that there was no statistical difference in flotation performance

- (i) between the no. 66 cells equipped with squirrel-cage and 1+1 mechanism,
- (ii) between the no. 120 cells with and without froth skimmers, and
- (iii) between the no. 120 and the no. 66 cells.

It was found that the larger cells consumed 25 per cent less power per unit cell volume than the no. 66 cells with 1+1 mechanisms whilst giving essentially the same metallurgical results. Experience has shown that fewer man hours are required in the maintenance and operation of the larger cells.

Dr Kind has pointed out and

clearly shown from the results of tests that an optimum condition is to be found for the various parameters he has mentioned. He has also said that, despite the recent progress in the field of hydrodynamics in the design of flotation cells, the major development work must still be done in industrial plants. I must agree with him on this and I am certain that there is still much to be gained by such development and optimization.

My thanks are due to the Managing Director of Impala Platinum Limited for permission to make this contribution.

R. J. Adcock†

The use of extremely coarse grinds and the presence of materials of high specific gravity such as magnetite, which are both conducive to settlement at the bottom of the tank, has led to research work by Wemco in the U.S.A. as well as by Fraser & Chalmers Equipment in South Africa. Coarse grinds in this instance are defined as those having less than 40 per cent minus 200 mesh in the flotation feed. Examples of this are the 32 to 35 per cent minus 200 mesh feed of a copper plant in Arizona at which modifications to the tank were carried out, and a grind of 35 to 40 per cent minus 200 mesh at Palabora Mining Company, at which rotor dimensions were altered.

Research work has centred round change in the design characteristics of the rotor dimensions and the shape of the tank bottom.

Dimensional Changes in the Rotor

At the Palabora Mining Company, where the coarse feed is further aggravated by the high percentage of magnetite, and hence where sanding problems have occurred, it was felt necessary to lengthen the rotor so that the suction of the rotor would penetrate deeper into the sand bed. The dimensions of the rotor in use were 660 mm diameter and 470 mm length. The rotor

rotated at a speed of 220 r/min, which is equivalent to 7.6 m/s. This-sized rotor was unsatisfactory and had the following detrimental effects on the flotation cell.

- (a) A sand bed formed and covered the false bottom, preventing circulation of the pulp.
- (b) Because of the sand bed, high-density layers at the base of the rotor caused high wear at this point, leading to short rotor life.
- (c) Because of inefficient circulation of pulp, the air drawn was below the requirements, resulting in insufficient froth depths.

The length of the rotor was then increased to 584 mm, the rotor speed and diameter being maintained as before. In the tests carried out, these large rotors were installed in two connecting cells, and the tests to date have been in operation for eight months. The observations made are as follows.

- (1) The sand bed is now almost non-existent except in the cell corners, which can be described only as natural settlement. The side intakes and suction holes of the false bottom are completely free of sand.
- (2) The air induction has been increased by 25 to 30 per cent, resulting in an increase in the froth depth from 50 mm to between 125 and 150 mm.
- (3) Indications are that, owing to the elimination of the heavy density at the bottom of the cell, rotor life will show an increase.

It should be noted that, as the tests were carried out in two cells in a rougher/scavenger bank containing 22 cells, it was not possible to measure the effect on recovery.

Tanks with Sloping Bottoms

The design of tanks with sloping bottoms originated in the Arizona copper complex. These have been installed in various concentrators in this area. Wemco claim the best installation has been in Florida on coarse phosphate rock. It is at present not possible to make a direct comparison in that tanks of

*Impala Platinum Limited.

†Fraser & Chalmers Equipment (Pty) Limited.

