

Magnetic Conditioning in Ultra Fine Grinding Process Plants – The Sky is the Limit

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Sandfire MATSA – Minas de Aguas Teñidas

- Located in southwestern Spain, in the Huelva Province, within the Iberian Pyrite Belt.
- A one-hour drive northwest from Seville.
- A 4.7mtpa Cu-Pb-Ag-Zn deposit currently owned by Sandfire Resources Ltd.
- Payable copper production accounts for almost two-thirds of total payable metal production.
- Payable zinc almost one-third of payable metal production, with the remainder lead and silver.



Source: Sandfire MATSA



Process Plant Characteristics

- Two primary concentrators; PTM1 and PTM2
 - PTM1 campaigns between a copper ore and polymetallic ore from its Sotiel mine.
 - PTM2 treats only a polymetallic ore from its Aguas Teñidas and Magdalena mine.
- PTM2 main paramaters are listed below:

Throughput t/d	p80 μm	%Cu	%Zn	%Pb	Ag g/t	%Fe
6700	44	1.79	3.77	1.13	45	31.8

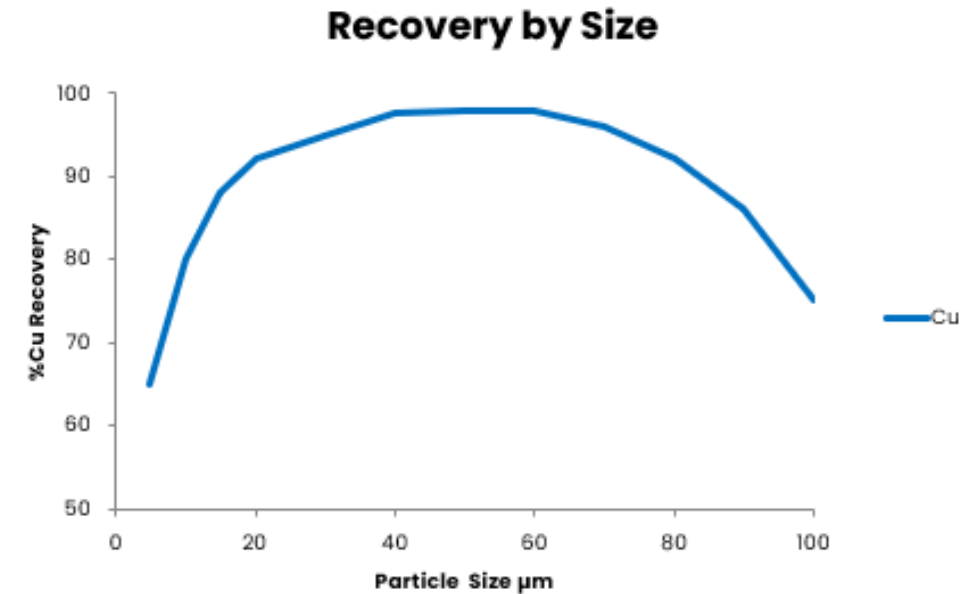
Source: Sandfire MATSA data from trial period.

PTM2 Process Plant Characteristics

- Ultra-fine grinding is crucial at Sandfire MATSA to achieve selective and economic metal recoveries in each circuit;
 - P80 from primary cyclone overflow to bulk circuit is ~ 44 microns but 70% of the copper and zinc is $<25\mu\text{m}$
 - P80 from copper & zinc circuit re-grinding is ~ 20 microns
- However ultra-fine grinding poses a significant limitation – metals are poorly recovered in flotation
- PTM2 copper and zinc circuit recoveries are about $\sim 70\text{--}75\%$ and $80\text{--}85\%$ respectively.
 - About 50% of copper lost to bulk tail (zinc circuit feed) is <25 microns
 - About 40% of zinc lost to final tailings is <25 microns

The Perils 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 ($p=mv$) 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

