CANADIAN PROCESS TECHNOLOGIES INC.

**NEW**


# CAVITATION SPARGING SYSTEM
# Enhanced Column Flotation

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# Introduction

Column flotation cells were introduced to the market place about thirty ago years as devices capable of producing concentrates that were lower in impurities than those produced by other types of flotation machines. The ability to operate columns with deep froth beds and to wash the froth was the main reasons cited for the improved metallurgical performance. In recent years, many producers have installed column flotation systems as a means of boosting production whilst reducing operating costs.

### History

G.M. Callow patented the first pneumatic flotation cell, which used air sparging through a porous bottom and horizontal slurry flow, in 1914. The first countercurrent column flotation device was designed and tested by Town and Flynn in 1919. Cross-current pneumatic flotation machines were widely used in industry in 1920's and 1930's, but were later replaced by the impeller-type flotation devices in mineral processing plants. Dissolved-air flotation became the main type of flotation for water treatment applications. These substitutions were the result of the absence of effective and reliable air spargers for fine bubble generation and by the lack of automatic control systems on the early columns. During this period, both the poor flotation selectivity and entrainment of slimes characteristic of impeller-type cells was offset by the use of complex flowsheets using large numbers of cleaner stages and recycle lines. Column flotation devices were re-introduced for mineral processing in the late-1960's in Canada by Boutin and Wheeler (1967) at which time wash water addition to the froth was used to eliminate entrainment of hydrophilic materials to the float product. By the late-1980's column flotation had became a proven industrial technology in the mineral industry. These separators are routinely used on their own or in conjunction with other types of devices within separation circuits

### Description

Column cells (Figure 1) are flotation devices that also act as three phase settlers where particles move downwards in a hindered settling environment countercurrent to a swarm of rising air bubbles that are generated by spargers located at the bottom of the cell. Within the vessel there is a distribution of particle residence times dependent on settling velocity that may impact on the flotation of large particles. Impeller devices do not suffer from this effect to the same degree but do require higher energy input to suspend larger particles.

Mechanism of particle/bubble collision in columns is different from intensive mixing devices such as impeller cells. Under the low-intensity mixing caused only by a rising bubble swarm, particle drift from the liquid streamlines is caused mainly by gravity and inertial forces and also by interception, while in mechanical cells, according to many researchers, bubble-particle collision occurs at their relative movement within turbulent vortex or at adjacent vortices. Also, as velocities of both bubble and particle during the attachment are slower under quiescent conditions in a column, the contact time is generally higher. Therefore, probabilities of both collision and adhesion (components of attachment probability) are different than that in mechanical flotation process.

A column can support a deep froth bed and may use wash water (Figure 2) to maintain a downward flow of water in all parts of the vessel. This essentially eliminates the entrainment of hydrophilic particles in the float product when the vessel is used for solid/solid separation. This property, along with the absence of stray flows of feed material to the float product from turbulence, means that column devices are normally superior to impeller type machines for the selective separation of fine particles.

