Imhoflot – The Evolution of Pneumatic Flotation – Roughing, Cleaning, Scavenging

Rainer M. Imhof – Maelgwyn Mineral Services Limited Germany
Julian V. Brown – Maelgwyn Mineral Services Limited, Wales
Samuel Sanchez Pino – Ingeniería de Minerales Limitada

General

There is little difference in age between the two major flotation techniques, namely mechanical and pneumatic flotation. But during the last century, from the onset of industrialized mining, mechanical flotation was the predominant technique. Most likely this was due to the greater reliability of mechanical devices, such as rotors and stator assemblies, compared with devices for producing fine air bubbles, such as porous media. In the 1960s the principles of column flotation were adopted, but as computer and PLC control technology was still in developmental stages, the column technique was not overly successful. In the 1970s the trend for larger capacity process flow streams intensified. Large flotation tanks of up to 36 m3 and more became widespread and in the 1980s it was also quite usual to replace cleaner banks with columns to improve concentrate qualities.

Pneumatic flotation, like the Bahr-cell, is a quite separate and different development. Process kinetics of pneumatic flotation should not be compared directly with column flotation. Whereas the separation process in a column is counter-current, the Bahr-cell operates with a co-current feed and product configuration. Therefore, the mineral process engineer should clearly distinguish between mechanical (agitated) flotation, columns and pneumatic flotation. Future trends are likely to retain columns for cleaning operations, but an overlap is developing between applications for large mechanical tanks and the new pneumatic flotation systems.

The pneumatic flotation technology of today has its origins in the Bahr-cell of the late 1970s. The first plant operations were commissioned on a coal mine in Germany. Air dispersion was achieved using porous media aerators, with pore sizes around 20 microns. But these devices sometimes had the disadvantage that the pores would choke. Smaller equipment suppliers manufactured the Bahr-cell under license, but little development took place over subsequent years. In Germany, only two companies invested in R & D, and the marketing effort was insufficient to make a significant impact on the industry. In the last 15 years about 30 plants were sold under different trade names.

The first large scale pneumatic flotation plant was built 1988 in Germany for treating old and aged flotation tailings stored in ponds. Significant combustible coal could still be recovered. A new flotation plant was built in the eastern Ruhrgebiet, consisting of scrubbing, two stage flotation, dewatering and drying. Picture 1 shows the design of the pneumatic flotation at that time. The aerator design required compressed air. The feed to the plant had about 45% ash, but concentrates with nearly 50% yield and grades around 10% ash could be obtained. The main reason for investing in pneumatic technology (and not mechanical flotation) was the superior performance demonstrated during pilot testing. The concentrates produced in pneumatic cells were much cleaner and also allowed improved filtration. Higher specific filtration rates were combined with products containing 2-3% lower moisture levels.

Picture 1 First pneumatic cell 1988 in Germany, treating coal ponds

Flotation cells with similar designs were built for magnesite plants in Austria and Spain, and in the mid 1990s plants were introduced in Chile for various metallic minerals – see Picture 2.

Picture 2 First commercial application for Copper in Chile   Compania Minera Michilla 1995/1996

These design developments during the last decade have resulted in IMHOFLOT technology. The principles have been applied in commercial scale equipment design, for a wide range of applications. IMHOFLOT technology is supplied by Maelgwyn Mineral Services (MMS) of the United Kingdom and presented here in Chile through Ingenierìa de Minerales (IDM) at Antofagasta.

Description of the Cell and the Process

Figure 1 illustrates the cell configuration. Aeration of the pulp takes place in the IMHOFLOT aerator, a proprietary device in which most of the applied energy is directed to the production of micro turbulences for dispersing air and maximizing the collision events between bubbles and particles. To create this energy in the aeration unit, the pulp is fed with a centrifugal pump. It is here in the aerator device that the essence of the flotation reaction takes place – the adhesion of the valuable hydrophobic particles onto the bubbles. The subsequent separation tank serves to provide a means of recovery of the mineral loaded air bubbles. The aerator is self-aspirating, which means there is no compressed air required, and when fitted with a throttle valve the airflow into the aerator can be adjusted. Air flow rate, geometric configuration of the aerator inserts and speed of the pulp determine the size of the bubbles and their size distribution. In “statu nascendi” the young bubbles are very active and spontaneously adhere to the hydrophobic minerals.

