Revisiting Gravity Concentration for Copper Beneficiation

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Abstract

The traditional method for copper beneficiation crushes the material to small sizes, using flotation for concentration. The process of crushing the material, though effective, is energy intensive (accounts for 90% of energy consumed) and is becoming costly to maintain as target copper grade decreases. Thus, a reanalysis of alternate concentration methods that could assist in minimizing energy demands by limiting the need for crushing is in interest. This was to be accomplished by sizing ball mill feed, followed by evaluating a jig, a shaking table, and a multi-gravity separator as means of concentrating the material and creating low grade tailings.

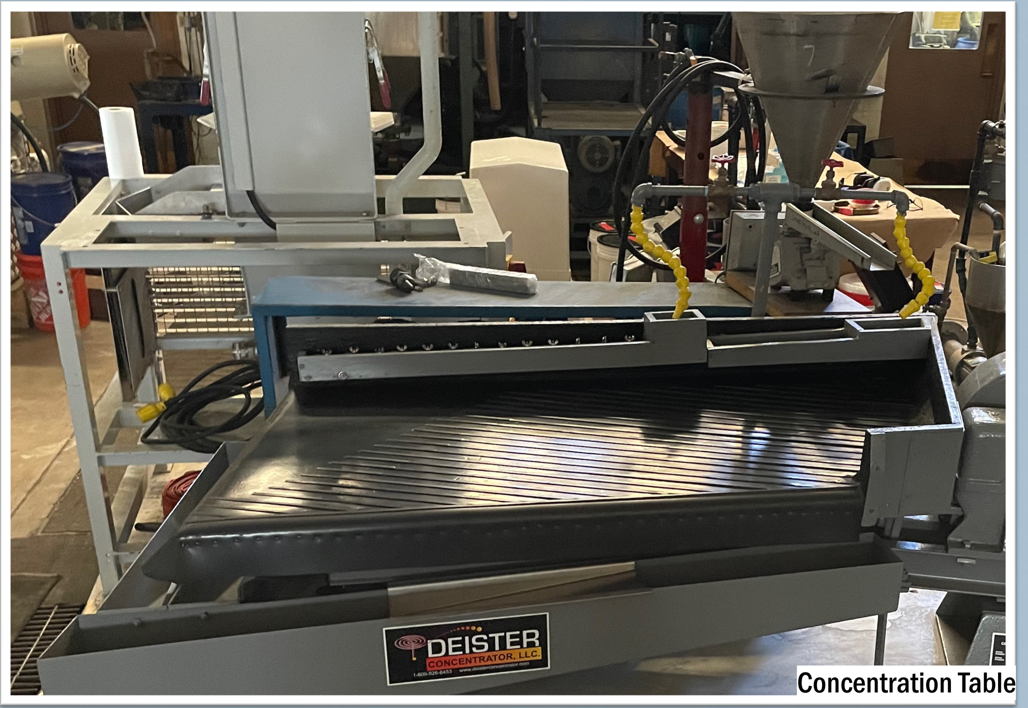
Purpose: Why Copper?

Copper has become critical to the technological advancements of society, especially concerning the shift towards electric power sources for cars and homes. It is predicted that demand for copper will double by 2035; yet, simultaneously, we anticipate shortages especially given the decrease in ore grade

Objectives

- Conduct testing of several gravity concentration methods on sized copper ore
  - Concentrating Table, Jig, Multi-Gravity separator
- Analyze products with X-ray fluorescence to evaluate effectiveness of separation, ideally creating low grade tailings while concentrating the copper

