History of Coarse Particle Flotation and the Eriez HydroFloat®

The advent of fluidized-bed flotation began innocuously with a visit By Michael J. Mankosa, Ph.D. to a coal preparation facility in which a teeter-bed separator (TBS) was employed for the density separation of valuable coal from high-gravity refuse. During this plant visit, at a time when the facility was idle, some misplaced coarse coal was observed sitting on top of the fluidized bed. Under normal operating conditions, coarse coal that is too massive to report to the low-density stream (overflow) of a TBS, will report to the high-gravity underflow where it is misplaced with the rock. This is an inherent deficiency with teeter-bed technology when treating coal. However, in this case, it was observed that an air bubble attached to the coarse coal particle affected its settling characteristics by increasing its buoyancy and decreasing its aggregate specific gravity thereby preventing it from penetrating the high-gravity fluidized bed.

Based on this observation, the first fluidized-bed flotation device, the HydroFloat®, was developed by Eriez. Much of the initial investigative work was conducted in the Florida phosphate industry during the late 1990's. During this effort, a 5 t/h pilot plant was operated to demonstrate the ability to float coarse particles that were traditionally lost while using conventional approaches (Mankosa et al., 2002). A patent application for this technology was first filed in 1999 and ultimately granted in July of 2002 (Mankosa and Luttrell, 1999). Shortly thereafter, the first order for an industrial unit was received in April of 2004. Later that year, the first 3-meter diameter unit was installed and commissioned at PotashCorp's Rocanville potash mill to treat approximately 125 t/h of coarse tailings from existing conventional cells. Test work showed that by using this approach, the recovery of potash could be increased from approximately 50% to over 90% (Kohmuench and Thanasekaran, 2013).

While information on this novel technology was present in the literature from the outset of the development work, it was first presented globally in 2000 at the International Mineral Processing Congress in Rome, Italy (Mankosa et al., 2000) and then later in more detail at the 2005 Flotation Centenary Symposium held in Brisbane, Australia. The presentation and manuscript for the Symposium (Kohmuench et al., 2005) detailed the theory of operation of the HydroFloat and the effects of the various operating parameters on coarse particle flotation learned during the earlier phosphate test work.

More successful installations of coarse particle flotation technology followed in the industrial minerals sector. This includes a nearly plant-wide retrofit installation at Mosaic's South Fort Meade Mine (Kohmuench et al., 2007) and at PotashCorp's Aurora beneficiation plant (Piegols et al., 2015). At South Fort Meade, the capacity of the two coarse flotation circuits were improved dramatically with a simultaneous increase in phosphate recovery and significant reduction in reagent addition rate. At the Aurora plant, the implementation of this technology represented an additional recovery of 11,000 t/month of coarse phosphate which would have otherwise reported to tailings. In addition to fertilizer minerals, the HydroFloat has been commercially used to recover vermiculite in the United States, diamonds in Canada, and spodumene in Australia, Canada, and Brazil. Initially applying this technology to industrial minerals was reasonable given the relatively large particle sizes treated in flotation, coarse liberation characteristics, and generally lower specific gravities relative to polymetallic ore. Research efforts quickly focused on sulfide and base metal applications due to the recognized increase in capacity and associated energy savings (Awatey et al., 2015; Awatey et al., 2013; Fosu et al., 2015).

By the early 2010's, there was increasing awareness in the sulfide world that a significant fraction of semi-liberated coarse ore was not being floated in conventional concentrator plants and was instead accumulating in tailing impoundments around the world. This was a recognition of the phenomenon reported by Klassen in his 1960 textbook. "In most cases, complete liberation of minerals can be obtained with particle sizes much larger than those that can be floated. The ore is therefore ground finer that is necessary for liberation. If it were possible to float larger particles with high efficiency, then the cost of grinding, filtration, thickening and drying would be much lower". With the advent of the Eriez HydroFloat coarse particle flotation machine and its commercial acceptance in the phosphate and potash markets several years earlier, the stage was set to bring the HydroFloat technology to other markets.