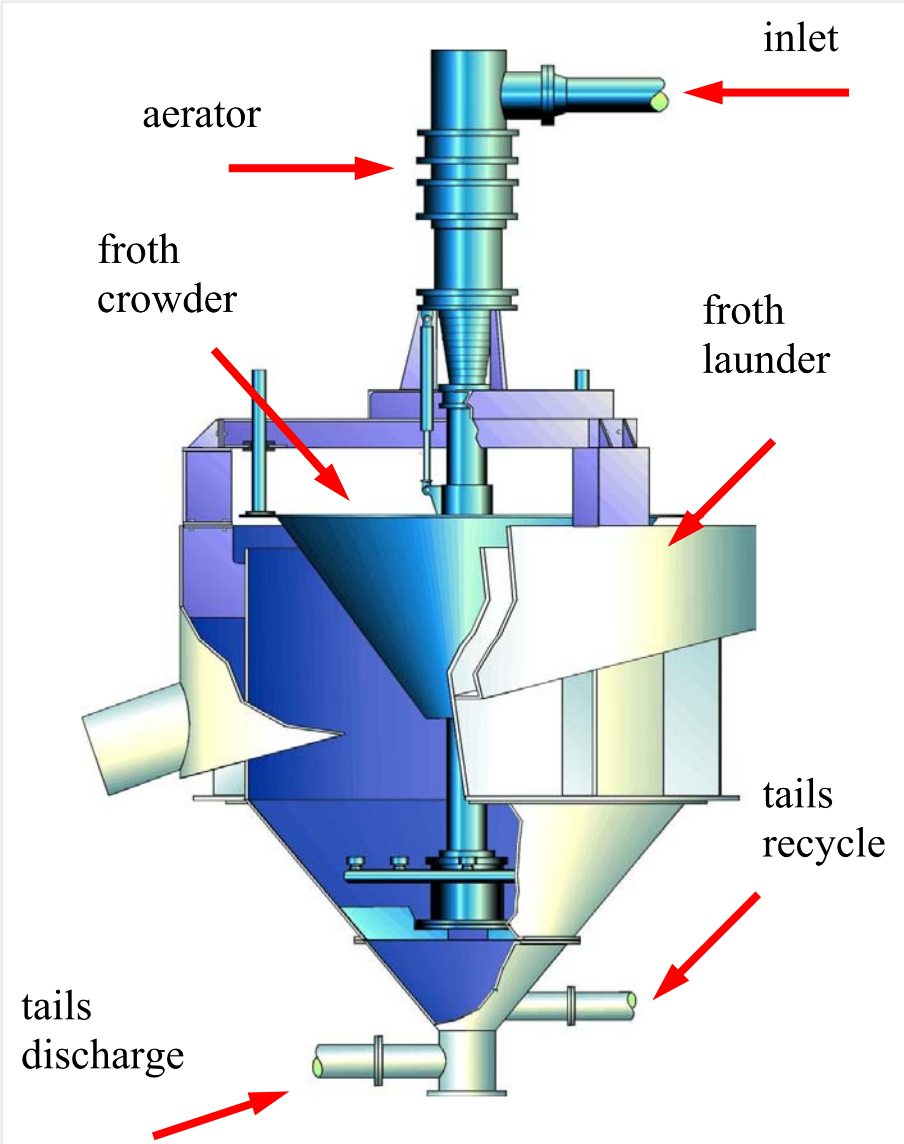
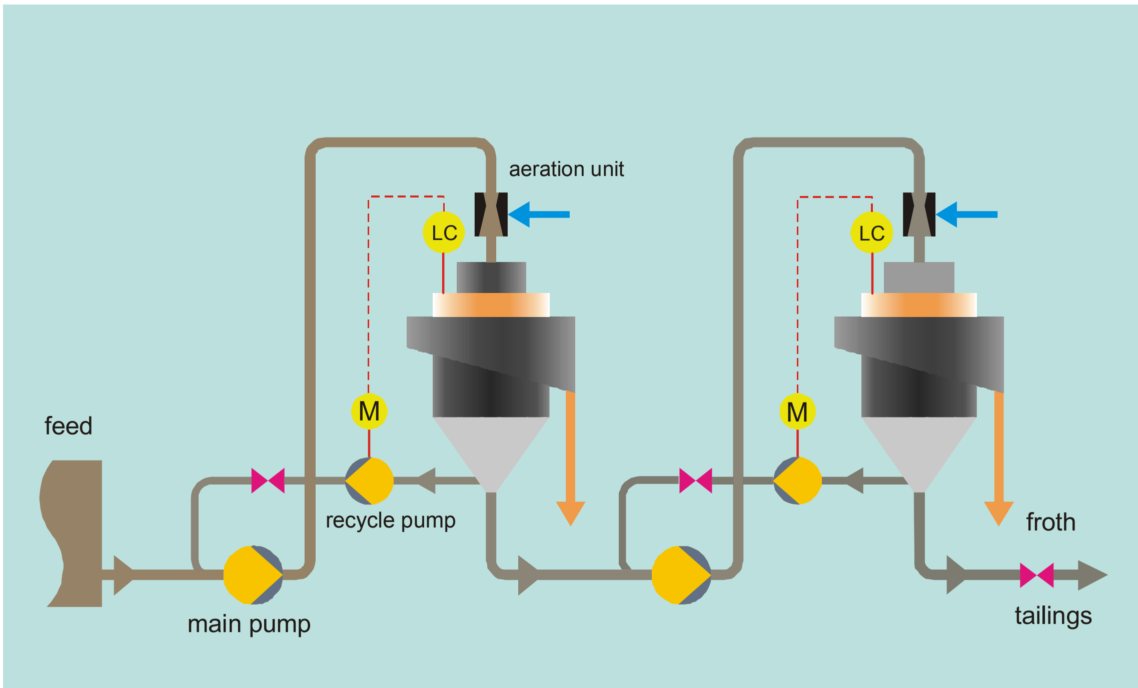