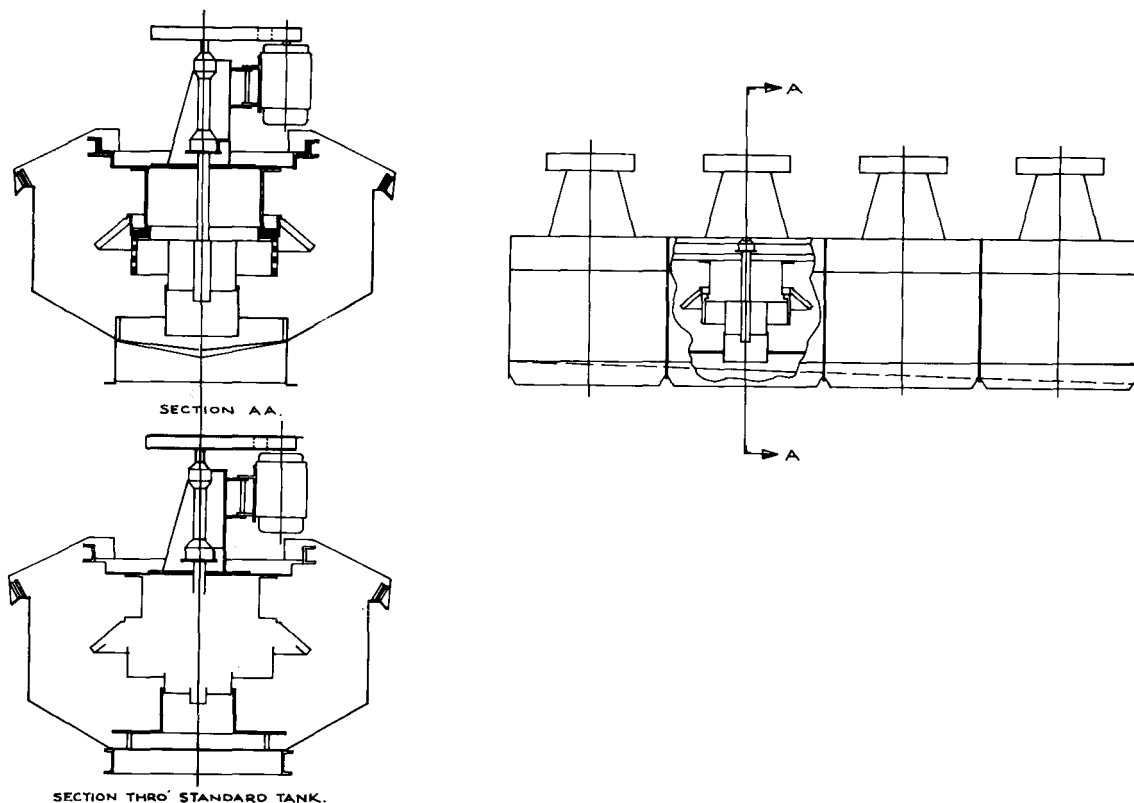


Fig. 1—The standard flat bottom tank is shown in the bottom left-hand corner. It can be seen that the draught tube does not protrude below the false bottom as it does in the sloping-bottom type. The upper diagrams show the change in slope across the length and breadth of the cell. As can be seen, the slope takes place between the cell-supporting steel and therefore does not increase the overall cell height. If this were the case, it would increase the building dimensions.

both designs are not in operation in the same plant. However, Wemco are at present delivering standard flat-bottom no. 144-inch tanks to the Florida phosphate operations, where it will be possible to make comparisons.

Manufacturing costs are high for sloping-bottom tanks and, unless coarse material is involved, sloping-bottom tanks are not recommended. Sloping bottoms have been incorporated only in the no. 120 cell, i.e., 8,4 m³.

The sloping-bottom tank obtains its slope in two directions:

- (a) in a longitudinal direction, i.e., along the length of a bank, the drop being 1 in 30, which is equivalent to a drop of 76 mm per tank;
- (b) across the width of the cell forming a sloping trough.

The slope is easily seen in Figs. 1 to 6.

