

# INVESTIGATING THE POTENTIAL OF HYDROFLOAT™ COARSE PARTICLE FLOTATION TECHNIQUES ON COPPER SULPHIDE ORES

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## ABSTRACT

Recovery of mineralized coarse particles is notoriously low in conventional concentrators that treat copper porphyry ores. The application of coarse particle flotation techniques has the potential to achieve comparable metallurgical performance at significantly coarser primary grind sizings. ALS Metallurgy has been conducting both internal research and commercial test programs to investigate the potential of Eriez HydroFloat™ technology on copper sulphide ores. Test data indicates that significant improvements in the recovery of copper sulphide bearing particles between 200µm to 850µm can be achieved using Hydrofloat technology compared to conventional flotation techniques. This paper summarizes the results from a selection of test programs that includes recovery by size data from both conventional flotation and HydroFloat™ tests. An explanation of the apparatus and test procedure will be given. Mineralogical analyses of the test products and characteristics that limit metallurgical performance will be discussed.

## KEY WORDS

**Coarse particle flotation, HydroFloat™, surface exposure**

## DESCRIPTION OF APPARATUS AND TEST PROTOCOL

The HydroFloat™ laboratory cell is a clear plastic column with an internal diameter of 14 cm. Water and air are introduced to the cell through a circular manifold located in the lower portion of the cell. The cell has a conical bottom which directs slurry to a pinch valve that controls the discharge of tailings. Feed solids are introduced to the upper portion of the cell in slurry form. The cell is operated in a manner such that the manifold water creates a teeter bed zone of suspended solids in the middle portion of the cell. Tailings exit the bottom of the cell at a high pulp density, and most of the introduced water overflows the top of the column and is collected in a launder. Particles with a hydrophobic surface may attach to air bubbles that percolate through the teeter bed, rendering them sufficiently buoyant to be transported to the overflow launder.

Three significant features of this arrangement enhance the potential to recover coarse, low grade particles by flotation techniques. Firstly, the hindered settling conditions created by the rising column of water allow coarse particles to become buoyant once attached to a modest sized air bubble. Secondly, the flow conditions within the cell are relatively quiescent compared to a conventional flotation cell that utilizes an agitator. This allows particles that have limited hydrophobic portions of their surface, due to a low content of exposed sulphide mineral, to maintain a somewhat fragile attachment to air bubbles long enough for successful recovery to the overflow. Finally, the absence of a froth phase at the top of the cell allows particles attached to air bubbles to immediately exit the vessel, reducing the potential to drop back into the pulp phase as bubbles burst or coalesce.

Testing is often conducted by first classifying the feed sample to obtain a suitable particle size range for the HydroFloat™ device. This is generally a top size of 1mm and a bottom size of approximately 150µm. The feed slurry is conditioned with appropriate reagents prior to addition to the cell. A sufficient feed mass, supplied in a continuous manner, is required to ensure that pulp conditions within the cell achieve steady state. Once steady state conditions are achieved, samples of the concentrate and tailings can be collected for metallurgical analysis.

## EXPERIMENTAL

A number of tests were conducted on variety of copper sulphide ore samples. Fresh feed samples were ground in a rod mill to coarse size distributions, while plant samples were only screened to remove excessively coarse material. For each set of tests, a conventional rougher flotation test was conducted using a Denver laboratory flotation cell. A HydroFloat™ test was then conducted using similar reagent conditions. The conventional tests were conducted on feed containing minus 150µm material. The presence of these fines may have provided some froth stability that could be beneficial for recovery of coarse particles. The Hydrofloat™ tests were conducted on samples with most of the minus 150µm material removed by wet screening. Three test pairs are presented; feed characteristics and selected test details are presented in Table 1.

Table 1 - Feed and Test Details

Sample	Type	Sulphide Minerals	Head Assay Cu %	Feed F80 (µm)		HF Teeter Water (m <sup>3</sup> /hr/m <sup>2</sup> )
				Conventional	HydroFloat	
1	Fresh Feed	Chalcopyrite, Pyrite	0.30	547	675	20
2	Rougher Tails	Chalcopyrite, Bornite, Pyrite	0.04	447	546	20
3	Cyclone U/F	Chalcopyrite, Pyrite	0.23	383	412	16

The HydroFloat™ tests were generally conducted using a feed rate of 1.5 kg/hr, or 5.4 tph/m<sup>2</sup> of cell surface area. Air rates were maintained at 0.75 L/min. Each conventional flotation test utilized 8 minutes of flotation time.

