

Iron Ore 2011

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Magnetite Production at Ernest Henry Mining

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ABSTRACT

Ernest Henry Mining (EHM) is situated 38 km north-east of Cloncurry in the Mount Isa – Cloncurry mineral district of North-West Queensland. The EHM ore body is an iron oxide copper gold deposit with an average grade of 1 %copper, 0.5 g/tonne gold and 23% magnetite, with current reserves of approximately 88 million tonnes.

The copper concentrator is a single line plant with a nominal throughput rate of 1,300 tonnes per hour. An average of 350,000 tonnes of concentrate is produced each year containing around 100,000 tonnes of copper metal and 120,000 troy ounces of gold.

In December 2009 Xstrata Copper announced approval of a \$589 million investment to extend the life of EHM to at least 2024, through the transformation of open pit mining operations to a major underground mine together with the construction of an associated magnetite extraction plant.

The EHM magnetite plant extracts the magnetite from the copper concentrator's tailings stream. It will produce approximately 1.2 million tonnes of magnetite concentrate per annum at full capacity for export to Asia, making EHM Queensland's first iron ore concentrate exporter. Construction of the magnetite extraction plant commenced in July 2010 and was completed in January 2011.

This paper gives an overview of the development of the EHM magnetite extraction plant flow sheet from the early mineralogy and laboratory test work through to the plant commissioning and early operation of the base plant. It has a major focus on the commissioning learnings from the plant start-up and includes a review of the operational performance of the plant versus original design and expectations.

INTRODUCTION

In December 2009 the Xstrata board announced the approval of \$589 million to transform EHM into a major underground mine with an associated magnetite extraction plant which will extend the mine life to 2024. This will create 400 permanent jobs from 2013 in addition to the jobs created during the construction phase. The transformation from an open pit to a large scale underground operation will enable the extraction of 6M tpa of ore at full capacity to produce 1.2 Mtpa of tonnes of premium quality magnetite concentrate. The first exports of magnetite concentrate are planned for shipment from Townsville in the first half of this year.

The construction of the \$79 million magnetite base plant was completed in January this year followed by a period of process commissioning. As part of the base plant Xstrata is developing an \$8.6 million expansion of its 65 kt enclosed storage shed at the port of Townsville. While magnetite has traditionally been discarded as tailings at EHM, the magnetite extraction plant allows it to be captured as an important by-product of the copper-gold concentrating process, reducing the amount of tailings sent to the on-site storage facility. The production of magnetite concentrate enables EHM to maximise the value of its existing resources by creating an additional by-product, reduce the amount of tailings in the on-site storage facility and provide further employment opportunities in the region. The magnetite concentrate produced at EHM will be chiefly used to fuel Asia's steel industry, however, the commodity may also be utilised as a washing agent in coal operations.

The plant has 3 key circuits including an extraction plant which separates and upgrades the concentrator tailings to a marketable concentrate, a dewatering plant to remove the water from the magnetite concentrate for transport and a regrind circuit to maximise the recovery from concentrator tailings. The overview of the magnetite extraction process is shown in Figure 1.