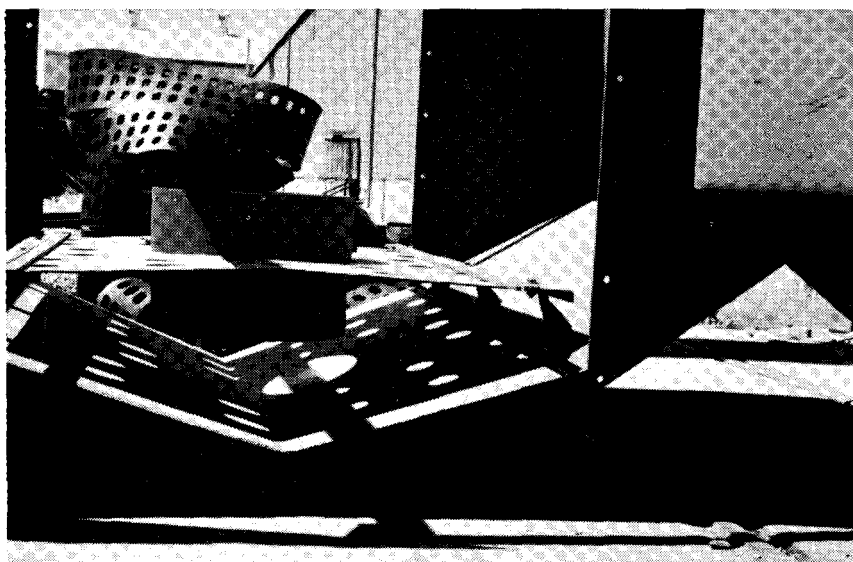


Fig. 2—A close up of tank 3. The slope is clearly seen and the extension of the draught tube below the false bottom.