Around this time, an important study by Jan Miller (Miller et al., 2016) confirmed through high resolution X-ray microtomography (HRXMT) that fluidized-bed flotation was able to recover metalliferous values at a grind size much coarser than that treated in industrial concentrators. Miller was able to show that the HydroFloat fluidized-bed flotation separator was able to recover nearly 100% of the multiphase particles in the range between 500 and 850 microns with as little as 1% surface exposure of sulfide mineral. This result has supported a continuous stream of test and pilot programs to exploit the HydroFloat's ability to recover coarse particles with minimal hydrophobic surface expression. An early application of the HydroFloat technology was scavenging sulfide tailings, where there is generally a low surface expression that is still sufficient for these particles to be recovered using fluidized-bed flotation.

In 2013, extensive lab and pilot campaigns were conducted by Eriez and Rio Tinto on tailings from the Kennecott Copperton concentrator facility in Salt Lake City, Utah, the second largest copper operation in the USA. Rio Tinto published a press release in 2017 stating that up to 70 percent of missed coarse copper-bearing particles and up to 90 percent of coarse molybdenum-bearing particles could be recovered from existing tailings using the HydroFloat technology. A full-scale demonstration module incorporating Eriez' CrossFlow and HydroFloat was installed and commissioned at the Copperton tailings impoundment area in 2019.

In parallel, the Technology and Innovation team at Newcrest identified the HydroFloat technology as having potential to effectively recover coarse gold and copper sulfide composite particles at their Cadia Valley copper-gold operation in New South Wales, Australia. The Newcrest team successfully tested the technology and rapidly took it through a study phase to a pilot-plant and pilot-scale continuous operation in less than 2 years. A full-scale demonstration plant treating one-third of Cadia's tailings was installed and commissioned in 2018 (Vollert et al., 2018). Following an extended period of commissioning and ramp-up in line with expectations for the adoption of novel technology, the Cadia installation achieved its performance targets. This was the first commercial installation of coarse particle flotation in a sulfide application. The success paved the way for an expansion that was added and commissioned in 2022 that treats the remaining two-thirds of the plant tailings. This installation fundamentally shifted the economic optimum grind size and allowed the comminution circuit to achieve higher throughput by producing a coarser flotation feed.

Starting in 2016, Anglo American began studying other applications for the HydroFloat, including the "Coarse Gangue Rejection" circuit, where the HydroFloat receives as its feed, mill circuit output prior to conventional flotation and produces a coarse, barren tailings. A demonstration module was engineered and built at the El Soldado concentrator in Chile which was commissioned in 2021 (Arburo et al., 2022). This was the first HydroFloat application to run in the Coarse Gangue Rejection application and also the first installation of the CPF-300, 5-meter diameter unit. Subsequent to El Soldado, two additional CPF-300 cells were commissioned at Anglo's Mogalakwena platinum concentrator in South Africa in 2022. Also starting around 2016, Anglo began studying the HydroFloat to treat the tailings from the Quellaveco greenfield project, which had not been built at the time. Based on the positive economic benefits, a coarse particle flotation plant was engineered and built in 2019-2022 to process the full Quellaveco tailings stream. That plant began commissioning in Q4 2023.

In addition to phosphate, lithium, potash and sulfide minerals, there are now a number of studies and projects using the Eriez HydroFloat for coarse gangue rejection of silica in iron ore upgrading (Hobert et al, 2023). Over the years, the value proposition from the customer's perspective has shifted from additional coarse mineral recovery, to include reduced specific mill energy and increased throughput. This idea was first demonstrated at Newcrest's Cadia Valley operation. Later, proponents recognized that a coarser final tail has attendant benefits including improved tailings de-watering (less energy and time) and more geotechnically stable impoundments, as foreseen by Klassen.

Fast forward to 2023. There have been a number of coarse particle flotation projects around the world that have been designed, constructed and are in operation. There is a growing body of knowledge and expertise around the flowsheets and unit operations that can be used alongside the HydroFloat to yield the best performance. Several engineering companies are advertising themselves as having special expertise in CPF plant design which is creating a vital CPF engineering ecosystem with many competent, experienced players. Eriez continues to work with mining companies, engineering companies and other original equipment manufacturers such as Weir to identify complementary equipment and configurations that can be used to optimize CPF flowsheet operation and reduce costs.