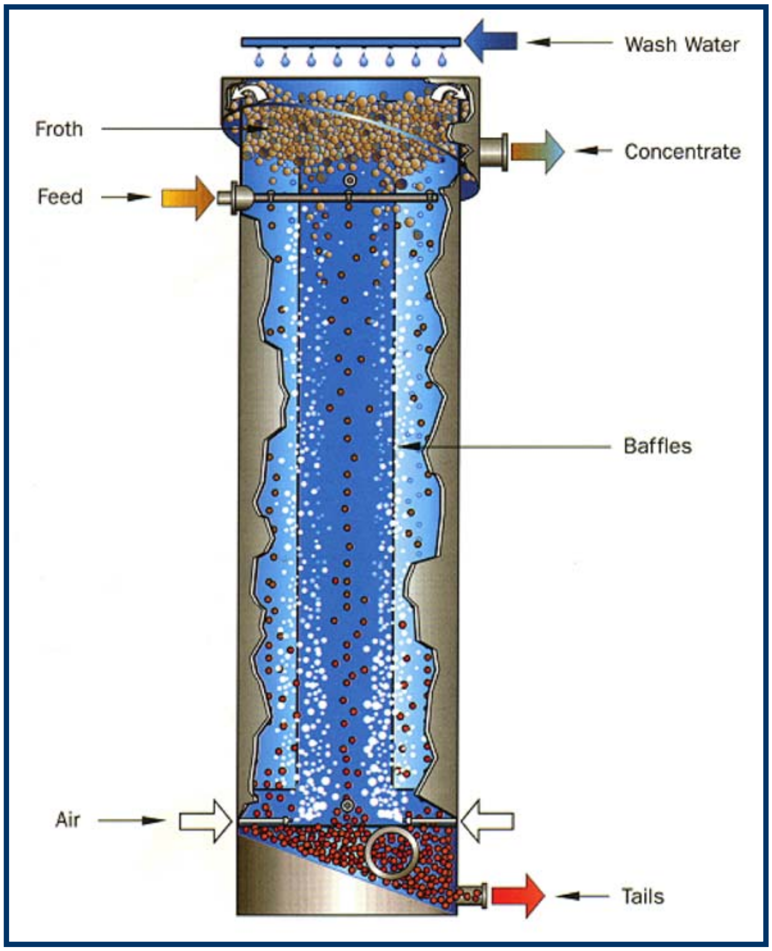



**Figure 1: Typical Column Cell**

**Figure 2: Wash water addition improves concentrate quality**

The bubbles used in a column are usually generated within the size range that maximizes interfacial surface flux and collection intensity through the vessel. In mechanical cells bubbles are usually generated by shear action of the impeller; thus, bubble size is dependent on both airflow rate and impeller rotation speed. As such, bubble size cannot be controlled independently of cell turbulence.

Figure 3 shows the relationship between bubble diameter and bubble surface area rate.

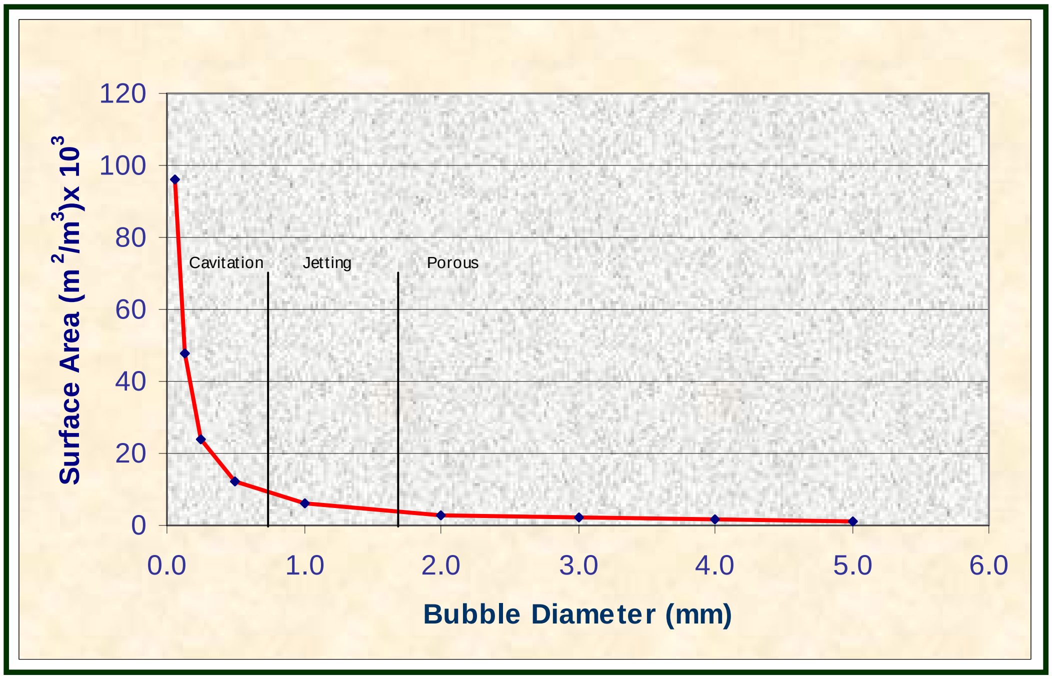



**Figure 3: Bubble surface area as a function of diameter.**

To maximize the bubble surface area generation, CPT has developed an industrial sparging system based on hydrodynamic cavitation. Hydrodynamic cavitation is the process of creation and growth of gas bubbles in a liquid due to the rupture of a liquid–liquid or a liquid–solid interface under the influence of external forces. Hydrodynamic cavitation occurs when the pressure at a point in a liquid is momentarily reduced below its vapor pressure due to high flow velocity. Minute air or vapor-filled bubbles are carried on by the flow to regions of higher pressure.