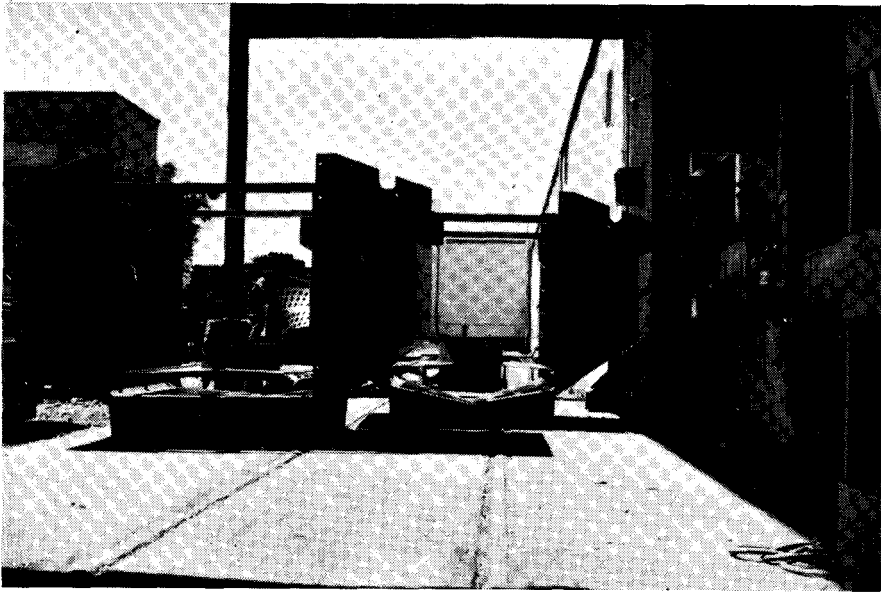


Fig. 3—Tanks 1 and 2

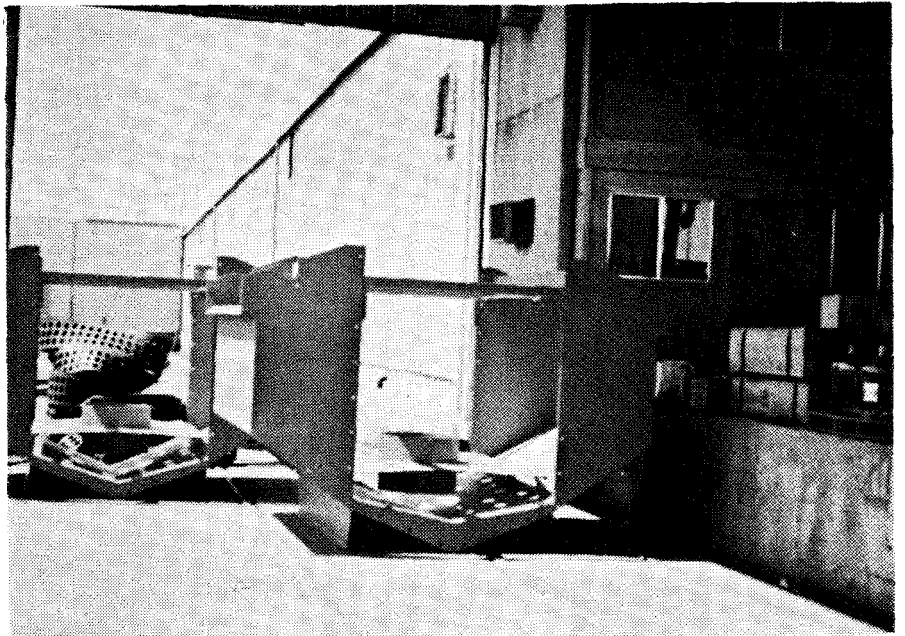


Fig. 4—Tanks 3 and 4

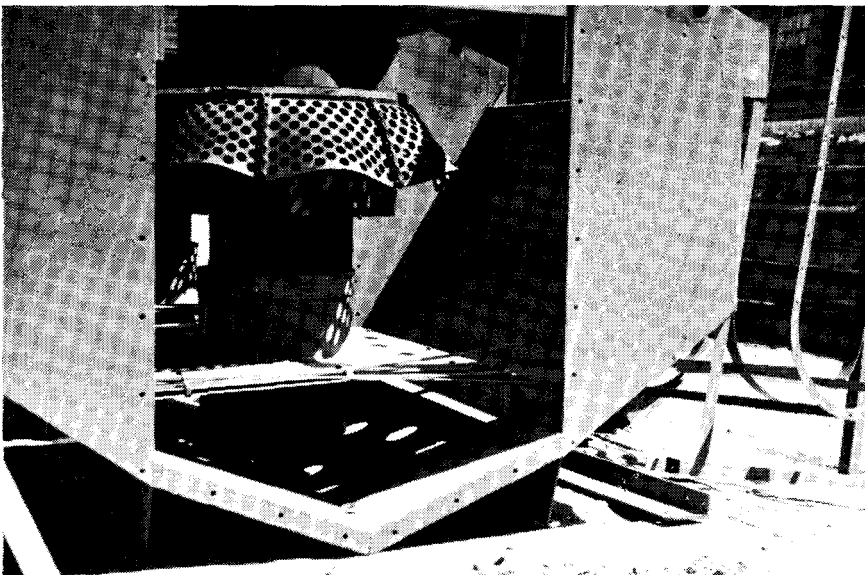


Fig. 5—A tank with a mechanism installed

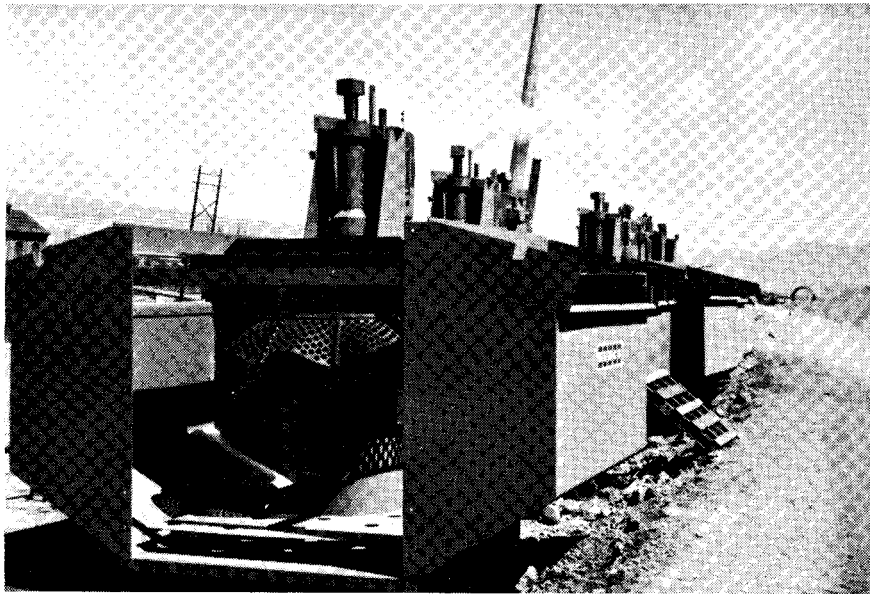


Fig. 6—The standard flat-bottom tank (no. 144, 14,3m³), taken at the Kennecott McGill Concentrator in Nevada

Company Affiliates

The following members have been admitted to the Institute as Company Affiliates.

- AE & CI Limited.
 Afrox/Dowson and Dobson Limited.
 Amalgamated Collieries of S.A. Limited.
 Apex Mines Limited.
 Associated Manganese Mines of S.A. Limited.
 Blackwood Hodge (S.A.) Limited.
 Blyvooruitzicht G.M. Co. Ltd.
 Boart & Hard Metal Products S.A. Limited.
 Bracken Mines Limited.
 Buffelsfontein G.M. Co. Limited.
 Cape Asbestos South Africa (Pty) Ltd.
 Compair S.A. (Pty) Limited.
 Consolidated Murchison (Tvl) Goldfields & Development Co. Limited.
 Deelkraal Gold Mining Co. Ltd.
 Doornfontein G.M. Co. Limited.
 Durban Roodepoort Deep Limited.
 East Driefontein G.M. Co. Limited.
 East Rand Prop. Mines Limited.
 Envirotech (Pty) Ltd.
 Free State Saaiplaas G.M. Co. Limited.
 Fraser & Chalmers S.A. (Pty) Limited.
 Gardner-Denver Co. Africa (Pty) Ltd.
 Goldfields of S.A. Limited.
 The Grootvlei (Pty) Mines Limited.
 Harmony Gold Mining Co. Limited.
 Hartebeesfontein G.M. Co. Limited.
 Highveld Steel and Vanadium Corporation Limited.