Figure 1 Cross-section of a vertically operated pneumatic cell

The aerated pulp flows downwards through a pipe into the separating tank, where it is distributed internally by means of specially designed nozzles fitted to a radial sparge assembly. The relatively large number of nozzles serves to provide a symmetric and uniform supply in the separating tank, and ensure a calm froth build-up with minimal entrainment of gangue material. This way the need for wash-water is avoided. The froth flows without any mechanical device into the peripheral launder. An inverted conical and concentric froth crowder, adjustable with a hydraulic drive, allows the operator to vary the cross-sectional froth area and thereby adapt the froth flow to specific process requirements - large areas for roughing, small areas for scavenging.

The retention time in the separating tank is normally about 2,5 minutes. One pass through a cell generally provides a similar recovery to that produced by treatment in conventional mechanical cells for 8 to 10 minutes. For example, if the layout for conventional cells for a roughing flotation process is designed for 20 minutes, then three pneumatic cells in series would obtain a comparable recovery. But the quality of the froth achieved in the pneumatic cell would be significantly better. The recovery of a single pneumatic cell cannot be improved by prolonging the retention time in the separation tank, since the essential flotation reaction has already taken place, as mentioned above, in the aeration system and in the distribution assembly. Additional collection of valuable minerals in the tank itself is insignificant. Longer retention times would not improve recovery, and shorter times in this vertical cell design run the risk of loosing fine mineralized bubbles with higher velocity down-flow near the bottom outlet of the tank.

Figure 2 below explains the standard flowsheet for 2 in series operating cells.