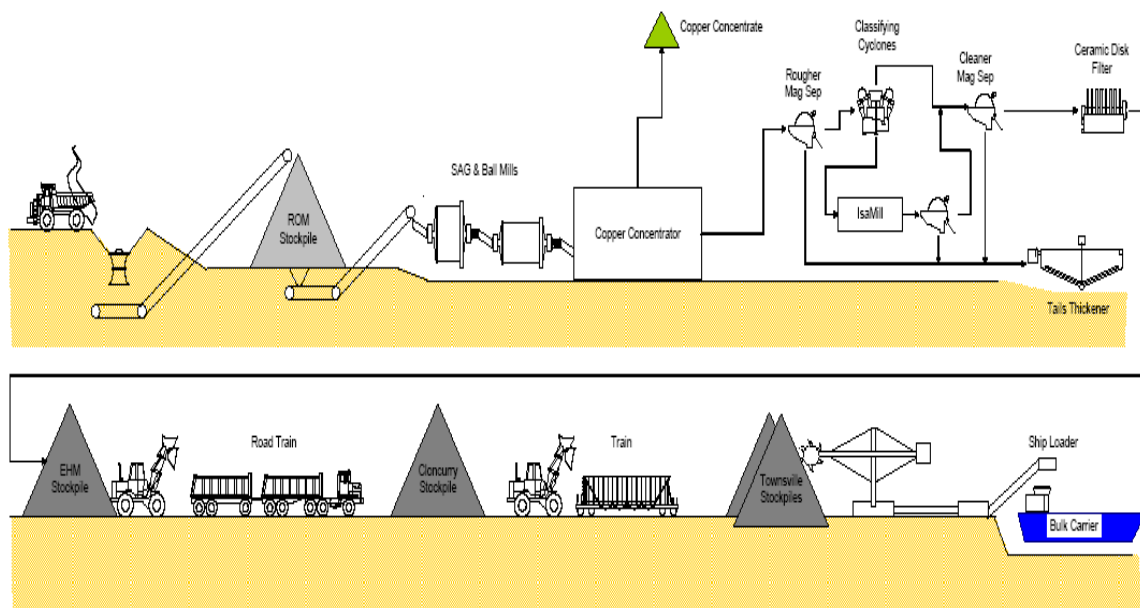


Figure 1: Overview of the EHM magnetite extraction process

MINERALISATION AND ORE RESERVES

The Ernest Henry ore body is an iron oxide copper gold deposit (IOCG) discovered in October 1991 by airborne geophysics. Similar examples are Olympic Dam and Prominent Hill in South Australia, and Osborne in Queensland. It is located in the Eastern Fold Belt of the Mount Isa Inlier under approximately 50m of sand and clay cover. The mineralisation at Ernest Henry has formed in a south-east plunging body of altered and variably brecciated felsic volcanic rock. The combined thickness of the mineralised sequence is approximately 250 m, width averages 300 m and the down dip length is approximately 1,000 m in a pipe like formation which dips 40 degrees to the SSE and is still open at depth (Ryan, 1998).

The primary ore mineralogy is dominated by chalcopyrite within a magnetite-carbonate gangue. The mean magnetite content of the primary ore is between 20 and 25 wt%. The copper grade increases with increasing magnetite grade (EHM Feasibility, 1995).

The Ernest Henry underground deposit is known to extend to at least 400 m below the open pit final stage 7 (575 m deep, 1.5 km x 1.3 km). In June 2010, lithology caving estimates were given at 76 million tonnes containing 1.3 %Cu, 0.7 g/t Au and 28% FexOy which is made up of measured and indicated resource, and 13 million tonnes containing 1.2 %Cu, 0.6 g/t Au and 26% FexOy of inferred resource. The width of the mineralised deposit is 200 m. The overview of the underground ore body is shown in Figure 2.

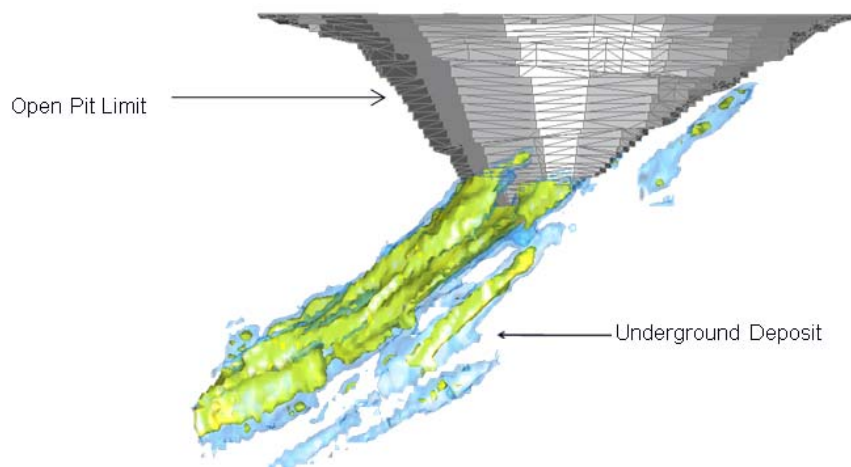


Figure 2: Overview of the EHM underground deposit

The dominant iron oxide species in the ore is magnetite; varying significantly from 4.6% to 46.7%. Historical plant averages from the open pit are 17.6 %. Monthly composite analyses of the final concentrator tail for the previous two years are in average 25% magnetite. Magnetite and hematite are well liberated (Middleditch, 2008) showing minimum association with chalcopyrite in the rougher tailings.

TESTWORK OVERVIEW

There have been numerous investigations into magnetite processing at EHM since operations started in 1997, with emphasis on how it can be removed, both for product development, and to assist in reducing the circulating load in the grinding circuit. Early studies using an onsite pilot plant in conjunction with large scale laboratory test work at CSIRO demonstrated that suitable product grades and production rates could be achieved. These test programs demonstrated that magnetite production via magnetic separation was viable, but limited by impurity grades and liberation (Zhu et al 2007). Most of the programs contained either a comminution or impurity reduction stage. Where grinding was not employed, the yield achieved at acceptable product quality was very low. The results of the historical studies are shown in Table 1.

