Flotation Cell Design: Application of Fundamental Principles

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Introduction

The froth flotation process is commonly employed for the selective separation of a mineral species from a liquid–solid suspension of both valuable and unwanted gangue mineral particles. The valuable mineral species (which needs to be separated) is rendered hydrophobic by controlling its surface chemistry to provide the potential conditions for the attachment of the particles to air bubbles. The bubbles and particles are made to interact with each other inside a flotation machine. The flotation machine, depending on its operating conditions, provides an environment for the bubble–particle attachment and permits levitation of bubble–particle aggregates to the froth. The manner in which bubbles and particles interact with each other depends on the cell operating conditions and the type of flotation machine used.

Flotation machines, in general, may be categorized into four different classes: (i) mechanical or conventional cells; (ii) energy-intensive pneumatic cells; (iii) column cells; and (iv) froth separators. Of these, mechanical flotation cells have dominated the mineral industry since the early days of flotation and account for a significant amount of minerals processed. The aim of this article is to describe the operation and design of mechanical flotation cells.

Cell Operation

A mechanical flotation cell essentially consists of a vessel or a tank fitted with an impeller or rotor. The impeller agitates the slurry to keep particles in suspension, disperses air into fine bubbles and provides an environment in the cell tank for interaction of bubbles and hydrophobic particles and their subsequent attachment and therefore separation of valuable mineral particles from the undesired gangue mineral particles. The bubble–particle aggregates move up in the cell by buoyancy and are removed from the cell lip into an inclined drainage box called a launder (**Figure 1**). The launder product is commonly known as concentrate. The particles that do not attach to the bubbles are discharged out from the bottom of the cell tank to the discharge or tailings box (Figure 1).

Hydrodynamic Zones

A mechanical flotation cell necessitates generation of three distinct hydrodynamic zones for effective flotation. The region close to the impeller encompasses the turbulent region necessary for solids suspension, dispersion of gas into bubbles and bubble–particle interaction for collection of minerals on the surface of the bubbles. Above the turbulent region lies the quiescent zone where the

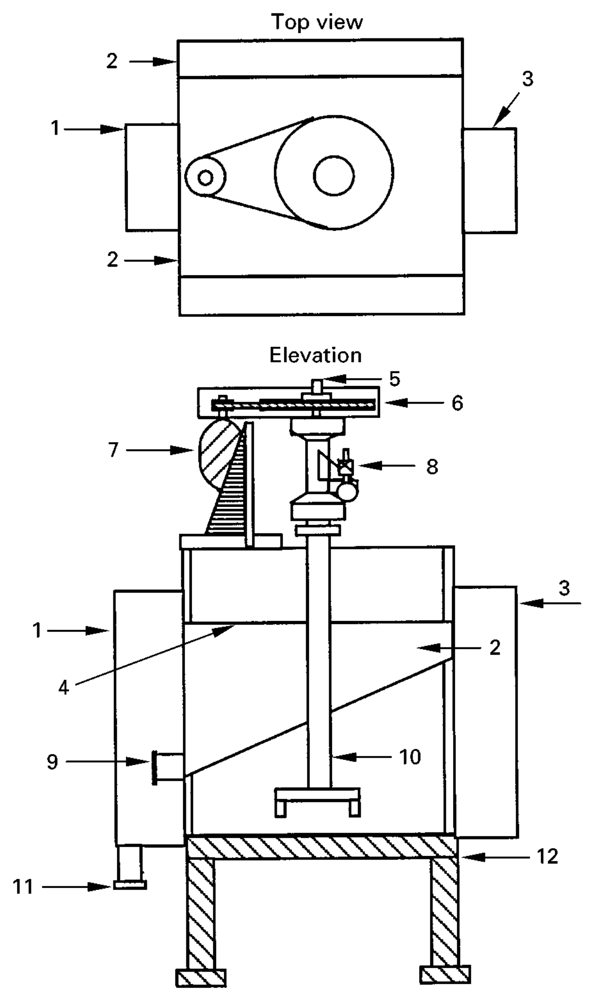

Figure 1 Schematic diagram of a mechanical flotation cell. 1, Discharge box; 2, concentrate launders; 3, feed box; 4, cell lip; 5, bearing shaft; 6, drive pulley with guard; 7, three-phase induction motor; 8, air inlet pipe with control valve; 9, concentrate launder discharge point; 10, impeller shaft; 11, tailings discharge point, 12, base support for the cell tank.

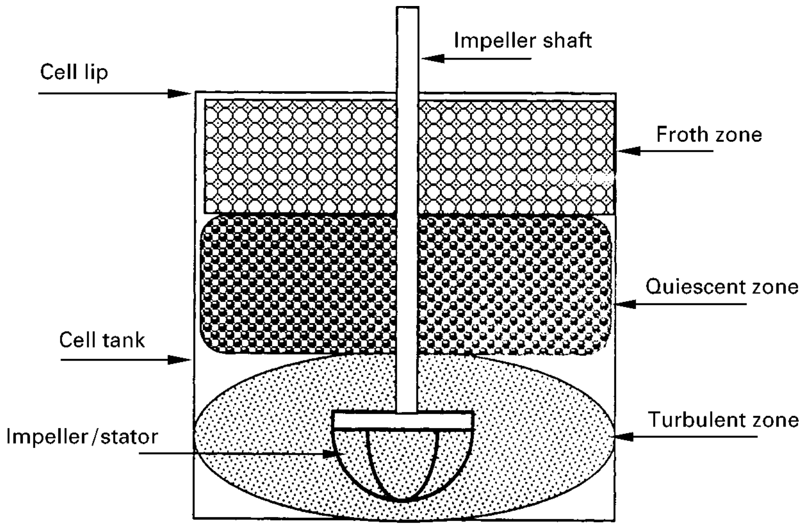

Figure 2 Hydrodynamic zones in a mechanical flotation cell.

bubble–particle aggregates rise up in a relatively less turbulent region. This region also helps in reducing the number of gangue minerals which may have been entrained mechanically or entrapped between bubbles for upgrading of valuable minerals. The region above the quiescent zone is the froth zone that serves as an additional cleaning step and improves the grade of the concentrate product. The three hydrodynamic zones in mechanical flotation cells are depicted in **Figure 2**.