### Comparison of Recovery by Size Results

Recovery of copper and mass by size fraction was assessed across five size fractions, results are presented in Figures 1 through 4. Results indicate that the HydroFloat™ device was able to recover coarse particles more effectively than the conventional Denver flotation cell. For Sample 1, a significant mass recovery accompanied the increased copper recovery, particularly in the <212>150 $\mu$ m fraction. An additional 41 percent of the copper contained in the >212 $\mu$ m fractions was recovered in the HydroFloat™ test compared to the conventional test.

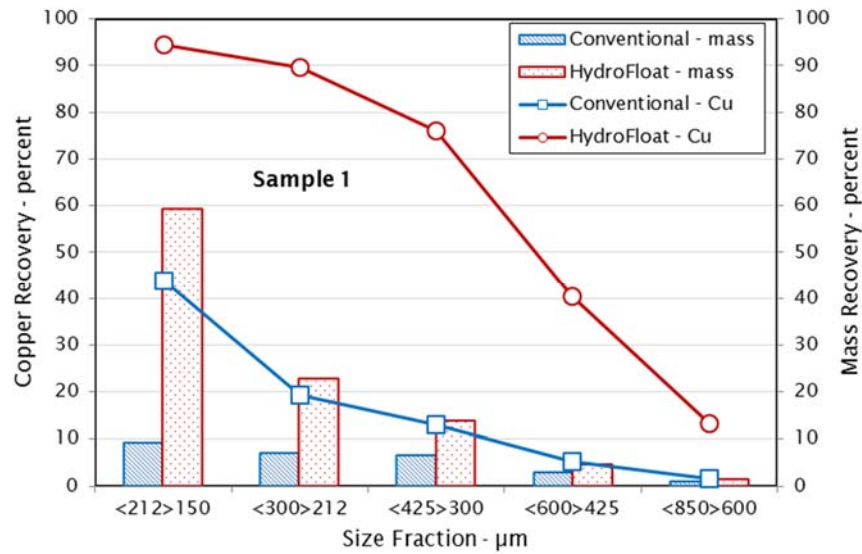


Figure 1 - Copper and mass recovery by size fraction, Sample 1.

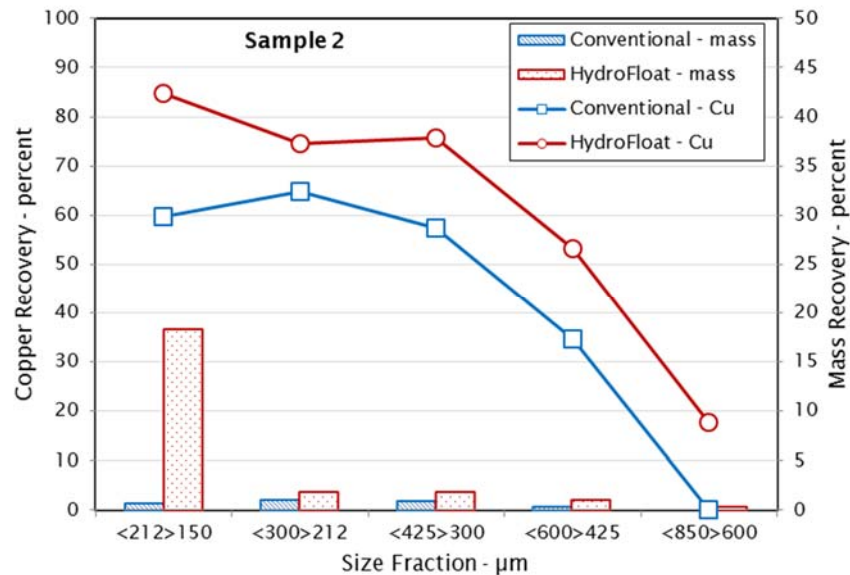


Figure 2 - Copper and mass recovery by size fraction, Sample 2.