These early testwork campaigns showed that the magnetite in the EHM comminution circuit is preferentially milled due to the hydraulic rather than size-based nature of the magnetite in the primary classification circuit of the copper concentrator (Zhu et al 2004). The consequence is that the classifiers treat fine magnetite in exactly the same way as coarser gangue, concentrating it to the cyclone underflow resulting in preferential liberation of magnetite in the ball mill. Practically, due to the relatively liberated nature of the feldspar and magnetite, the hydro- cyclones operate with two independent efficiency curves (one for magnetite and one for feldspar), which overlap as a function of co-liberation of the two minerals (Zhu et al 2006).

Table 1
Historical testwork results

Program	Tailings Sample		Product								
	Grind P80	Yield (%)	Fe (%)	Cu (%)	P (%)	S (%)	Al ₂ O ₃ (%)	As (%)	SiO ₂ (%)	K ₂ O (%)	Na ₂ O (%)
EHM 2001 Laboratory	No	0.60	66%	0.23	N/A	1.11	1.0	0.010	7.4	0.63	0.03
CSIRO August 2004 Pilot Run 1	No	47.2	34.7	0.23	N/A	1.11	6.9	0.010	30.4	N/A	N/A
CSIRO August 2004 Davis Tube	39µm	28.8	70.0	0.02	0.004	0.10	0.36	0.003	1.64	0.21	0.05
IMO Nov 2004 Pilot Phase 5	No	20.3	57.0	0.07	NA	0.20	2.6	NA	14.2	N/A	N/A
CSIRO Feb 2007 Laboratory	38µm	20.5	68.9	0.02	0.005	0.08	0.6	N/A	2.5	0.31	0.05
CSIRO June 2008 Laboratory	35µm	23.3	66.8	0.02	0.007	0.13	1.2	N/A	4.8	0.66	N/A

In 2008, after assessing the strengths and weaknesses of the previous programs, further metallurgical test work was conducted by Xstrata as part of a feasibility study to demonstrate if an iron ore concentrate meeting steel industry specifications could be produced at a reasonable yield by controlling particle size distribution. The work was completed at laboratory pilot scale, and used the laboratory flowsheet shown in Figure 3.

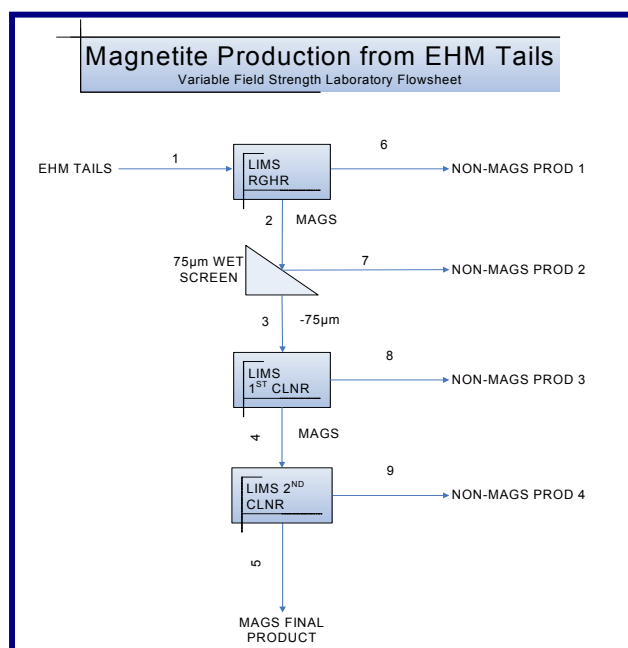


Figure 3 - Final design metallurgical testwork flowsheet

The metallurgical testwork completed confirmed that magnetite concentrates containing 69% iron with minimal impurities can be produced with suitable mass recoveries by controlling particle size distribution of the magnetite product (Magee, 2009).

In addition extensive mineralogy was completed on test products, and demonstrated that the majority of the rougher magnetic separator losses were in the <20wt% Fe-Oxides liberation class. The majority of the losses from the cleaner magnetic separators were in the form of hematite, which is co-reported with magnetite as Fe-Oxides, but is non-magnetic. Approximately 15-20% of the Fe-Oxides in the EHM final tailings are hematite, rather than magnetite. The hematite is present in rims or inclusions around the partially liberated magnetite particles as shown in Figure 4.