- 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**

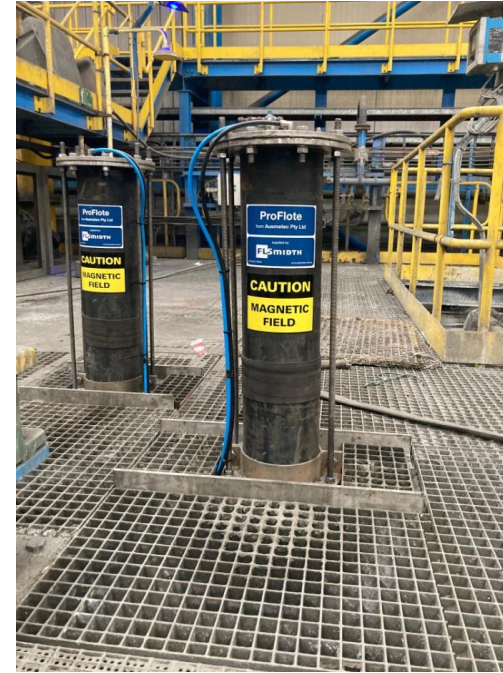
Mineralogy is critical – magnetic aggregation is mineral selective

Final Conc Sample (Published)	Magnetic Susceptibility x 10 ⁻⁹ m ³ kg ⁻¹
MATSA – Cu Conc	423
MATSA – Zn Conc	801
Constancia Mine – Cu Conc	1628
Kennecott Copper – Cu Conc	1570
Red Dog – Zn Conc	347
Cannington – Pb Conc	820
Kansanshi – Cu Conc	480
Chalcopyrite Concentrate – Literature (Svoboda, 1987)	1596

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

Test Design

- Test 1: ON-OFF ProFlote trial in Zn circuit for 04 months
 - ProFlote installed in the Zn rougher conditioning tank and 1st cell of the secondary Zn rougher.
 - 2 day ON OFF test schedule turning on and off at 8AM.
 - Analyse 24hr plant and sizing composite automatic samples.
- Test 2: ON-OFF ProFlote trial in Cu and Zn co-currently for 04 months
 - ProFlote installed in Cu rougher conditioning tanks and Cu pre-cleaner cells with ProFlote in existing Zn circuit.
 - Same test schedule with 24hr plant and sizing composite automatic samples to be analysed.

'Pair' collection must only be adjoining ON OFF days!!

Test 1 – Results from Paired Analysis

- Upstream variables statistically insignificant ($P > 0.05$ – 2sided) allows for a reliable analysis of the 'change' being measured downstream.

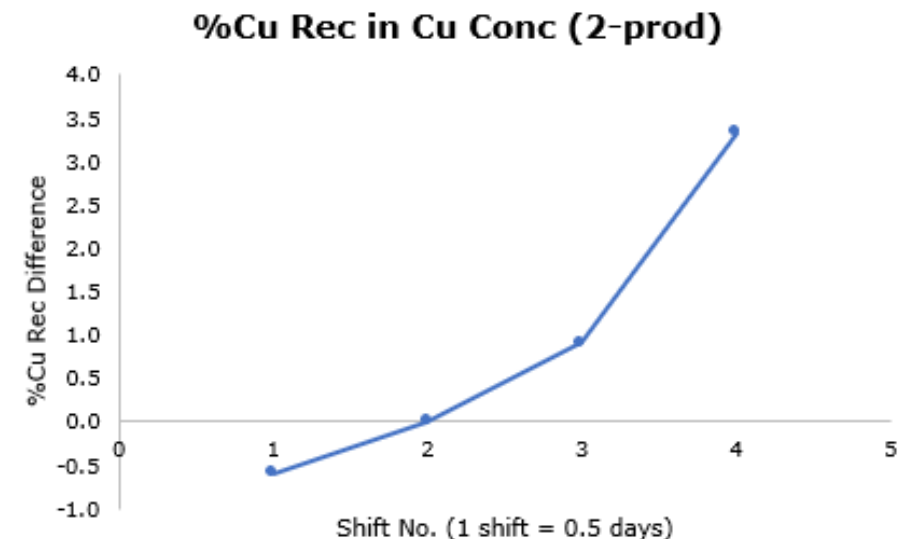
Adjoining Pairing	%Zn in Final Conc	%Zn Circuit Rec	>25um %Zn Circuit Rec	<25um %Zn Circuit Rec	Calc %Zn Rec using sizing
ProFlote ON	45.66	81.00	70.96	87.70	80.86
ProFlote OFF	45.64	79.14	67.21	85.09	79.11
Difference	0.02	1.87	3.75	2.61	1.75
Confidence Level (one-sided)	low	97%	94%	>99%	94%

Confidence levels for downstream variables should be analysed 1-sided as the metallurgist is seeking an improvement (Napier-Mun, 2010).