The conflicting functional requirements in different zones in a mechanical flotation cell are a challenge in terms of the cell design and a fine balance of hydrodynamic conditions is necessary for the optimum recovery of valuable minerals in a cell.

Gas Dispersion

One of the most important hydrodynamic conditions in a mechanical flotation cell is dispersion of gas into fine bubbles. The bubble generation mechanism in a mechanical cell is a two-stage process. Firstly, air cavities are formed at the trailing edge of the impeller blades, which is the low pressure region. Thereafter, bubbles form by shedding of vortices from the tail of the cavity, as shown in **Figure 3**.

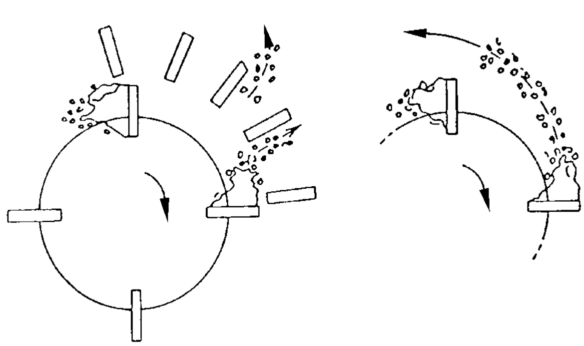

Figure 3 Schematic diagram of formation of bubbles in mechanical cells (after Grainger Allen, 1970; courtesy of Transactions of the Institute of Metallurgy, UK).

The dispersion of air into bubbles can be characterized by three properties: bubble size, gas hold-up and superficial gas velocity. Mean bubble size in industrial mechanical cells varies, in general, from 0.5 to 2 mm; gas hold-up varies from 5 to 15% and superficial gas velocity varies from 0.6 to 1.5 cm s^{-1}, depending on cell operating conditions (impeller speeds and air rates) and the cell duty in plant operation – roughers, scavenging, cleaners, etc. Recent studies have shown that bubble size, gas hold-up and superficial gas velocity cannot describe the gas dispersion in a mechanical cell adequately when taken individually; but when taken together the gas dispersion properties determine the bubble surface area flux S_b in the cell, which has been shown to characterize gas dispersion very well. Typical S_b values in industrial cells vary from 30 to 60 s^{-1}. The concept of S_b has been found to be useful in metallurgical scale-up and cell optimization, design and selection.

Mode of Air Entry

In mechanical cells there are two modes by which air is introduced into the cells; one is the forced air entry mode carried out using a blower and the other is the self-induced air entry mode, in which air is sucked into the cell by vortexing. The two cell designs can be distinguished by the difference in vertical location of the impeller in the cell. In the forced air-type machine, the impeller is located close to the cell bottom with a deeper impeller submergence, and an external air blower is used to supply air under pressure through the hollow shaft to the impeller region. Self-induced air machines utilize a standpipe which shrouds the drive shaft which is solid. The impeller is located almost in the midpoint of the cell which draws air through the space between the standpipe and the solid shaft.

Flow Patterns

The impeller in a mechanical flotation cell, during rotation, generates a vortex at the bottom of its blades drawing slurry from its lower section and discharging out from its upper section of the blades. Air is introduced through the impeller shaft or in the spacing between the shaft and a standpipe depending on whether the cell is forced air type or self-induced type, as described above. The dispersed air bubbles come in contact with the slurry close to the impeller discharge point. The aerated slurry flow then leaves the impeller mechanism for the surrounding tank volume. The impeller, therefore, acts as a pump drawing in slurry from below and expelling the aerated slurry to the cell volume. A typical flow pattern of a mechanical cell is shown in **Figure 4**.

Cell Design

The essential components of a mechanical flotation cell are described below.

Cell Tank

The profile of a cell tank is rectangular with truncated corners, U-shaped, conical or cylindrical, depending on cell type and size. Typically, mechanical cells are designed with a rectangular tank bottom for cells with volume up to 3 m^3 and a U-shaped bottom for cells with volume up to about 38–45 m^3. Cells larger than 38–45 m^3 are typically cylindrical with either a conical or a flat bottom. **Figure 5** shows a schematic of different tank designs.

In a typical plant, the mechanical cell tanks are arranged in a series called a bank. The number of cells in a bank varies depending on cell size, application and plant circuit configuration. The tailings from the first cell move on as the feed to the second cell and so on and the tailings from the last cell form the final tailings of the bank. The concentrates from different cells are combined in different ways depending on the requirements of the circuit. For example, in a cleaner bank, the concentrates from the first two cells may be combined to form the final concentrate products, whereas the concentrate product from the rest of the cells may be combined and recirculated to the feed of the cleaner bank.