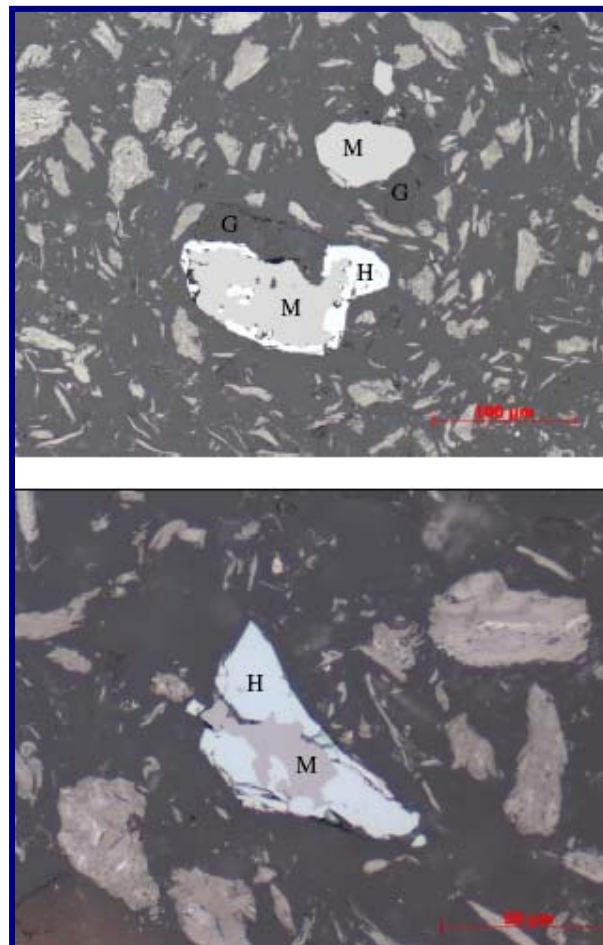


Figure 4 – Hematite rimming of magnetite particles

H = Hematite
M = Magnetite

In the 2009 testwork hematite represented the majority of the Fe-Oxide losses. Hematite recovery cannot be practically improved and hematite as it is not magnetic and will decrease with fine grinding due to derimming of the composite particles. Evidence of this exists throughout the circuit, but is clearest in the rougher non-magnetics stream, where 90% of the Fe Oxides that are lost are actually hematite rather than magnetite (Magee, 2009).

FLOW SHEET DEVELOPMENT AND EQUIPMENT

In order to benchmark the proposed flowsheet and to understand the process risks and plant operation site visits to La Candelaria and Los Pelambres in Chile were undertaken. These sites had similar magnetic separation and filtration technology to that being considered for the project. Ceramic disc filters were observed to be working effectively in concentrate filtration applications at these sites. The magnetic separation plant was observed to have poor process control but was achieving the desired product quality and demonstrated the robust nature of the magnetic separators to a range of operating conditions.

The magnetite plant is divided into 3 circuits. The extraction (magnetic separation) and dewatering (filters) form the base plant (which has been commissioned). The regrind circuit which is due for SMP construction in June is scheduled for process commissioning in August this year. A flow sheet of the base plant is shown in Figure 5.