Micro Multi-Gravity Separator



Concentration Table

Jig

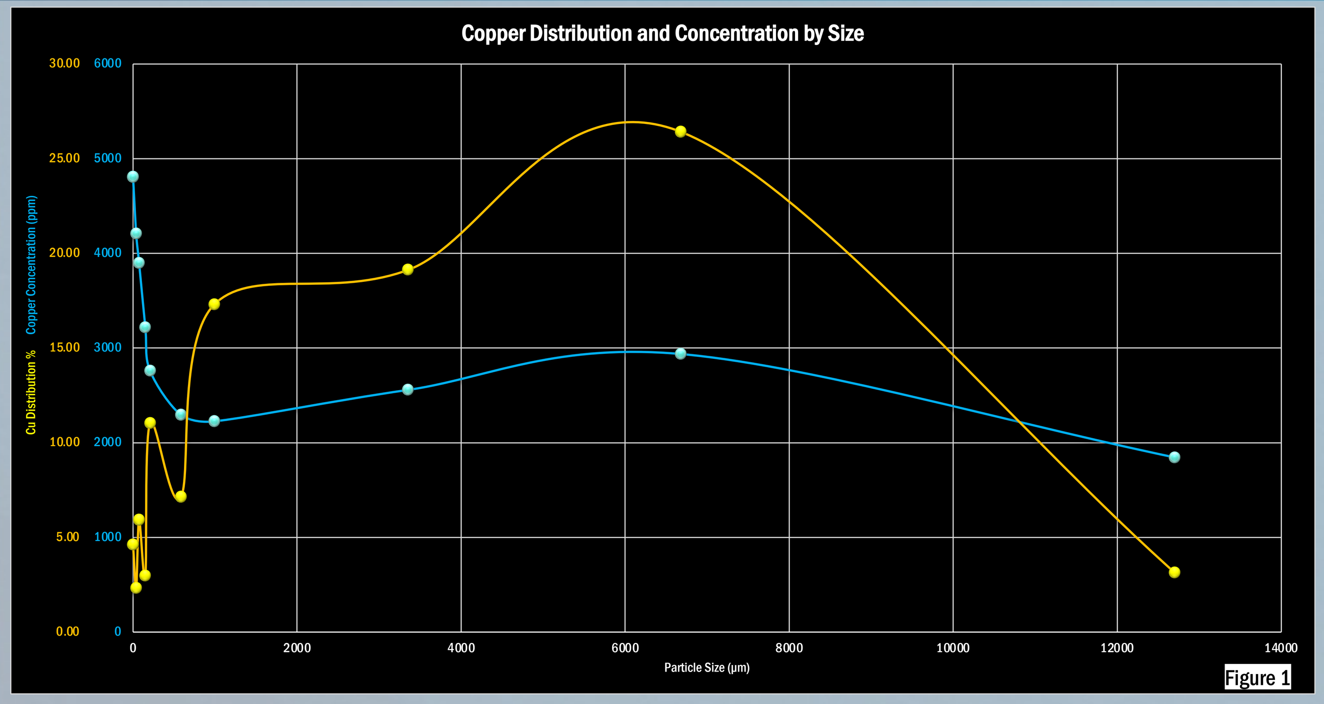


Figure 1

Jig Results [Feed size: +16mesh/+1.18mm]

- Least successful of the three methods.
- Though there is a gradient, it yielded a minimal copper separation

To the right is the layering for the material larger than 0.25 inches. Though the lower (heavier material) layers can be up to twice as concentrated as the top (light material) ones, the ~2000 ppm Copper resulting is far above the threshold of tailings that we can reasonably throw away without wasting large amounts of copper.

+6.5 mm	Cu (ppm)	Recovery
Layer 6	2178	0.81
Layer 5	1687	0.63
Layer 4	1437	0.53
Layer 3	3110	1.16
Layer 2	4644	1.73
Layer 1	3237	1.20

~5mm	Copper (ppm)	Recovery
Layer 4	1970	1.01
Layer 3	1768	0.91
Layer 2	2090	1.08
Layer 1	2237	1.15
~2mm		
Layer 4	2018	1.08
Layer 3	1935	1.04
Layer 2	2096	1.12
Layer 1	2058	1.10

Material Analysis

Head sample – X-ray data looking for presence of Chalcopyrite ($CuFeS_2$)

- 2410 ppm Copper, 21149 ppm Iron, 12932 ppm Sulfur
  - All copper is assumed to be attributed to chalcopyrite
  - Rest of Sulfur is attributed to Pyrite (FeS_2)
  - Still left with very Large Iron content, used magnet to identify as magnetite$_{(fig\ 2)}$
- Roughly 50% of copper is accounted for in the largest 3 sizes$_{(fig\ 1)}$
- Evidence of locked particles as fine as 100 micron sized quartz$_{(fig\ 4)}$