Feed Box and Discharge Box

Each bank in a flotation circuit (which could also be an individual cell) is usually fitted with a feed box

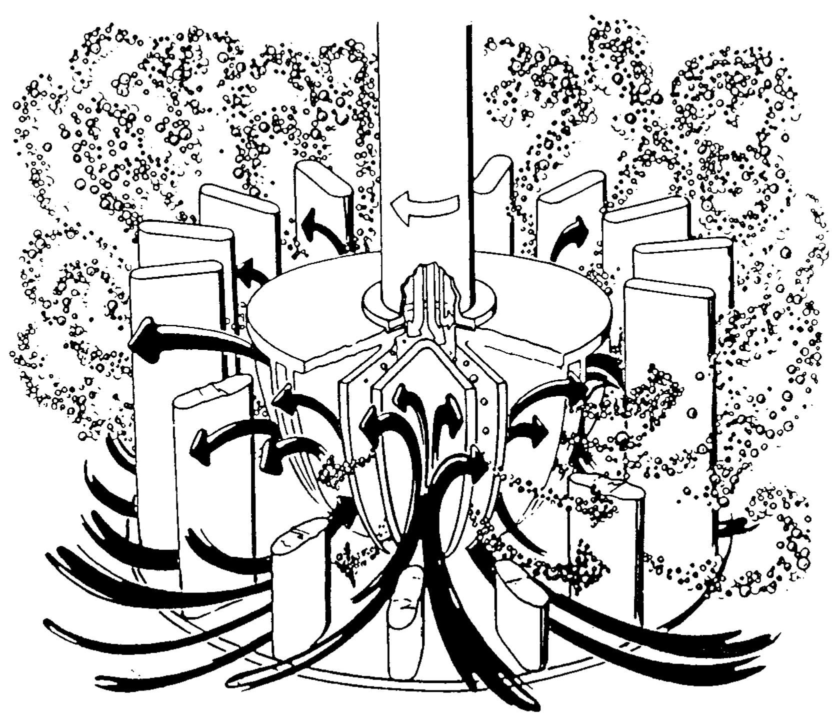

Figure 4 Typical flow patterns in a mechanical flotation cell (courtesy of Outokumpu Mintec Oy, Finland).

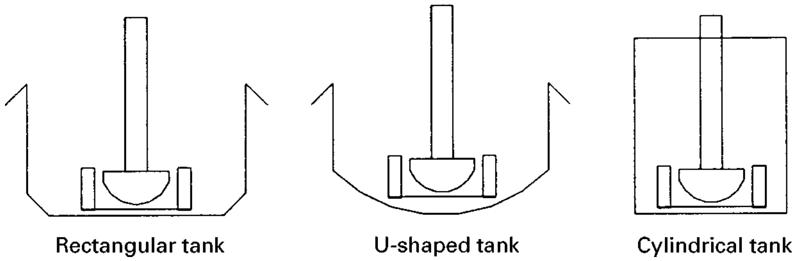

Figure 5 Typical tank designs in mechanical flotation cells.

with a rectangular opening at the bottom of the box to allow entry of slurry into the cell bank for flotation. The feed box is rectangular or half-cylindrical in shape depending on cell type and size. A tailings box or discharge box is also fitted at the end of the bank (or on the opposite side of feed box in an individual cell) to allow discharge of tailings. The discharge box is also rectangular or half-cylindrical in shape. **Figure 6** shows a typical arrangement of a feed and a discharge box in mechanical flotation cells. For some cell types and sizes, a dart valve or overflow weir are fitted in the discharge box to control pulp level in the cell tank. For other designs, a discharge box is not used and a pinch valve is fitted to the tailings outlet pipeline instead for pulp level control.

Cell Launders

Launders in flotation cells are located outside the overflow lip to collect and transport the froth or concentrate product out of the cell tank. Launders are typically located on the top of the cell tank, as shown in Figure 1. Launders are designed with a slope of about 10–15° for smooth transportation of froth without blockage in the launders.

The design of launders varies with cell size and type. The launders are located on opposite sides adjacent to the feed and discharge boxes in rectangular cell tank designs, as shown in Figure 1. Launders on three sides are also common in rectangular cells arranged in series. Large cylindrical cells have concentric launders which can be either internal or external or both, depending on the capacity of launder necessary for froth removal.

Impellers or Rotors

The impeller or agitator, also referred to as the rotor, is considered to be the heart of a mechanical flotation cell as it provides the energy to perform the following functions necessary for the flotation process:

1. Suspension of solids in the cell tank.
2. Dispersion of air into bubbles.
3. Creation of microturbulence for effective bubble–particle collision.
4. Suction of air into the cell in self-induced type cells.

The design of an impeller varies with cell type. Most impeller designs have a flat circular disc with different shapes of blades or fingers fitted to the disc concentrically to the lower section of the disc. The shape of the blades or fingers varies from cylindrical to tapered (half-spherical). The half-spherical impeller design is more popular in the new design of cells and details of this design will be discussed later in this article. The top section of the disc connects to a drive shaft which in turn connects to the pulley/gear-motor drive assembly. The impeller is located in the centre of the cell cross-section with its

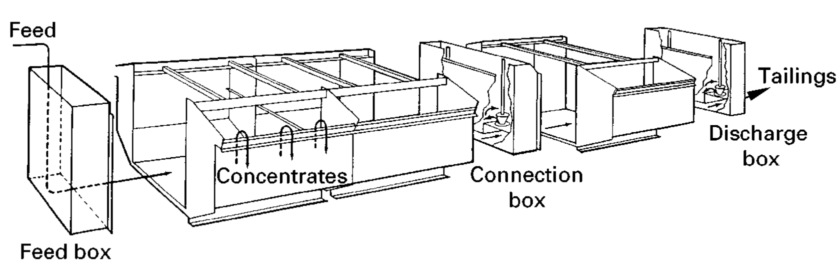

Figure 6 Schematic of a mechanical cell showing feed box and discharge box and concentrate launders.