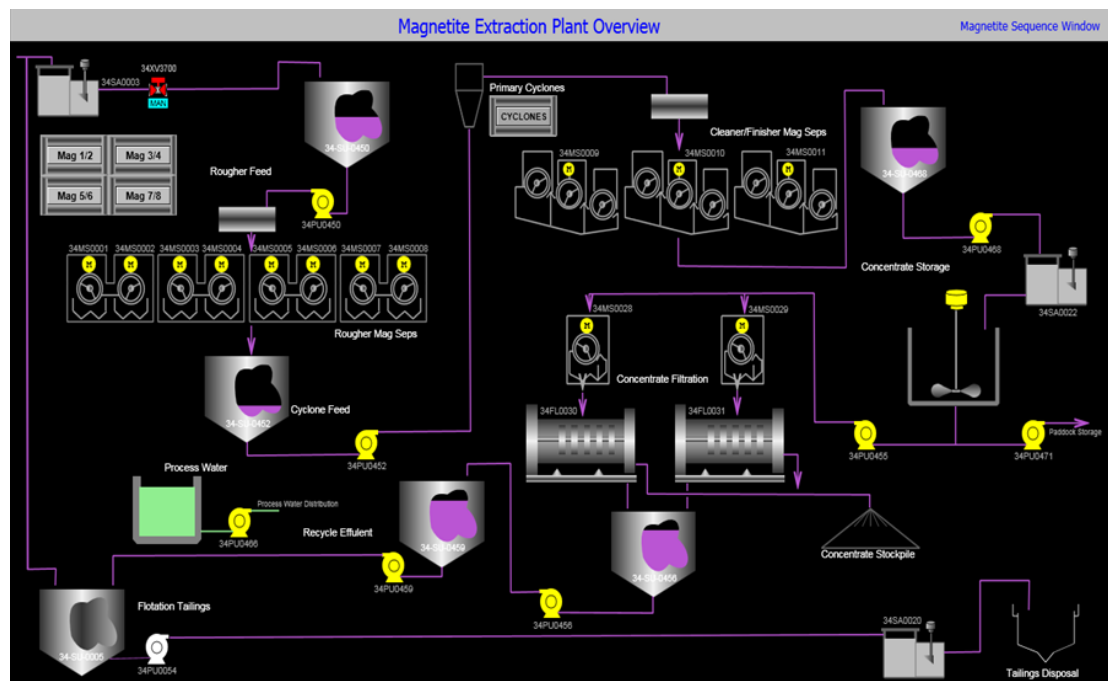


Figure 5 –Magnetite extraction plant flowsheet for Ernest Henry Mine in Australia

Base Plant

The base plant is a simple beneficiation process that uses magnetic separators to extract the magnetite from the copper concentrator tailings. A detail of the process parameters is shown in Table 2. It is divided into the following circuits:

- Rougher magnetic separator circuit that processes raw flotation tailings
- Primary cyclone cluster that separates out particles less than 75 μm
- Cleaner/finisher magnetic separator circuit that upgrades the rougher magnetic concentrate
- Dewatering circuit that removes the excess water from the recovered magnetite

Table 2
EHM base plant process parameters

Circuit	Process Inputs	Process Outputs	Equipment Details
Rougher Circuit	Throughput: 721 t/h-1350 t/h Magnetite content: 14-24% Feed solids: 35-42%	Mass yield: 30% - 33%	Rougher units constrains (m drum h): Magnetic loading: 26 t Volumetric loading: 130 m ³
Classification Circuit	Throughput: 220 t/h- 525 t/h Feed solids: 33%	Product target: P ₉₉ 75 µm Mass yield to COF: 46% - 47% Product solids: 20%	Cyclone diameter: 400 mm No of cyclones: 8 Operating pressure: 80-120 KPA
Cleaner Circuit	Throughput: 95t/h- 230 t/h Feed solids: 20%	Mass yield: 97% - 99%	Cleaner units constrains (m drum h): Magnetic loading: 26 t Volumetric loading: 105 m ³
Dewatering Circuit	Throughput: 75/h- 207 t/h Feed solids: 60%	Moisture content: < 8%	Filtration rate: 1.187 t/m ³ Filtration area: 163 m ²

The purpose of the rougher magnetic separation circuit is to separate the coarse magnetite material from the copper flotation tail. The circuit treats the material using four (4) twin magnetic separation drum units. The rougher magnetic separators are permanent low intensity magnets with a magnetic strength of 1000+ Gauss. Each unit is composed of two counter-current wet drum separators running in parallel with one another and fitted with respective launders for concentrate and tailings discharge. The concentrate produced from the separator consists mostly of fully liberated magnetite with some unliberated magnetite and middlings. The rougher magnetic separator recovers 78% of the magnetite from the rougher feed. Figure 6 shows the design and operating conditions of the rougher circuit.

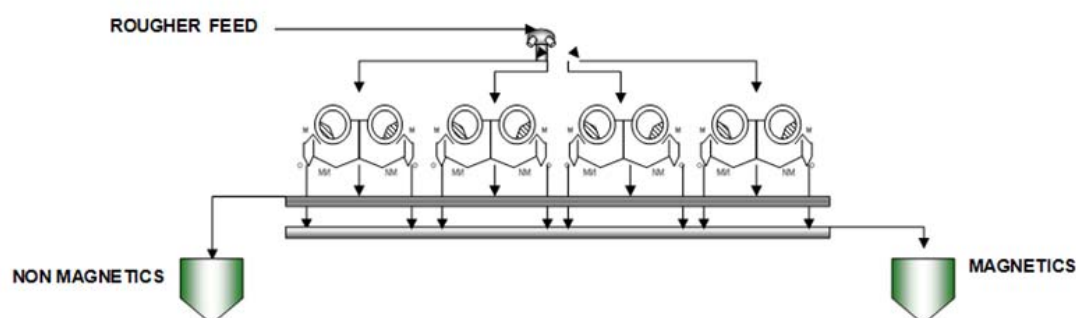


Figure 6 – EHM Magnetite rougher circuit

The concentrate produced from the rougher magnetic separation still contains considerable amounts of impurities. The test work results from the rougher feed material suggests that particle sizes of less than - 53 µm consist mostly of liberated magnetite while the upper size is composed of unliberated magnetite, which requires further size reduction by milling. A size separation through a cyclone classifier is applied to reject most of the tailings and upgrade the rougher concentrate.