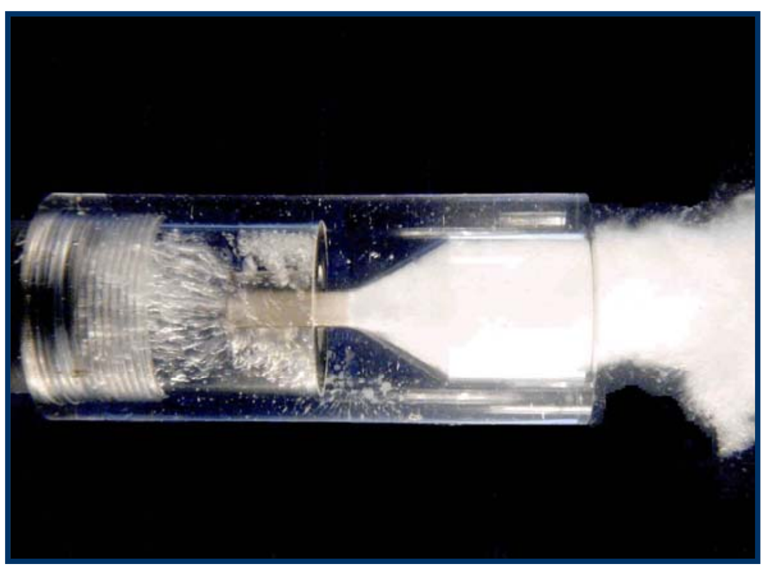


**Figure 4: Cavitation Tube**

The operation of the CPT Cavitation Tube is illustrated in Fig.4. The liquid in the cylindrical throat is higher in flow velocity and lower in pressure than liquid in the entrance cylinder, resulting in cavitation. Researchers (Holl,1970) have shown that the cavitation was directly proportional to the dissolved air content in liquid. Addition of chemicals such as frothers produces smaller and more copious cavities by stabilizing the cavity and preventing cavity collapse and coalescence.

Tiny bubbles, referred to as Picobubbles, naturally exist in liquids such as seawater and distilled water. Picobubbles attach more readily to particles than large bubbles due to their lower ascending velocity and rebound velocity from the surface and higher surface free energy to be satisfied. More efficient attachment of particles and improved flotation rates have been observed when tiny bubbles co-exist with air bubbles commonly used in flotation cells. Klassen and Mokrousov showed that the combined flotation by gas nuclei from air supersaturation and by mechanically generated bubbles produced higher flotation recovery than by either of them alone. Gas nuclei or picobubbles on a particle surface activate flotation by promoting the attachment of larger bubbles (as shown in Fig. 5) since attachment between gas nuclei or picobubbles and large bubbles is more favored than bubble–solid attachment. In other words, picobubbles act as a secondary collector for particles, reducing flotation collector dosage, enhancing particle attachment probability, and reducing the detachment probability. This leads to substantially improved flotation recovery of poorly floating fine and coarse particles and reduced reagent cost, which is often the largest single operating cost in commercial mineral flotation plants. Application of this process to coal flotation in Australia resulted in an increase in flotation yield up to 15 wt%, a frother dose reduction of 10%, and a collector dose reduction of 90%. Zhou et al. showed that hydrodynamic cavitation significantly increased flotation kinetics of silica and zinc sulfide precipitates.