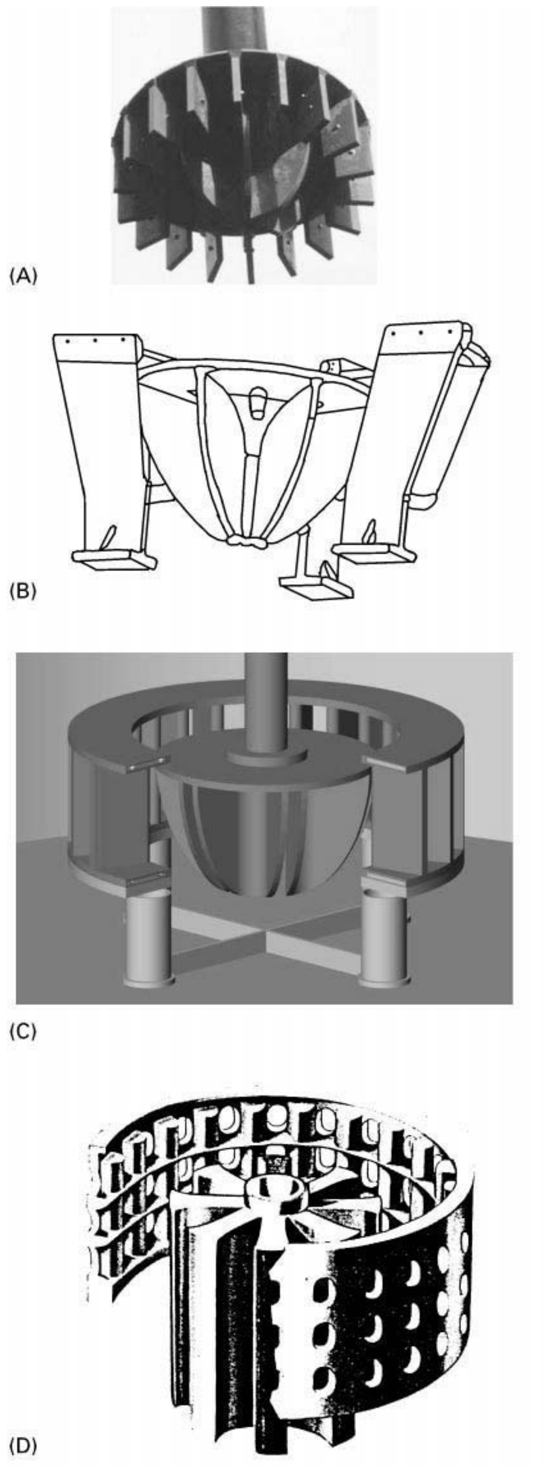

Figure 7 Shapes of different impellers and stators. (A) Bateman; (B) Dorr-Oliver; (C) Outokumpu; (D) Wemco (courtesy of Bateman Process Equipment, Dorr-Oliver, Outokumpu Mintec Oy and Baker Process, respectively).

submergence varying with cell type and mode of air entry. **Figure** 7 shows the shapes of different commercially available impellers.

Stators or Diffusers

A stator or diffuser is an important component of a mechanical flotation cell, which surrounds the impeller and acts as an internal baffle useful in reducing pulp vortex in the cell. The tangential flow of the agitated slurry (due to rotation of the impeller) is transformed to a radial direction for effective dispersion of gas and solids in the cell tank. This reduction in the vortex flow helps in maintaining a stable pulp–froth interface, essential for flotation.

A stator consists of a number of blades arranged in a concentric circle with gaps between the blades to facilitate movement of slurry in the cell tank. A stator is usually mounted on the bottom of the cell tank surrounding the impeller concentrically from its bottom. In some cell designs the stator is fitted to the standpipe such that the stator shrouds the impeller from the top and hangs with an open space at the bottom: this is commonly known as an overhung stator.

The impellers and diffusers are moulded and coated with rubber or polyurethane for abrasion resistance.

Impeller Drive Assembly

The impeller connected to the shaft (hollow or solid) is driven by a three-phase induction motor with the help of V-belts, pulleys or gear box. A typical drive arrangement in a mechanical cell is shown in Figure 1. The size of the drive and the motor pulleys determine the speed at which an impeller operates.

Cell Types and their Designs

Most of the industrial mechanical flotation cells in the early days (before the 1970s) were of the cell-to-cell type (tanks of different cells connected in a row) for small plants and multistage cleaner floats where the pumping action of the impellers permitted the transfer of intermediate flows without external pumps. With the emergence of large flotation cells, since the early 1980s, dictated by economic considerations, open flow cells (with slurry flowing openly through a series of cells in a bank) have become prominent.

In the 1980s many mechanical cell designs were prevalent around the world. The major ones are:

1. Agitair cells from Galigher company, USA.
2. Aker machines from Aker Trondelag, Norway.
3. BCS cells from Minemet Industrie, France.
4. Booth cells from Booth Company, USA.
5. Denver cells from Denver Equipment Limited, Joy Industrial Company, USA.

6. Krupp cells from Krupp Polysius AG, West Germany.
7. Maxwell cells from Technequip Ltd, Canada.
8. Mechanobre cells from Machineoexpert V/O, USSR.
9. OK cells from Outokumpu Oy, Finland.
10. Sala cells from Sala International AB, Sweden.
11. Wedag cells from KHD Humboldt Wedag from West Germany.
12. Wemco cells, Wemco division, Envirotech, USA.