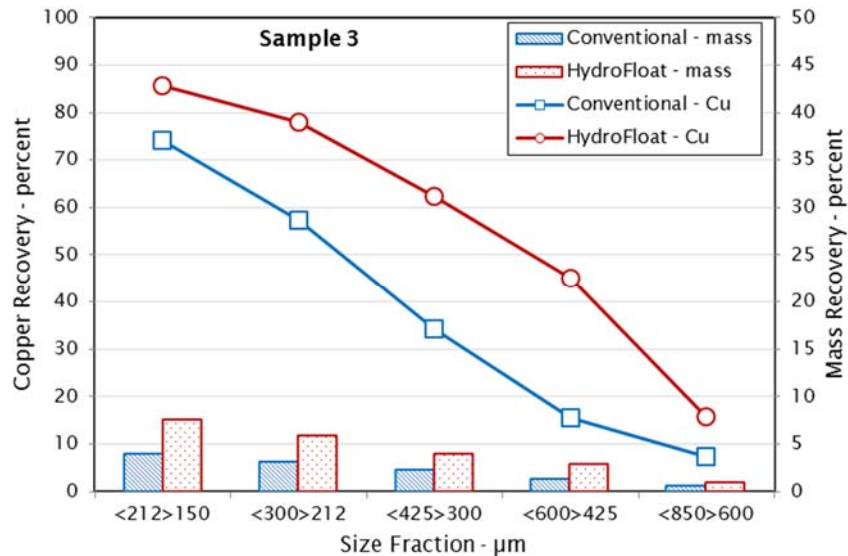


Figure 3 – Copper and mass recovery by size fraction, Sample 3.

The improvement in recovery in the HydroFloat™ cell was not as great for Sample 2, mostly due to quite good performance in the conventional cell. Still, an additional 18 percent of the copper contained in the >212μm fractions was recovered in the HydroFloat™ test compared to the conventional Denver test.

A considerable improvement in copper recovery performance was measured using the HydroFloat™ cell on Sample 3. An additional 24 percent of the copper contained in the >212μm fractions was recovered in the HydroFloat™ test compared to the conventional test. For all tests, copper recovery tended to decrease significantly in fractions coarser than 600μm.

### Mineralogical Assessments of Test Products

Mineralogical analyses using QEMSCAN™ technology were conducted on the HydroFloat™ test products to help understand characteristics that may limit recovery. Particle Mineral Analyses (PMA) were conducted on the four coarsest fractions for each test. Multiple sample mounts were required to ensure that an adequate number of sulphide bearing grain observations were obtained for a reliable assessment. Protocols were utilized to assess the sulphide mineral exposure characteristics for each observation, on a 2-dimensional basis. Exposure qualities were binned into groups for ease of data analysis, with more resolution at lower exposure levels.

The distribution of copper sulphides in each test feed by exposure class was calculated by summation of the concentrate and tails data. Distribution of copper sulphides in the sample feeds by exposure class data is presented in Figures 4 through 6. Sample 1 had a low degree of copper sulphide surface exposure, despite being a fresh feed sample. Sample 2, a rougher tails sample, still had some of the copper sulphides occurring in grains with high surface exposures, but approximately 62 percent of the copper sulphides in these fractions occurred in grains with surface exposures lower than 10 percent measured in two dimensions. Sample 3 also showed low surface exposures of copper sulphides.

Recoveries of copper sulphides were then calculated by size fraction and exposure class. Plots of copper sulphide recoveries by size fraction and surface exposure class are presented in Figures 7 through 9.