The conditioned feed is pumped via a centrifugal pump to the aerator of the first cell. The entrance pressure for the aerator has to be in the range of 2 to 2,5 bar. The froth of the first and second cell are combined as concentrate, the tailings of the first cell are retreated in the second cell, to obtain more recovery of the desired mineral. Some part of the tailings of each cell is recycled to the main feed pump and gives these minerals a further chance to get attached to the bubbles produced in the aerator of that same cell. With this philosophy of recycling – like in a mill circuit – two pneumatic cells recover more then they would do, connected in series without recycling. The recycling pumps are equipped with frequency inverters and control the level of the flotation tank.

For fast floating minerals like coal or salts the recycling system is not necessary, since two cells in series already obtain optimal recovery without using the recycling effect.

Sizing and Plant Layout

Smallest pilot cells have an internal tank diameter of 1m, while the standard pilot size is 1,4 m for a throughput rate of 25 to 30 m3 pulp per hour. Their results provide reliable data for scale-up. Full scale sizes for plant operations start with 2 m diameter for 100 m3/h, and a 3,5 m size can process about 450 m3/h. The biggest cell in operation so far is 5 m wide and can treat more than 1000 m3/h.

For an estimate of the number of cells required for economic recovery in the rougher-scavenger circuit, batch flotation tests in conventional laboratory cell will provide sufficient pre-information. It is generally preferable, however, to operate a pilot plant to treat a bypass from an existing plant. This is possible, if this plant is to be retrofit or expanded. In the case of metal or industrial minerals the test rig should ideally consist of three cells in series to produce full recovery data. The pilot rig can be used at different points of the existing process circuit e.g. on the tailings, to test potential improvements in performance. The feed to the cleaners in particular should be tested, to prove the benefits of the technology, in terms of cost savings for replacement, and furthermore to prove by how much the current concentrate quality could be improved. On the other hand, the considerable experience with during the years in mineral flotation tests at pilot scale means that now even tests in conventional laboratory cells for easier applications can provide sufficient information to guarantee process plant design.

The payback for the investment of two or three cells can generally be accommodated within one year.

An ideal application in existing flotation circuits is the installation of IMHOFLOT cells to increase plant capacity or mineral recovery. Due to decreasing head grades of the metal minerals in many mines the mine production is increased to compensate any concentrate production losses. A further production line solely based on pneumatic cells will be the most economic option, due to the much smaller space required and the fast return of payment. Many large, new copper operations still suffer too high losses either in the scavenger and/or in the cleaner-scavenger circuit. One or two pneumatic cells in addition would solve these problems.

In consideration of investment in IMHOFLOT cells for existing flotation plants the following benefits should be considered:

- better product quality
- higher recovery of the mineral
- lower operating costs in comparison to traditional flotation

Improvements in Design of the Separating Tank – The "G-Cell"

Since the flotation of the minerals, the attachment to the bubbles, as described before, happens outside the tank, and the tank's purpose is only for collecting the bubbles into the froth phase, the tank's shape recently has been optimized in regard of shortest possible retention times.

Like in the earliest of designs, the aerated pulp is fed into a tank tangentially, but with the intention to produce a noticeable centrifugal field to assist the separation of gangue particles and bubbles. Since no sedimentation is possible, the shell is flat at the bottom. The retention time is now only about 30 seconds, which is 5 – 6 times shorter than the time the pulp stays normally in the pneumatic flotation tank.

Three proto-types have so far been built. One was tested as a cleaner for potash in Europe. The cell has a diameter of 1.7m and processed 150 m^3/h high grade potash concentrate with successful results. Another, with a diameter of 2,2 m, has been built and will go into operation in October 2002 in South Africa, treating ultra fine coal at a throughput in the range of 300 – 350 m^3/h. There is no drop off in metallurgical performance with the G-Cell and the economic benefits of dramatically reducing the size of installation resulting from the very short retention times are obvious. Picture 3 shows the test rig being used for potash.

Picture.3 Test rig Imhoflot G17 1,7 m diameter, feed rate 150 m^3/h for potash cleaning

Maelgwyn Mineral Services Ltd.
4A Mostyn Street
Llandudno. LL30 2PS, North Wales, UK
www.Maelgwyn.com

Ingeniería de Minerales Ltda.
Av. D. Hurtado 1423
Antofagasta – Tel. 055 224696