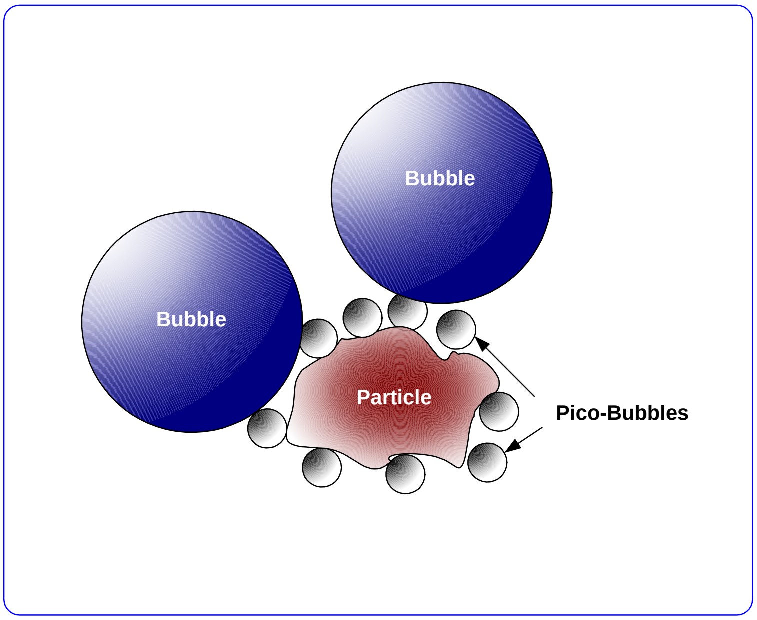



**Figure 5: Picobubbles enhance particle collection**

The bubbles generated on a particle surface by cavitation naturally attach to the particle, eliminating the collision and attachment process, which is often the rate-determining step for flotation. Cavitation also improves the flotation efficiency of coarse particles by reducing the detachment probability during the rise of particle–bubble aggregate in liquid. This is best illustrated in Fig. 6 where the large bubble represents the one produced by breaking the external air and smaller ones (picobubbles) are created by cavitation. While the large bubble may run away from the particle, the cavitation bubbles, particularly those underneath the particle, will push the particle upward, facilitating particle recovery. Without cavitation-generated bubbles, particles will detach from the bubble surface when the capillary force and other attachment forces are exceeded by detachment forces, such as the viscous or drag force (Fd), the gravitational force, and the hydrostatic pressure. As the drag force is directly proportional to the particle diameter; coarse particles are more likely to detach from the bubble surface than fine particles. This is the main reason for low flotation recovery of coarse particles, which is recognized by many researchers.

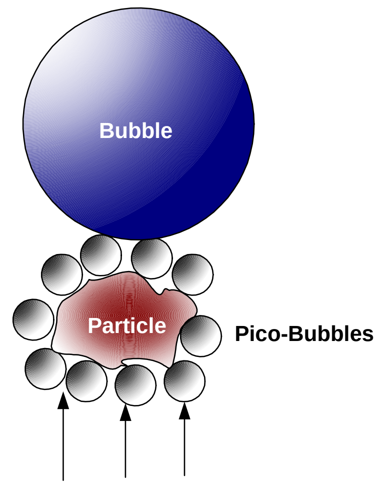



**Figure 6: Picobubble assisted flotation**

**Industrial Cavitation System**

Figure 7 is a general illustration of a column cell fitted with a cavitation sparging system. The CPT Cavitation Tube (CT) Sparging system consists of a recycle pump, a slurry distribution manifold and a series of tubes designed specifically to induce cavitation and generate fine micro bubbles.

A portion of underflow slurry is withdrawn from the column and recycled using a centrifugal pump to a distribution manifold where it is divided equally between pluralities of Cavitation Tube (CT) spargers. Process air is injected under pressure at the inlet of the cavitation tube to provide additional air for flotation. The two phase mixture passes though the CT sparger and is reinjected into the bottom of the column cell.

Within the cavitation tube, two mechanisms occur almost simultaneously. Picobubbles are precipitated onto the hydrophobic mineral surfaces as a result of cavitation and then immediately are subjected to intense mixing with air in the pressure recovery zone of the sparger to ensure maximum collection.

The spargers are manufactured using a variety of very durable materials such as polyurethane, ceramic, tungsten carbide and hardened steel to provide long life under a wide variety of applications.