The primary cyclone circuit is designed to separate the fine liberated magnetite from the coarse material. This process stage incorporates a cluster of 8 Cavex 400 cyclones. The

feed density to the cluster is controlled to ensure the correct cut point is obtained while the number of cyclones operating can be altered to match the feed flow volume.

The cyclones produce an overflow product of 20% solids with a P80 of 53µm containing mostly liberated magnetite and a small amount of low-SG gangue material. The cyclone underflow which consists of mostly unliberated magnetite and low-SG gangue is sent to the existing flotation tailings sump. In the size classification circuit, 47% of the magnetite is recovered from the cyclone feed. A regrind circuit has been incorporated into the design to treat the cyclone underflow and recover the unliberated magnetite. Figure 7 shows the design and operating conditions of the classification circuit:

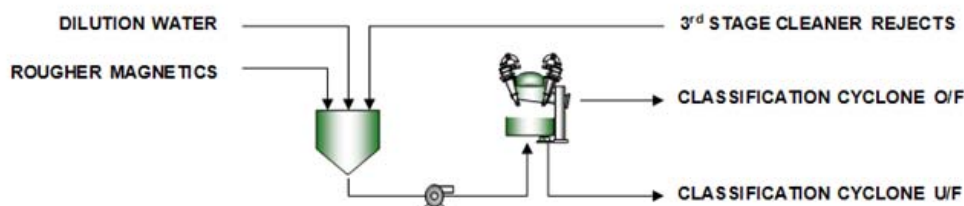


Figure 7 – EHM Magnetite classification circuit

The effective classification of the magnetite is paramount to the success of the separation process. This is complicated by the bimodal density properties of the high-SG magnetite and the low-SG gangue. This was evident throughout the metallurgical testwork campaigns and the JKTech was approached to model the suitability of 400CVX cyclones as a classification method.

A series of simulations were performed on the magnetite feed using the multicomponent Nageswararao cyclone model in JKSimFloat and independently verified using other tools, including JKSimMet. The plant feed was divided into three density categories and fewer than two feed conditions, underground and open cut mining, which produced different particle size distributions. The main objective was firstly to determine whether the proposed cyclone cluster could handle the feed flow rate and density in the magnetite recovery circuit. Secondly, the predicted flow splits, densities and size distributions of the overflow and underflow streams were also of importance. Finally, the recovery of magnetite to the overflow was a key variable. The outcome of the modelling was that the 400CVX cyclone was deemed to be suitable in the Magnetite recovery circuit at EHM.

The cyclone overflow is gravity fed to the cleaner/finisher circuit. The purpose of the cleaner/finisher circuit is to remove the final gangue that is entrained in the magnetite slurry. This stage incorporates three magnetic separator banks operating in parallel. Each bank comprises three magnetic separators operating in series.

The cleaner/finisher magnetic separator works under the same principle as the rougher magnetic separator but at a different magnetic strength. The slurry is introduced into the cleaner separator first, which is a permanent low intensity magnet and operates with a magnetic strength of 750 Gauss. The cleaner separator produces a concentrate which flows into the feed launder of the following finisher drum separator which also operates at 750 Gauss. The last finisher drum separator is operated at 550+ Gauss and serves as a polishing separator for magnetite and non-magnetic gangue materials. At the end of this stage, 99.8% of the magnetite is recovered from the feed and a clean concentrate containing up to 98% iron oxides is produced, which is suitable for sale. Figure 8 shows the design and operating conditions of the cleaner circuit.

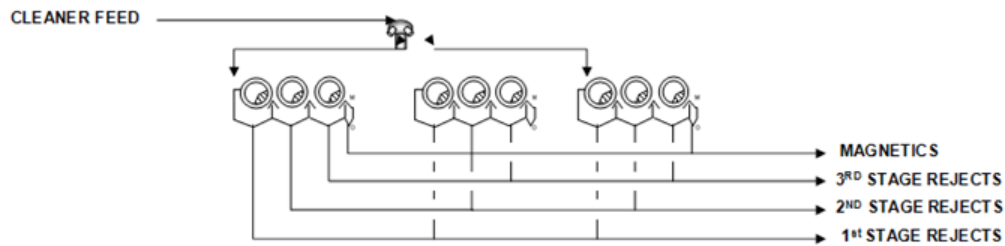


Figure 8 – EHM Magnetite cleaner circuit

The purpose of the dewatering circuit is to condition the extracted magnetite to make it more suitable for storage and transportation. The circuit consists of two CC60 Larox ceramic disc filters. Due to the physical properties of the magnetite and the location of the dewatering plant the clean magnetite is required to be maintained as slurry prior to the dewatering process. This is achieved by agitation in holding tanks and continuous circulation of the slurry prior to entering the dewatering filters. Once dried the product is transferred by gravity directly to the stockpile area located underneath the plant. Figure 9 shows the design and operating conditions of the dewatering circuit:

