

Enhancing Flotation Efficiency:

Magnetic Conditioning in Atalaya's Rougher Flotation Circuit

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Atalaya's Riotinto Mine

- Riotinto copper deposit is a low-grade copper volcanic massive sulfide deposit.
- Ore is processed at 50,000tpd at a 0.35-0.40% Cu feed from the Cerro Colorado Mine.
- Chalcopyrite is the dominant copper sulfide mineral and naturally occurs within small fractures in the pyrite and occurs in isolation to a lesser extent.

	Tonnage	Grade			Contained Metal		
		Cu	Zn	Pb	Cu	Zn	Pb
	Mt				Mt	Mt	Mt
Cerro Colorado							
Proven & Probable Reserves	132.0	0.37%	–	–	0.49	–	–
Measured & Indicated Resources	156.6	0.37%	0.15%	0.03%	0.58	0.23	0.05
Inferred	4.2	0.40%	0.15%	0.04%	0.02	0.01	0.00
Total Resources	160.8	0.37%	0.15%	0.03%	0.60	0.24	0.05

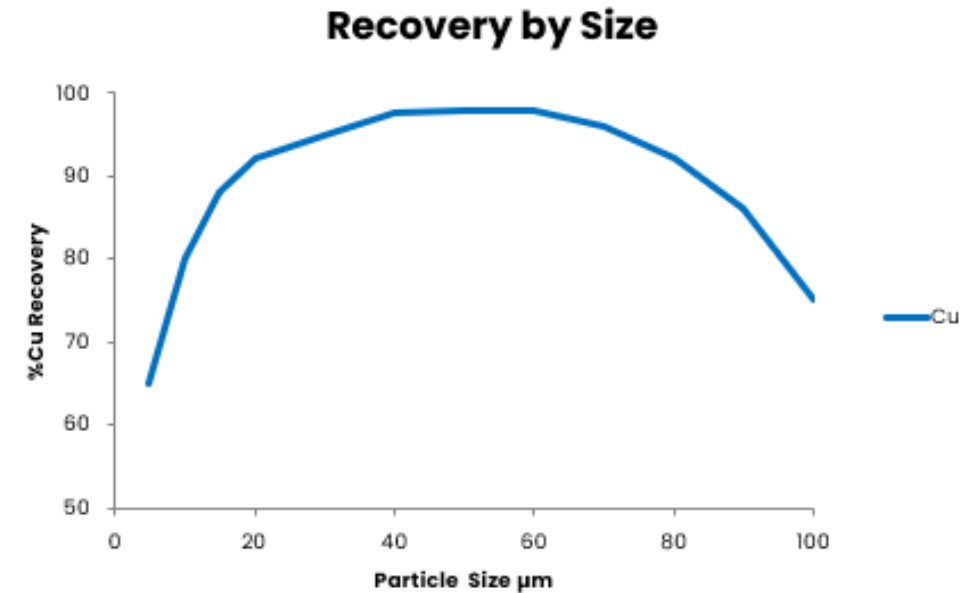
Source: NI 43-101 (Nov, 2022)

Process Plant Characteristics

- Feed from grinding goes to the rougher circuit which is splitted into 2 lines.
- Line 1 is the original flotation plant and treats about 40-50% of the total fresh feed while Line 2 is a more modern design and treats the remainder.
- Flotation recoveries yield between 85-90% - exceptional considering the low copper feed grade and complexities with periods of high proportion of zinc in feed.
- Despite a coarse grind, a significant amount of copper which is either fully liberated or partially locked is lost to tail and so has the potential to be recovered.
- Why?

The Challenges of Ultra-Fine Mineral Recovery

- Why are ultra-fine particles so difficult to recover when in theory they are fully liberated and should be recoverable?
- Flotation efficiency is related to collision, attachment and detachment (Duan & Ralston, 2003)
- Momentum for ultra-fine particles is poor largely due to its mass ($\mathbf{p=mv}$) so reducing collision efficiency
- So how can we increase the momentum of these ultra-fine particles??

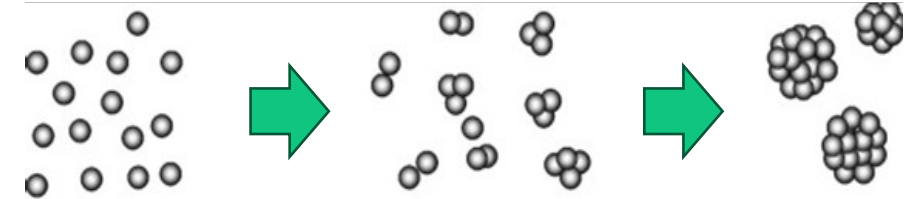


Source: Ausmetec

Magnetic Agglomeration - A Practical and Economic Solution ($p=mv$)

- To understand magnetic agglomeration of paramagnetic minerals we can first apply the fundamentals of magnetism.
- A permanent magnet has a North and South pole and so two magnets attract when opposite poles come together.
- When two magnets come together, the effective mass ultimately increases.
- So in flotation plants, if we can magnetise paramagnetic minerals and bring them together (aggregate) then the effective mass of the particle increases and thus particle momentum increases and thus collision efficiency increases.
- If we increase the particles momentum we increase the chance of bubble-solid collision and attachment.

Magnetic agglomeration process



Source: Ausmetec

Paramagnetic Minerals?