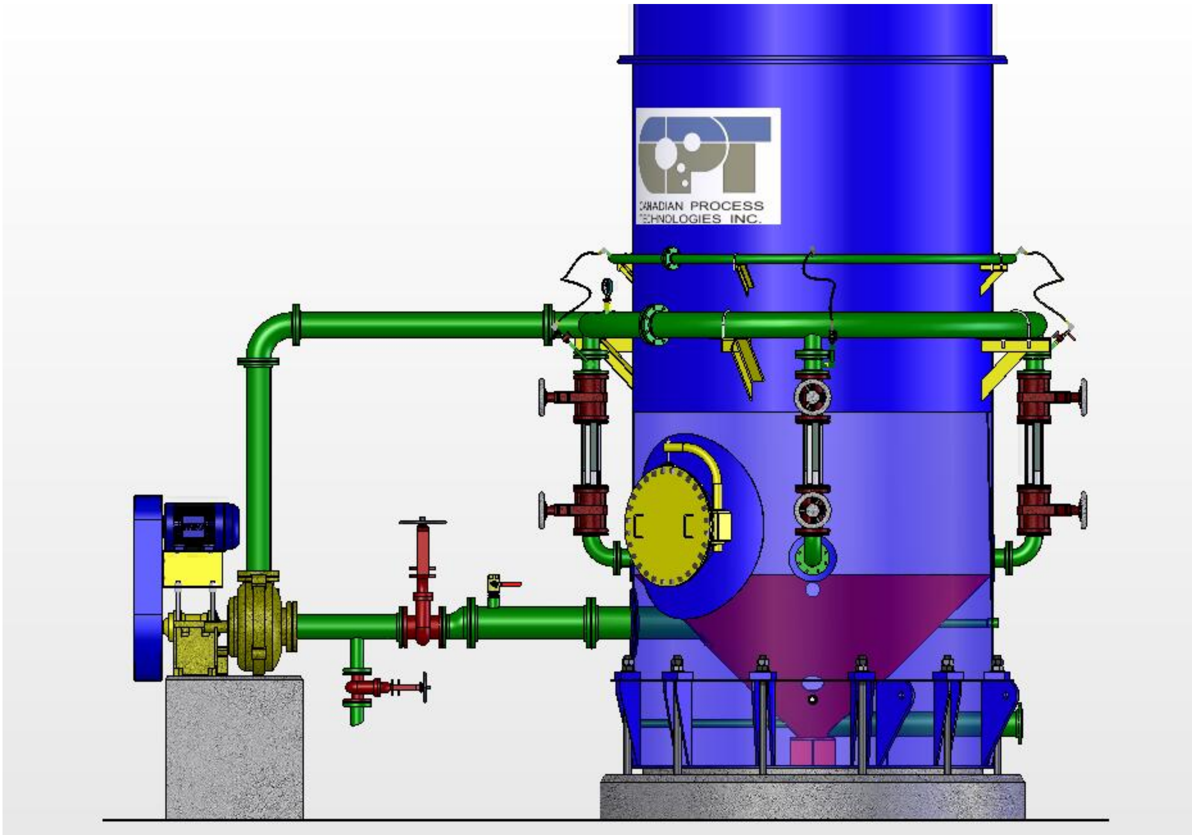
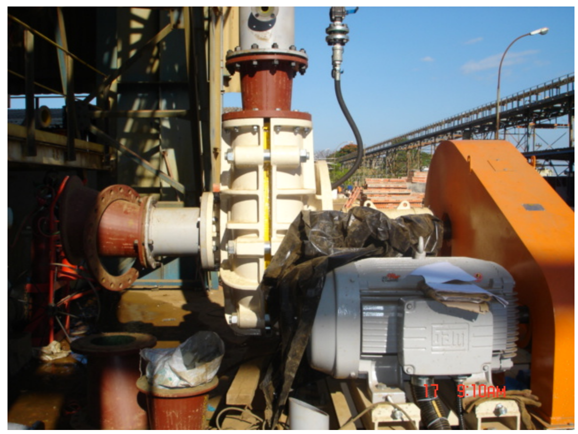



**Figure 7: Column fitted with Cavitation Sparging System**



Cavitation Tube installation in 26 m$^3$ Feldspar Column


Cavitation Tube installation in 250 m$^3$ Phosphate Column


Operation on water only


Regular operation