Only a handful of these cell manufacturers have survived the competitive global market by improving their products or by mergers or by diversification. Manufacturers of Wemco and Outokumpu cells, through research and development, have consistently updated their technology to remain competitive. The recent Tankcells (designated as OK-TC) and Smartcells from the manufacturers of Outokumpu and Wemco cells, respectively, are an example. Some new designs, such as the Bateman BQ and Svedala RCS cells, have emerged in the mid 1990s. The companies which manufactured Denver and Sala cells have been procured by Svedala and their cells are marketed by Svedala's Pumps and Process division. The Agitair cells are now marketed by Baker Process (previously known as EIMCO Process Equipment Company). KHD Humboldt Wedag have stopped manufacturing mechanical cells and now market a newly developed pneumatic cell known as Pneufloat.

Presently there are five major manufacturers of mechanical flotation cells. Details of the design features of different cells are described in the sections below.

Bateman Cell

The Bateman flotation mechanism was developed in 1993 and is presently marketed by the Bateman Process Equipment Limited. The BQR series of Bateman cells have a round tank design with cell sizes varying from 5 m^3 (BQR 50) to 100 m^3 (BQR 1000). The tank dimensions of different cells of varying sizes are given in **Table 1**. The unit cell design Bateman cells are called HiFlo™ and HiClean™ machines.

Table 1 Bateman cell tank dimensions for different cell sizes (courtesy of Bateman Process Equipment, South Africa)

Model	*Volume (m^3)*	*Height (m)*	*Depth (m)*	*Installed motor (kW)*
BQR 50	5	2	2	NA
BQR 100	10	2.5	2.5	45
BQR 200	20	3.2	3	55
BQR 300	30	3.6	3.4	75
BQR 400	40	4	3.75	75
BQR 500	55	4.2	4.34	115
BQR 750	75	5.2	4.5	132
BQR 1000	100	5.5	4.95	132

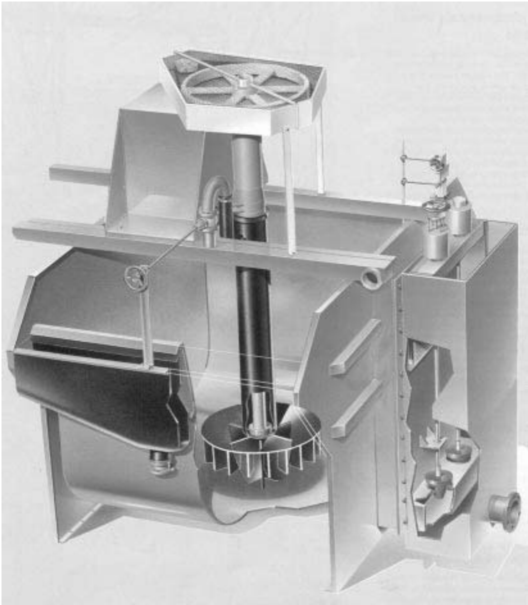

Figure 8 A schematic diagram of the Bateman flotation cell (courtesy of Bateman Process Equipment, South Africa).

The Bateman mechanism consists of a hemispherical-shaped impeller which is connected to a solid drive shaft. The impeller is designed with no disc on the top and the impeller blades have both the top and bottom opened. The drive shaft is shrouded with a stand pipe. The Bateman mechanism utilizes the forced air entry mode and air is supplied into the mechanism through the gap between the standpipe and the shaft. The mechanism utilizes an overhung-type stator (or diffuser) connected to the bottom of the standpipe, which is a horizontal hood with baffle plates projecting downwards (**Figure 8**).

Dorr-Oliver Cells

The Door-Oliver cell is marketed by Dorr-Oliver, a global corporation and member of the Krauss-Maffei Group.

The Dorr-Oliver Company Limited manufacturers flotation cells in a wide range of sizes. Cells with a volume of 0.03 m^3 (DO 1) to 2.8 m^3 (DO-100) have a flat-bottom tank design. Cells with volumes from 4.2 to 44 m^3 come with a U-shaped tank bottom. Cells with volumes from 50 to 150 m^3 are available with a round tank with a conical bottom. Details of tank dimensions for the Dorr-Oliver cells are given in **Table 2**.

Table 2 Dorr-Oliver cell tank dimensions for different cell sizes (taken from Dorr-Oliver flotation cell brochure; courtesy of Dorr-Oliver, Australia)

DO conventional cells					
Model	*Volume (m^3)*	*Length (m)*	*Width (m)*	*Height (m)*	*Installed motor (kW)*
DO 1.0	0.03	0.3	0.3	0.33	0.55
DO 3.5	0.1	0.45	0.45	0.5	0.55
DO 10	0.3	0.65	0.65	0.66	1.1
DO 25	0.7	0.9	0.9	0.86	2.2
DO 50	1.4	1.2	1.2	0.97	4.0
DO 100	2.8	1.52	1.52	1.22	5.5
DO 150	4.2	1.83	1.83	1.53	7.5
DO 300C	8.5	2.29	2.29	1.88	7.5
DO 300	8.5	2.29	2.29	1.88	11.0
DO 500C	14	2.69	2.69	2.46	15
DO 600	17	2.95	2.69	2.46	22
DO 1000	28	3.35	3.35	2.89	30
DO 1350	38	3.81	3.58	3.22	37
DO 1550	44	3.96	3.96	3.22	45
Tank design					
Model	*Volume (m^3)*	*Height (m)*	*Diameter (m)*	*Installed motor (kW)*	
DO 1750	50	3.86	4.32	56	
DO 3500	100	5.49	4.65	93	
DO 5300	150	6.71	4.72	131	

The Door-Oliver mechanism consists of a hemispherical-shaped impeller fitted to a hollow shaft. The mechanism utilizes the forced air entry mode in which air is introduced to the impeller through the hollow shaft. The stators for the Dorr-Oliver cells are generally mounted on the bottom but the large cells mechanisms are designed with an overhung stator.