Test 2 – Cu Results from Paired Analysis

- The Cu circuit at MATSA has large re-circulating loads so an equilibrium period needs to be applied to the data to account for true 'ON' and 'OFF' periods (Napier-Munn, 2010).

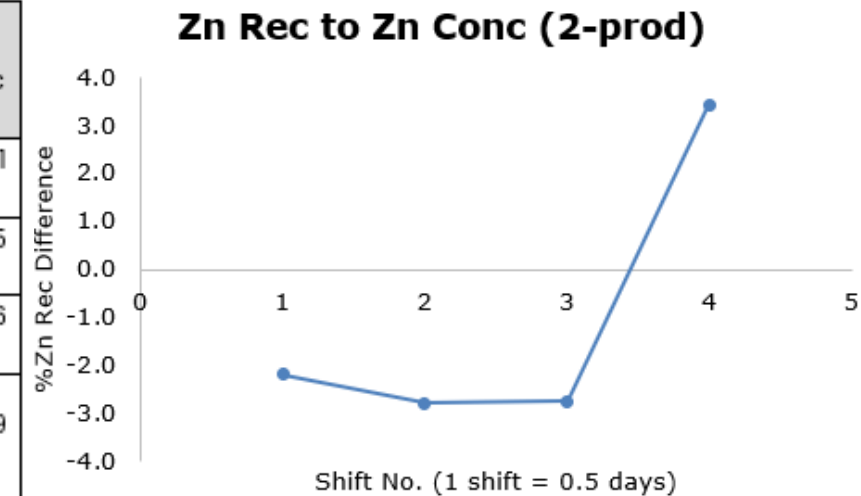
4 th shift ON - 4 th shift OFF	%Cu in Cu Conc	%Cu Rec in Cu Circuit (2-prod)	%Cu Rec in Cu Circuit (3-prod)
ProFlote ON	20.23	73.23	71.04
ProFlote OFF	20.38	69.90	67.74
Difference	-0.15	3.33	3.31
Confidence Level (one-sided)	low	99.8	96



Test 2 – Zn Results from Paired Analysis

- Magnetised particles in the bulk tail from the 2 day ON period took a long time to discharge during the OFF period in the Zn circuit.
- As such, an equilibrium period was also required for Zn circuit analysis to measure true 'ON' and 'OFF' periods.

4 th shift ON - 4 th shift OFF	%Zn in Zn Conc	%Zn Rec in Zn Conc (2 prod)	%Zn Rec in Zn Conc (3 prod)	>25um %Zn Rec in Zn Conc	<25um %Zn Rec in Zn Conc
ProFlote ON	46.21	81.83	78.44	63.70	88.51
ProFlote OFF	46.01	78.40	72.91	62.89	85.05
Difference	0.20	3.43	5.53	0.81	3.46
Confidence Level (one-sided)	low	97	99.9	low	99



Economic Benifit to Sandfire MATSA

- Payback of the ProFlote technology in the Cu circuit was <2months.
- Payback of the ProFlote technology in the Zn circuit was also <2months.
- A 'no brainer.'
- The technology is operating continuously.



Source: Online pictures via Microsoft

Conclusions and Next Steps

- Always design the test correctly before the trial begins!! The right experiment and analysing the data in the right way will always produce the right answer in the minimum time and cost (Napier Munn, 2010). People tend to cut corners!
- Plant testing the magnetic aggreation technology showed large and economic improvements in Cu Rec and Zn Rec to respective concentrates.
- Did we undersize the ProFlote installation in the Zn circuit after measuring a greater improvement in Zn Rec when ProFlote was installed in the Cu circuit – upstream from the Zn Circuit?
- Future test in PTM1?