- **Cu sulfides** – chalcopyrite, bornite, natural chalcocite
- Natural sphalerite and galena: 1-5% of iron substitution makes these minerals strongly paramagnetic.
- Some copper oxides - malachite, azurite, chrysocolla
- Porphyry Cu/Mo molybdenite in South America, particularly in Peru
- Cassiterite, pentlandite, platinum and palladium ores and others
- **NOT pyrite, clays and siliceous gangue**

Mineralogy is critical – magnetic aggregation is mineral selective

Final Conc Sample (Published)	Magnetic Susceptibility x 10 ⁻⁹ m ³ kg ⁻¹
Chalcopyrite (Svobada, 1987)	1596
Constancia – Cu Conc	3880
Atalaya – Cu Conc	1770
Kennecott – Cu Conc	1570
NorthParkes – Cu Conc	638
Kansanshi – Cu Conc	480

Source: Ausmetec Database

ProFlote™ Technology

- A 3m long rubber-lined stainless steel which contains a rare earth high gradient permanent magnet.
- Compressed air to move the magnet UP and DOWN inside the tube.
- Control system used to distribute air to each ProFlote unit.
- Low maintenance and no operator input.
- Low risk project to trial in plant – cannot reduce recoveries.
- ON/OFF plant trial using paired t-test; the most powerful statistical method to measure small incremental benefits (Napier-Munn, 2010).



Source: Ausmetec



Source: Ausmetec

Line 2 Test Design

- Paired ON-OFF plant trial of ProFlote for 06 months in Line 2.
- Normal automatic samples of plant feed, Line 2 tail and final concentrate grade used to measure Line 2 recovery with ProFlote ON and OFF. Sizing of the feed and tail was carried out at +/-25 microns.
- Testing in Line 2 posed the lowest risk to both parties;
 - Line 2 treats a portion of the total feed
 - Line 2 was a straight forward installation compared to the much smaller cells in Line 1

Line 2 Test Results

- Plant results over 8-months of testing showed a 6.2% reduction of %Cu in Line 2 final tail and a 0.77% increase in Line 2 recovery both to >95% statistical confidence.
- While sizing was done for 4-months of testing, results showed improvements in both the (+) and (–) 25 micron size fraction such that calculated and actual copper circuit recoveries matched well.

77 pairs	Tonnes (tpd)	%Cu <u>Fd</u>	Pb (ppm)	%Zn <u>Fd</u>	% Cu Final Conc	%Cu Final Tail	%Cu Plant Rec	<25um Cu Rec*	>25um Cu Rec*	Calc Cu Rec%
ProFlote ON	48,790	0.384	153.4	0.138	20.80	0.052	86.67	84.38	88.07	86.53
ProFlote OFF	48,554	0.388	149.9	0.139	21.02	0.055	85.90	83.69	86.98	85.72
Difference	236	-0.004	3.5	-0.001	-0.22	-0.003	0.77	0.69	1.08	0.81
Confidence Level	low	low	low	low	low	96	96	82	96	91

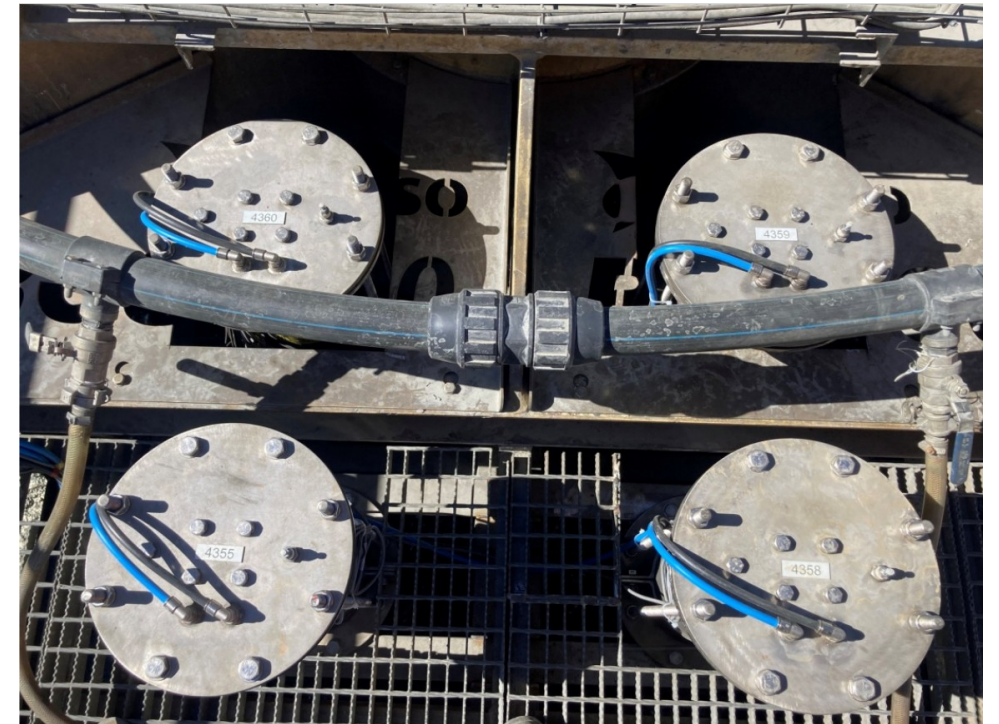
*Sizing results contain 40 pairs since there are missing sizing assays and sizing stopped halfway through testing.

‘Payback of the ProFlote technology was only 3 months.

Low maintenance required to operate the technology.

Conclusions

- Benefit in Line 2 copper recovery was measured both in the plant and sizing data – emphasising that the mechanism of ProFlote is the cause of the incremental difference.
- ProFlote has been operating continuously after the test was completed.
- Maintenance of equipment occurs every 4 months. Robust equipment.



Source: ProFlote in Atalaya's FLO 9 Circuit (Ausmetec)

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