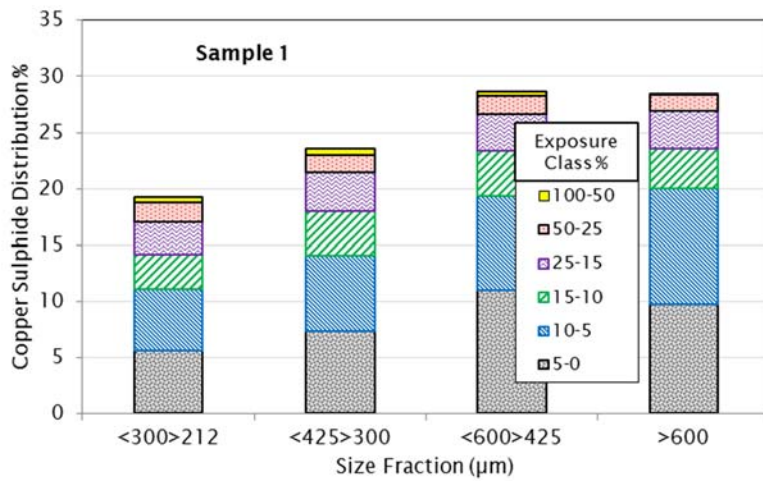


Figure 4 – Distribution of copper sulphides by exposure class, Sample 1.

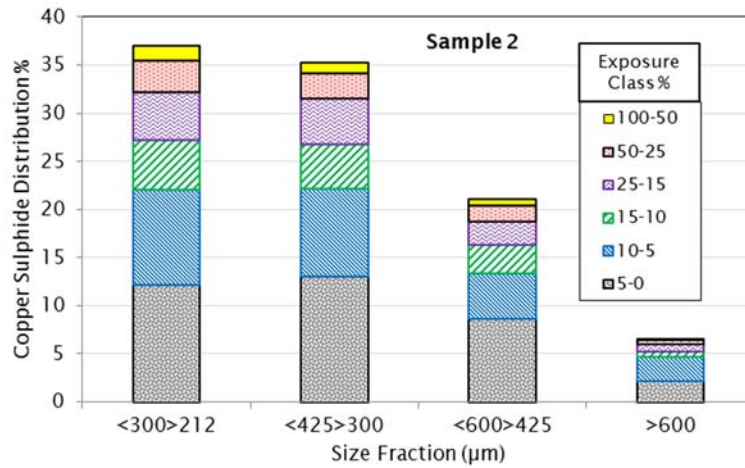


Figure 5 – Distribution of copper sulphides by exposure class, Sample 2.

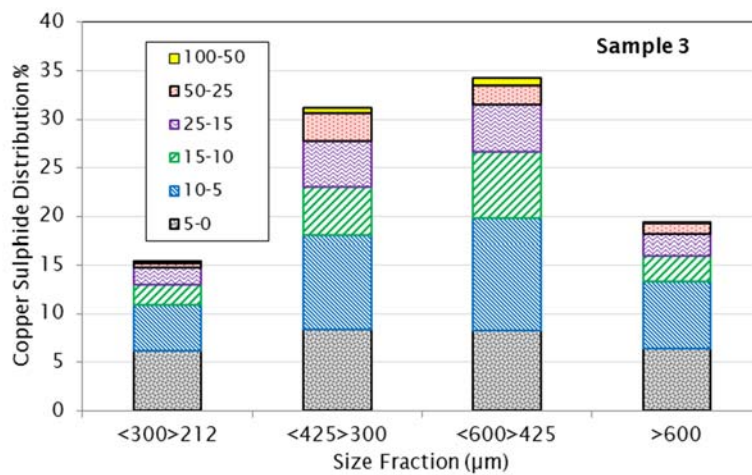


Figure 3 – Distribution of copper sulphides by exposure class, Sample 3.

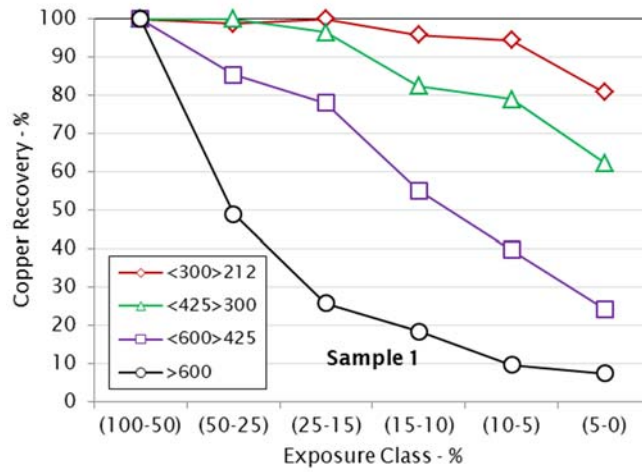


Figure 7 – Copper recovery by size fraction and exposure class, Sample 1.