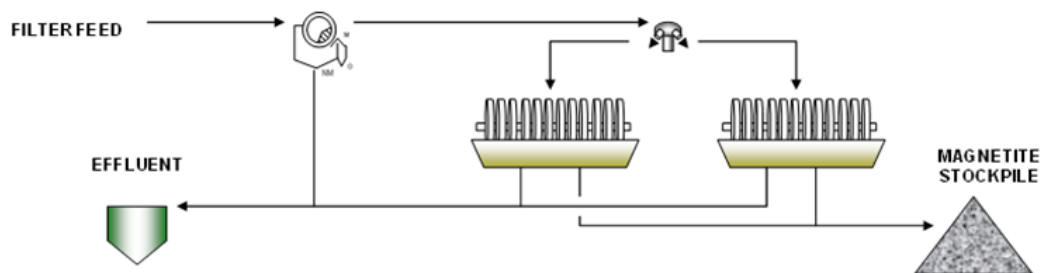


Figure 9 – EHM Magnetite dewatering circuit

Regrind Circuit

In May 2005, Xstrata Technology completed ISAMill characterisation testwork on a sample of EHM tailings. The testwork sample had a P80 of 130 μm , and was ground progressively to 8.4 μm . The testwork showed that the ISAMill technology was able to produce material down to 13 μm from a feed size of 113 μm . Alternative technology tested failed to produce material less than 31 μm as shown in Figure 10 (Burford and Niva, 2008).

The reason for the difference between the mills was the smaller grinding media used in the ISAMill testwork. Media selection was based on what a full scale plant can realistically operate at. A full scale ISAMill can be supplied and operated with ceramic media from 1 to 3.5mm, however Tower Mills can only realistically operate with 12mm media and larger, which means that they cannot achieve the grind sizes that a full size ISAMill can.

ISAMills have been in fine grinding applications in base metal circuits since 1994. The ISAMill technology was selected due to its high energy efficiency and intense grinding action. Developments in this technology have allowed the mill to treat coarser feed sizes at high energy efficiency compared to traditional grinding technologies.

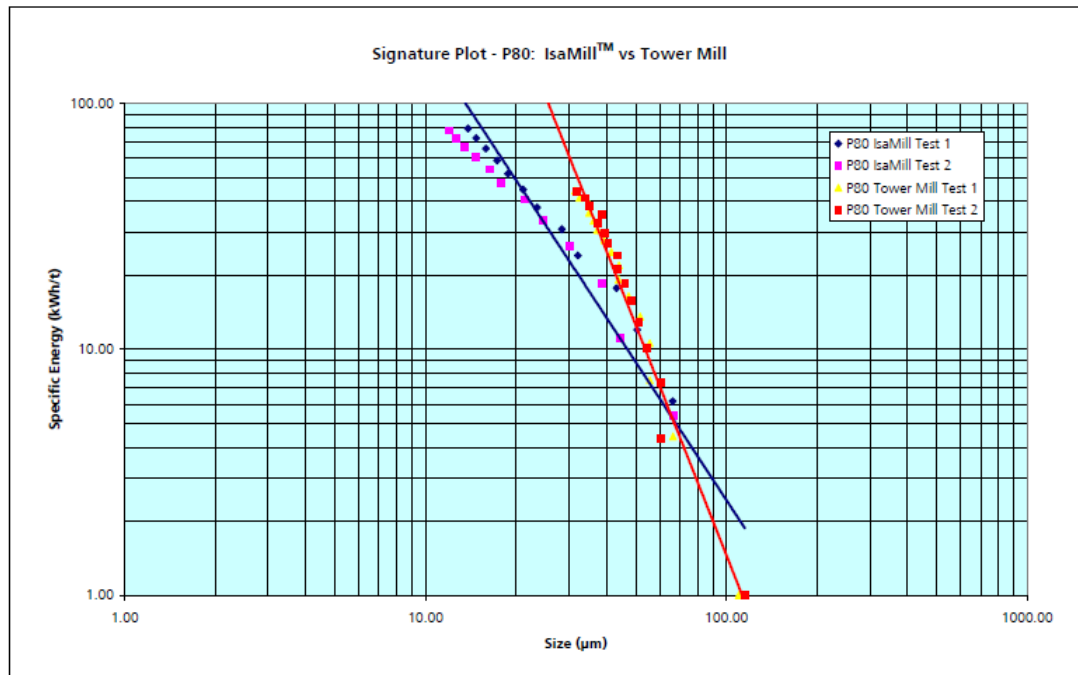


Figure 10 – Comparisons of IsaMill and Tower Mill

Further regrind studies before and after the magnetite project feasibility study included: Bond Index, Levin tests and ISAMill signature plots were carried out on EHM rougher magnetics. These additional studies identified that with rougher magnetic concentrate regrinding, Fe-Oxide recovery to final magnetite product could be increased from 48% to 80% (Magee, 2009). The regrind testwork showed that 1xM10000 (3MW) Isamill would be sufficient to process the cyclone underflow stream followed by rougher magnetic separation. The rougher magnetics will be pumped to the existing cleaner circuit in the base plant which has been designed to accommodate the extra flow.