 Hudemco (Pty) Limited.
 Impala Platinum Limited.
 Ingersoll Rand Co. S.A. (Pty) Ltd.
 Kinross Mines Limited.
 Kloof Gold Mining Co. Limited.
 Lennings Holdings Limited.
 Leslie G.M. Limited.
 Libanon G.M. Co. Limited.
 Lonrho S.A. Limited.
 Lorraine Gold Mines Limited.
 Marievale Consolidated Mines Limited.
 Matte Smelters (Pty) Limited.
 Northern Lime Co. Limited.
 O'okiep Copper Company Limited.
 Palabora Mining Co. Limited.
 Placer Development S.A. (Pty) Ltd.
 President Steyn G.M. Co. Limited.
 Pretoria Portland Cement Co. Limited.
 Prieska Copper Mines (Pty) Limited.
 Rand Mines Limited.
 Rooiberg Minerals Development Co Limited.
 Rustenburg Platinum Mines Limited (Union Section).
 Rustenburg Platinum Mines Limited (Rustenburg Section).
 St. Helena Gold Mines Limited.
 Shaft Sinkers (Pty) Limited.
 S.A. Land Exploration Co. Limited.
 Stilfontein G.M. Co. Limited.
 The Griqualand Exploration and Finance Co. Limited.
 The Messina (Transvaal) Development Co. Limited.
 The Steel Engineering Co. Ltd.
 Trans-Natal Coal Corporation Limited.
 Tvl Cons. Land & Exploration Co.
 Tsumeb Corporation Limited.
 Union Corporation Limited.
 Vaal Reefs Exploration & Mining Co. Limited.
 Venterspost G.M. Co. Limited.
 Vergenoeg Mining Co. (Pty) Limited.
 Vlakfontein G.M. Co. Limited.
 Welkom Gold Mining Co. Limited.
 West Driefontein G.M. Co. Limited.
 Western Deep Levels Limited.
 Western Holdings Limited.
 Winkelhaak Mines Limited.