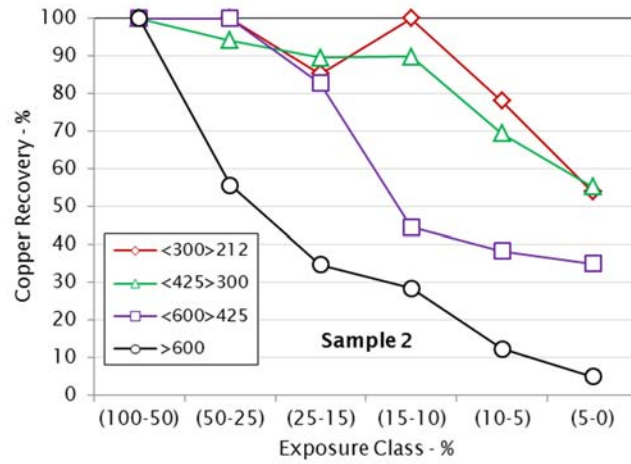


Figure 8 – Copper recovery by size fraction and exposure class, Sample 2.

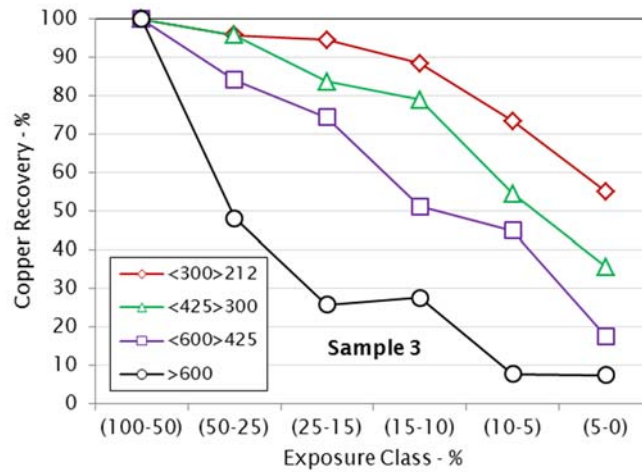


Figure 9 – Copper recovery by size fraction and exposure class, Sample 3.

The data suggests that particles with copper sulphide exposures of greater than 10 percent are generally well recovered up to a top size of 425µm. Particles greater in size than 425µm required copper sulphide exposures of greater than 15 percent as measured in two dimensions in order to be well recovered in a HydroFloat™ cell operating under the conditions tested. Note that these surface exposure levels would likely decrease significantly if measured in three dimensions.

## **CONCLUSIONS**

Three sets of tests were conducted on copper sulphide bearing samples using laboratory scale HydroFloat™ and conventional Denver flotation test cells. The tests were conducted at relatively coarse flotation feed sizes, obtained by grinding in a rod mill or as received size distributions. The size distributions tested ranged from approximately 80 percent passing 400 to 675µm. Recovery by size data indicates that considerable improvements in copper recovery could be achieved on coarse fractions using the HydroFloat™ device, with modest increases in mass recovery. Additional recovery of copper sulphides present in fractions coarser than 212µm point ranged from 18 to 30 percent. Mineralogical assessments were conducted on HydroFloat™ test products using QEMSCAN. An efficient and cost effective methodology to assess target mineral exposure values in two dimensions on coarse fractions has been developed by ALS Metallurgy. These assessments indicate that particles with copper sulphide mineral exposures as low as 10 percent measured in two dimensions were well recovered in the HydroFloat™ apparatus, up to grain sizes of 425µm. Copper sulphide bearing particles coarser than 425µm required two dimensional surface exposures of greater than 15 percent to achieve copper recoveries greater than 75 percent under the conditions tested. These results suggest that including HydroFloat™ techniques in a flowsheet to treat a copper sulphide ore by flotation could significantly increase the recovery of coarse copper sulphide bearing particles. This application could reduce grinding energy requirements, or allow for increased throughput on existing circuits without compromising metal recovery.