Figure 9 shows a schematic diagram of a large Dorr-Oliver cell with a tank design.

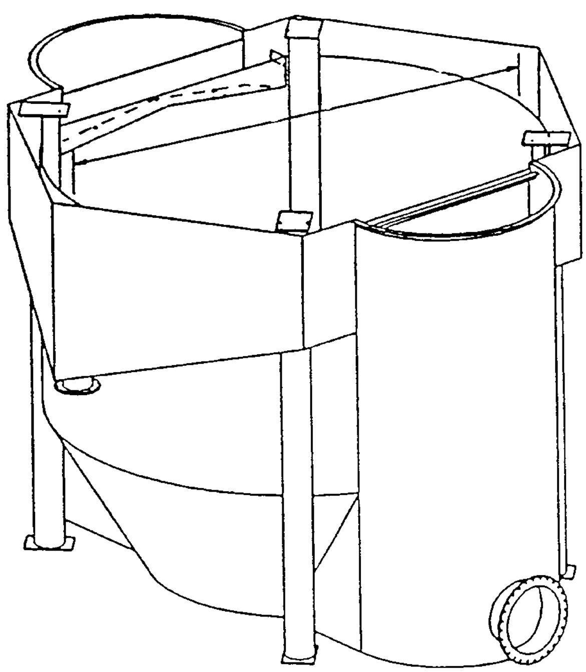

Figure 9 Schematic diagram of a large Dorr-Oliver cell (courtesy of Dorr-Oliver, Sydney, Australia).

Outokumpu Cells

Outokumpu Mintec, a Finnish company which belongs to the Outokumpu Group, operates internationally and has been the manufacturer of the Outokumpu flotation cell for the last 30 years.

Outokumpu produces different flotation machines which can be catgorized as:

1. OK conventional flotation machines: for rougher, scavenger and cleaner flotation.
2. OK-TC (TankCell) flotation machines: for rougher and scavenger flotation.
3. SK flotation machines: for Skim-Air Flash flotation in the grinding circuit.
4. HG flotation machines: for cleaner flotation.

The OK conventional flotation cells are available in volumes up to 38 m^3. Conventional cells have a rectangular tank design for cell volumes up to 3 m^3; above 3 m^3 and up to 38 m^3 the cells have a U-shaped tank. TankCell designs are available from a volume of 5 m^3 to a volume of 160 m^3 and are essentially a cylindrical

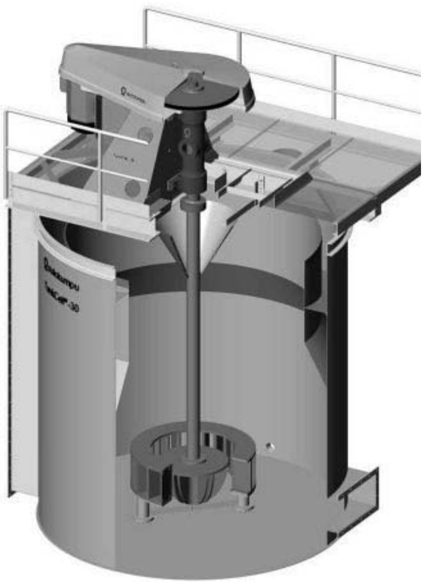

Figure 10 A schematic diagram of Outokumpu TankCell (courtesy of Outokumpu Mintec Oy, Finland).

cell with a flat bottom (**Figure 10**). The tank dimensions of different cells are given in **Table 3**.

The OK impeller mechanism is designed with a hemispherical-shaped impeller consisting of a horizontal disc on the top which is attached to a number of narrow vertical slots tapered downwards. The impeller has separate slots for air and slurry movement. The mechanism has a forced air type entry mode in which air is brought into the impeller through a hollow shaft.

The stator in the OK mechanism is mounted on the bottom of the tank. There are two stator designs used in an Outokumpu cell: one is known as the multi-mix or conventional stator and the other is known as free-flow. The multi-mix stator is typically used for fine particle flotation, whereas the free flow stator is typically used for coarse particle flotation.

Svedala Cells

The former manufacturers of Denver flotation cells (Denver Equipment, USA) and Sala cells (Sala International in Sweden) have merged together to form the Svedala Pumps and Process Division, which is part of the worldwide Svedala Industri group. Both Denver and Sala cells are available through Svedala companies located worldwide.

The Svedala flotation cells include mechanical flotation cells in the AS range (previously known as Sala cells), in sizes from 0.03 to 16 m^3; the DR range

Table 3 Outokumpu cell tank dimensions for different cell sizes (taken from Outokumpu flotation cell brochure; courtesy of Outokumpu Mintec Oy, Finland

		OK conventional cells			
Model	*Volume (m^3)*	*Length (m)*	*Width (m)*	*Height (m)*	*Motor installed (kW)*
OK-0.5-R	0.5	NA	NA	0.84	2.75–3.75
OK-1.5-R	1.5	NA	NA	1.08	5.5–7.5
OK-3-R	3	1.52	1.52	1.21	7.5–11
OK-8-U	8	2.29	2.29	1.88	15–22
OK-16-U	16	2.95	2.69	2.46	30–45
OK-38-U	38	3.49	3.59	3.23	55–75
Model	*Volume (m^3)*	*Height (m)*	*Diameter (m)*	*Motor installed (kW)*	
		Tank Cells			
OK-5-TC	5	2.45	2.2	7.5	
OK-10-TC	10	2.85	2.7	15	
OK-20-TC	20	3.45	3.3	37	
OK-30-TC	30	3.9	3.9	45	
OK-40-TC	40	4.3	4.1	45	
OK-50-TC	50	4.6	4.6	75	
OK-70-TC	70	5	5	90	
OK-100-TC	100	5.3	5.6	110	
OK-130-TC	130	5.4	6.3	132	
		Extra Hard Duty			
OK-100-TC-XHD	100	4.6	6.3	90	
OK-130-TC-XHD	130	4.8	6.7	110	
OK-160-TC-XHD	160	5.1	7.1	132	