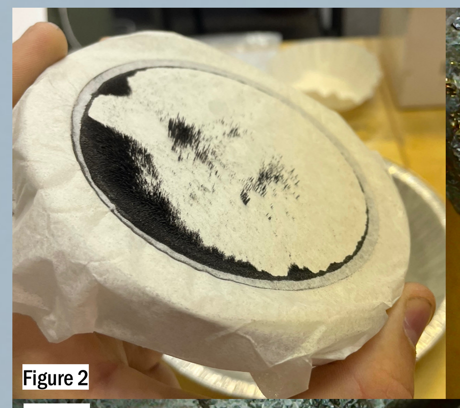


Figure 2

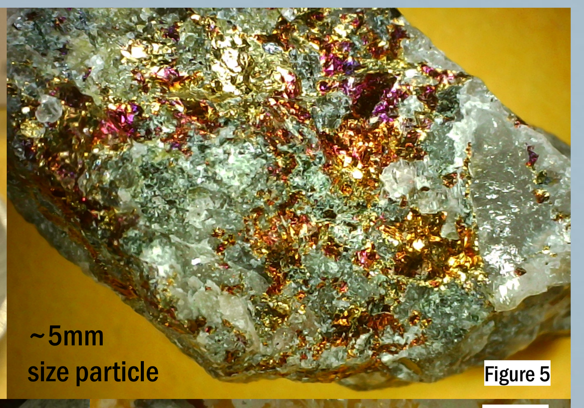


Figure 5

Figure 3

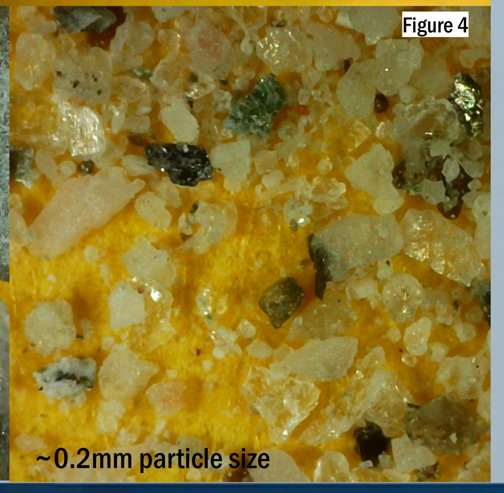


Figure 4

MGS Results [Feed Size: -65 mesh/-0.5mm]

- Most successful results of the three methods
  - Only was able to get 1 full scale test, so parameters were not optimized
  - Still was able to get 80-85% recovery, with tailings ~700 ppm Cu
- Limited in effective application as flotation alternative
  - Small feed size accounts for very small fraction of copper)
  - Notable drawback in long startup time that creates wasted material in the lab unit

Tabling Results [Feed Size: -6mesh+65 mesh/-3.4mm+0.2mm]

Pass	Split	Weight % TOTAL	Weight % per Pass	Copper (ppm)	Units (Cu)	Recovery (Cu)
1	Tailings	4.67	4.67	1348	6293.3	2.51
	Mids	81.77	81.77	1517	124050.3	49.54
	Conc	13.56	13.56	8854.4	120047.6	47.94
2	Tailings	7.74	57.11	1476	11428.6	4.56
	Conc	5.81	42.89	18679	108618.0	43.38
3	Tailings	2.55	43.84	2157	5498.3	2.20
	Conc	3.27	56.16	31577	103127.5	41.19
4	Tailings	2.33	71.38	23240	54177.2	21.64
	Conc	0.93	28.62	56471	52783.6	21.08

(Results shown for -0.65mm+0.23mm tabling)

- Over half of the copper was lost in the first table pass due to inexperience with the machine, however 86% of the copper in the first concentrate was recovered in following future runs
- The fourth table was used as a "high grade" attempt, which was mildly successful, yielding a 5.6% copper

Conclusions

- **Jig** – Results are far too minimal to apply to full scale production, nor does it show any promise in further testing
- **Concentrating Table** – Based on the small dataset, it is to early to make any statements on possible effectiveness the later results pose a promising application of tables to concentrate at a less crushed size yet lack enough data to make a clear statement
- **Multi-Gravity Separator** - The results were successful, yet due to the limited feed size, it wouldn't limit any crushing requirements for the concentration process
  - Though it does not solve the intended issues , the small feed size also poses a unique application that could work alongside flotation, allowing for recovery of copper in flotation tailings. However, that possibility would require further testing

Overall – The main limitation with this material is that the particles remain locked until small sizes. A realistically applicable separation wasn't obtainable until roughly 0.5 mm, and even at that size we have evidence of more locking. Due to this difficult nature of the material, crushing to a small size in order to utilize froth flotation remains the most effective option. However, the promising results of some of the concentration table testing leaves the door open for future reassessment

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