COMMISSIONING AND EARLY OPERATION

The EHM plant was designed to produce a premium product to supply steel industry requirements. The product specification will be published after the completion of the process commissioning. Process commissioning of the base plant commenced in January 2011 however it was delayed by the effects of the Brisbane Floods and Cyclone Yasi which affected a large area of South-East and North Queensland. Early results have achieved a product with the desired particle size distribute on as shown in Figure 13. In addition the magnetite concentrate grade is approaching the desired target. The current objective is to produce a consistent product specification followed a yield optimisation stage.

In addition the magnetite project team is also working to complete the operational readiness plan to hand over the operation of the magnetite plant to the copper concentrator team. The operational readiness tasks include asset management plans such as maintenance schedules and critical spares, training material and the development of operating parameters, targets and KPI's.

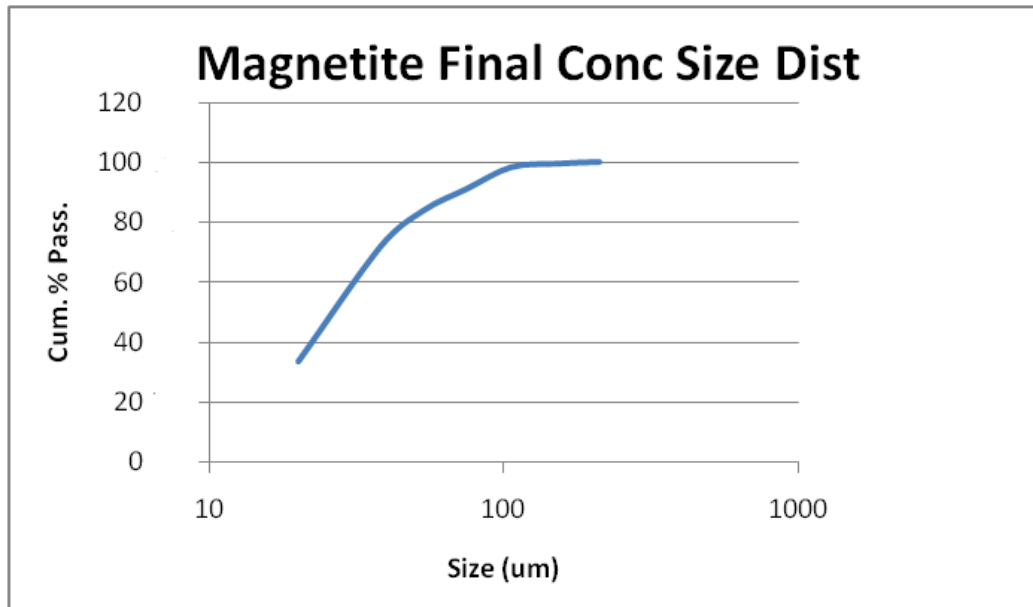


Figure 11– Final concentrate particle size distribution

The slurry commissioning plan includes a series of sampling campaigns to confirm the design parameters, optimise the operation of the plant, and develop guidelines for the daily operation. The sampling and testwork is focusing on collecting sufficient data points for statistical analysis.

- Confirm the specific gravities of all the process streams and compare with the design assumptions.
- Cyclone surveys to develop a size by size database to determine the optimum cut point for the cyclone overflow to achieve the desired magnetic separation.
- Determine the optimum cyclone operating parameters to achieve the target cut size.
- Determine cleaner efficiency and develop operational guidelines for water dilution to the cleaner circuit.
- Maximise ceramic filter throughput.
- Determine what impact if any water impurities could have on the final concentrate specification.

Future testwork is scheduled to understand and optimise the plant performance including full plant surveys, mineralogical analysis of all the process streams as well as IsaMill signature plots on the cyclone underflow.

CONCLUSIONS

The EHM magnetite extraction plant is part of the life of mine extension at Ernest Henry Mine and part of our strategic objective of maximising the value of our existing resources. It will provide an important source of growth and employment for the region. The EHM magnetite project has utilised a concise project management strategy and proven technology to maximise the value for shareholders in our pursuit for zero waste.

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