Table 4 Svedala cell tank dimensions for different cell sizes (taken from Svedala flotation brochure; courtesy of Svedala, UK)

Model	*Volume (m^3)*	*Height (m)*	*Diameter (m)*	*Installed motor (kW)*
RCS 5	5	1.9	2	15
RCS 10	10	2.4	2.6	22
RCS 15	15	2.5	3	30
RCS 20	20	3	3.25	37
RCS 30	30	3.4	3.7	45
RCS 40	40	3.8	4.1	55
RCS 50	50	4.1	4.5	75
RCS 70	70	4.6	5	90
RCS 100	100	5.2	5.6	110
RCS 130	130	5.6	6.1	132
RCS 160	160	6.1	6.5	160
RCS 200	200	6.5	7	200

(previously known as Denver cells), in sizes from 0.09 to 42.5 m^3; and cell-to cell machines in sizes from 0.08 to 14.2 m^3.

In 1995 Svedala developed a new design of flotation cell known as the RCS Flotation machine which comes in sizes from 5 to 200 m^3. The tank dimensions of different cells sizes are shown in **Table 4**.

The RCS Flotation machine utilizes a new DV (deep vane) mechanism. The DV mechanism consists of vertical rectangular blades or vanes tapered at the bottom. The blades are connected to a circular horizontal disc located just above the centre of the blades. The mechanism is designed with an overhung stator with vertical vanes projecting downwards connected to the mechanism standpipe. Depending on cell application, the DV mechanism can be modified in two different ways to suit the application. The design of the mechanism which allows entry of air through a hollow drive shaft is known as the DVH mechanism (deep vane and hollow shaft), whereas the design which allows entry of air through a concentric standpipe is known as the DVS mechanism (deep vane and solid shaft).

Figure 11 shows a schematic of the Svedala RCS flotation cell, showing the DV mechanism and the cell tank design.

Wemco Cells

Wemco flotation cells are manufactured by Baker Process, which also makes Agitair cells and pyramid column cells.

There are two major Wemco designs, the Wemco 1 + 1 design and new SmartCell design (**Figure 12**). The 1 + 1 design comes in cell sizes from 0.57 to 85 m^3. The SmartCell design comes in sizes from 8.5 to 160 m^3. The Wemco 1 + 1 cell utilizes the self-induced air entry mode and consists of a rotor,

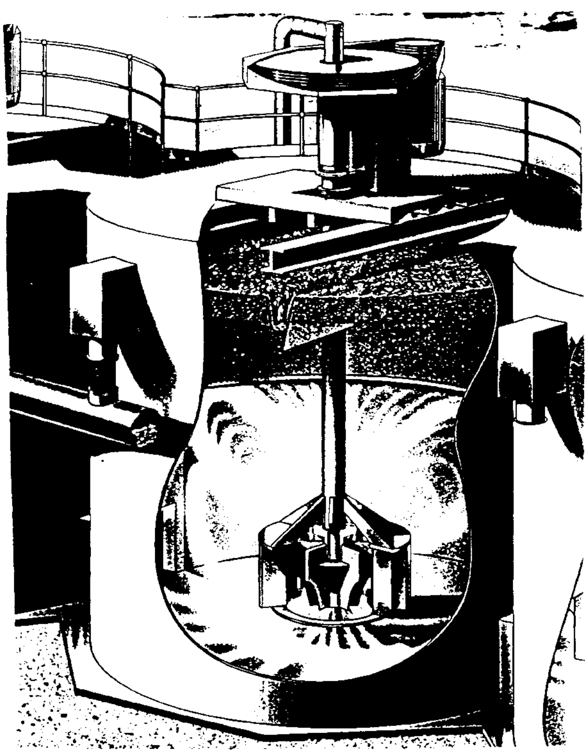

Figure 11 A schematic diagram of Svedala RCS cell (courtesy of Svedala, UK).

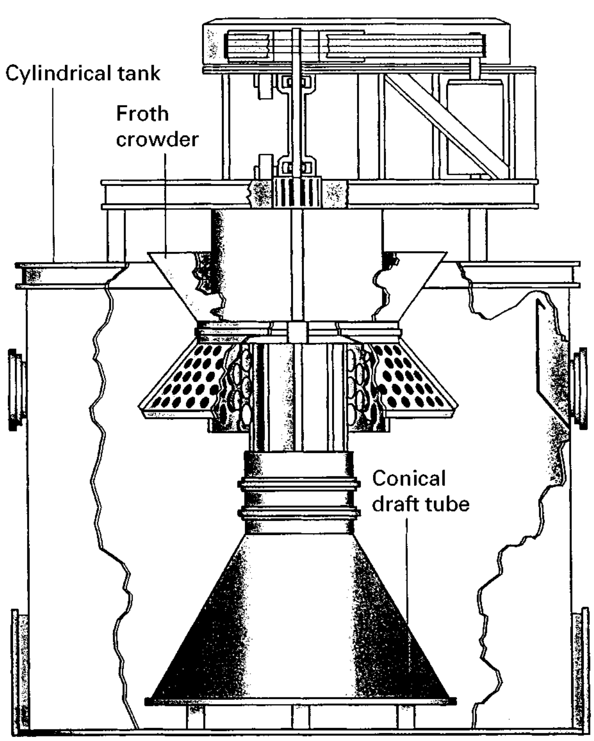

Figure 12 A schematic diagram of Wemco SmartCell (courtesy of Baker Process, USA).

Table 5 Wemco cell tank dimensions for different cell sizes (taken from Wemco flotation cell brochure; courtesy of Baker Process, USA)

Wemco 1 + 1

Model	*Volume (m³)*	*Length (m)*	*Width (m)*	*Height (m)*	*Installed motor (kW)*
44	0.57	1.12	1.12	0.57	3.75
56	1.1	1.42	1.42	1.1	5.5
66	1.7	1.52	1.68	1.7	7.5
66D	2.8	1.52	1.68	2.8	11
84	4.2	1.6	2.13	4.2	22
120	8.5	2.29	3.05	8.5	30
144	14.2	2.74	3.66	14.2	45/55
164	28.3	3.02	4.17	28.3	
190	42.5				
225	85				

Wemco SmartCells

Model	*Volume (m³)*	*Height (m)*	*Diameter (m)*	*Installed motor (kW)*
300	8.5	1.6	2.59	30
500	14	2.44	2.84	30
750	21	2.57	3.45	40
1500	42.5	2.82	4.32	75
2500	71	3.66	5.31	100
4500	127	4.65	6.2	200
5650	160	4.88	6.83	1.14

Wemco Agitairs

Volume (m³)	*Length (m)*	*Width (m)*	*Height (m)*	*Installed motor (kW)*
1.13	1.22	1.22	0.76	
1.7	1.52	1.52	0.76	
2.83	1.52	1.52	1.19	
4.25	1.6	2.13	1.35	
8.5	2.29	3.05	1.35	18.5
14.15	2.74	3.66	1.6	30
28.3	3.05	4.17	2.36	45

disperser, standpipe and a hood. The larger cells are designed with a false bottom and draught tube. The SmartCell flotation machine utilizes the Wemco 1 + 1 aeration mechanism which is reconfigured and embedded with an expert control system. The dimensions of different Wemco cells are shown in **Table 5**.

The air and pulp circulation in the Wemco cells are determined by the rotor size, speed and submergence in the pulp. Liquid circulation and air transfer are a function of rotor speed, size and submergence.

Present and Future Trends

Traditionally, flotation machine design closely follows the trend of comminution machines in mineral-processing plants. Due to economic considerations in the processing of low grade ores, the present comminution machines such as crushers, semi-autogous, autogenous and ball mills are designed for very high capacities. The Cadia Hill Mine in New South Wales, Australia, which treats a copper-gold ore at the rate of 2100 tonnes per hour, utilizes a 12 m diameter SAG mill (with a 20 MW motor) and two 6.5×11 m ball mills (each with a 8.75 MW motor). To be compatible with the comminution circuit, large capacity 150 m^3 flotation cells are used in the rougher circuit.

At present, cells are large as 300 m^3 are being designed by various manufacturers. Installation of large cells has many advantages:

1. reduction in capital costs;
2. reduced size of plants;
3. reduced power consumption;
4. reduced maintenance;

5. easy control;
6. reduced reagent consumption.

However, with increase in cell size, the problem of machine design and metallurgical scale-up becomes more acute. The scale-up features that may have been tolerated on smaller cells are not applicable to larger cells. The simple similitude considerations used in terms of dimensionless numbers (power number, Froude number, air flow number, Reynolds number) are not sufficient to design large machines. The development and evaluation costs rapidly increase with cell size, which calls for a more rational and fundamental basis in cell design. Extensive research at the Julius Kruttschnitt Mineral Research Centre in Brisbane has shown that bubble surface area flux or S_b is an important criterion for metallurgical scale-up, which will gain more prominence in the future and will be considered as a parameter in conjunction with other important dimensionless numbers used in machine design and scale-up.

An increase in cell sizes also requires more effective froth transportation due to the increase in travel time of bubble–particle aggregates which results in high drop-back and low froth recovery. To address the problem of froth transportation and stability in large cells, new design features such as internal launders, double launders, high capacity launders, booster cones, froth crowders, cross-launders and beehive launders are emerging. More work will be carried out by cell manufacturers and researchers to understand froth transportation and froth recovery. The effect of the interactions of different launder designs, froth crowders and cell-operating parameters such as impeller speed, air rate and froth depth will be the subject of further investigation for better cell design and optimization of cell operation.

The design differences of various cells marketed by different manufacturers are in fact differences in impeller/stator mechanisms and air input systems (either self-induced or forced air type through a standpipe with a solid shaft or through a hollow shaft). However, the design of tanks is similar for different cell types, and resembles the cylindrical design of the old Maxwell cells. The launder and froth crowding devices in different designs are tailor-made to suit different applications.

The large new flotation cells are equipped with integrated control systems. The recent trend of installation of a few large cells in a circuit will see more control instrumentation like air flow control, variable speed drive for speed control, as well as online measurement equipment for monitoring bubble size, superficial gas velocity, gas hold-up and bubble surface area flux, which will be used for better cell performance optimization. Froth vision equipment will also gain prominence for better control of froth in the large flotation cells.

The development of flotation cells will continue as more and more fine particle processing will be necessary in future. The large flotation machines will have to be designed to generate very small bubbles and a high degree of microturbulence for effective bubble–particle collision to remain competitive against other novel technologies like high intensity pneumatic cells. Entrainment will be a major issue in concentrators, which will need refinement of froth-washing technologies in mechanical flotation cells.

Acknowledgements

The authors would like to thank the manufacturers of Bateman, Dorr-Oliver, Outokumpu, Svedala and Wemco cells for providing sale catalogues, pictures and other information regarding their flotation cells.

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