McArthur River Mine Heavy Medium Plant – The Benefits of Applying Modern Coal Plant Design Principles to Base Metal Heavy Medium Separation

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ABSTRACT

In 2012, a single module heavy medium cyclone plant (HMP) was installed at the Glencore Zinc's (then Xstrata Zinc) McArthur River lead zinc mine. The HMP formed the first part of the MRM Phase 3 Project to increase run of mine (ROM) capacity from 2.4 to 5.5 Mt/a.

The purpose of the HMP is to remove liberated gangue from the crusher product at minimal loss of valuable mineral. The McArthur ores are very finely disseminated requiring a fine primary grind size prior to rougher flotation. Rejecting waste prior to grinding therefore offers significant power and grinding media savings. The plant was designed to treat only those ores with a reasonable upgrade ratio at the target zinc recovery across the HMP of 95%.

On this basis, a 1.8 Mt/a single module plant was built based on 250 t/h feed rate and 82% availability. In contrast to existing base metal heavy medium plants in Australia, the MRM Flow sheet utilised the principles in modern coal heavy medium cyclone plant design. Since commissioning, the plant feed rate has been significantly increased and is now normally operated up to 540 t/h (dry basis).

Although this throughput increase is partially due to debottlenecking work, it is also attributable to the conservative design parameters for base metal heavy medium cyclone circuits in comparison to those used in equivalent coal circuits.

This paper discusses Flow sheet design and compares traditional base metal design parameters with those achieved at MRM and those of modern coal plants. It provides information on plant capital and operating costs and the net savings realised by its installation. In addition to power and grinding cost savings, the paper also highlights the savings in water through rejection of near dry waste and reduction of tailings pumped to the storage dam.

INTRODUCTION

McArthur River Mine (MRM) is a lead-zinc mine wholly owned by Glencore located near Borroloola in the Northern Territory approximately 900 km south east of Darwin. The mine has been operational since 1995 producing a bulk concentrate containing lead and zinc sulphides. Although the deposit is relatively shallow, extraction was originally via underground mining (MRM phase 1) as the ore lay directly under the McArthur River. With the construction of a 5km diversion channel in 2007, the mining operation was changed to a more cost efficient open pit extraction (MRM phase 2). This allowed the mine throughput to be increased from the original capacity of 1.2 Mt/a to 2.4 Mt/a run-of-mine (ROM).

The ore is characterised by a particularly fined grained mineralogy. Although the deposit was first discovered in 1955 and the first feasibility study completed in 1977, the resource remained unexploited due to the absence of an economically viable comminution process to sufficiently liberate the minerals in the regrind phase. In the early nineties, the then deposit owner, Mount Isa Mines Ltd (MIM) undertook to develop a new fine grinding technology (the IsaMill™) to specifically treat the MRM ores. The Concentrator process involves crushing the ROM to -20 mm then primary grinding to less than 100 µm. Froth flotation is used for beneficiation. The rougher concentrate is reground in two-stage of IsaMills to an ultra-fine grind of 80% passing 5-8 µm before six stages of cleaner flotation to produce a bulk concentrate containing 46% zinc w/w and 10% lead w/w. Even at these very fine particle sizes it has not been possible to produce separate zinc and lead concentrates until the recent introduction of a proprietary leaching process to treat the bulk concentrate.

In 2014 MRM completed a phase 3 expansion to increase mine and plant capacity to 5.5 Mt/a ROM. As a precursor to the full phase 3 project, a single module heavy medium cyclone (HMC) plant was commissioned in 2012 with a design capacity of 1.8 Mt/a. The purpose of the plant was to selectively treat those ores most amenable to heavy medium separation and thereby reduce downstream grinding power requirements and increase the grinding capacity.

APPLICABILITY OF HEAVY MEDIUM SEPARATION

The lead and zinc sulphide minerals at MRM exist in several stratified ore bodies separated by barren, interbed material. There are eight separate ore bodies with 1 being the deepest and 8 the closest to the surface. Only ore bodies 2 to 8 are currently processed. The overall ore body has an average depth of 55 m. The interbed material is mainly silica with a specific gravity of less 2.7 t/m^3 compared to 3.3 t/m^3 for the ore. It is therefore possible to reject this material using separation by density differential. When assessing the proportion of ROM that can be rejected through pre-concentration, the maximum allowable reject grade is generally considered to no higher than the tails grade from the main down stream flotation separation process (Creswell 2001). In the case of the MRM ores the target recovery for pre-concentration was determined to be 95% for both zinc and lead.

To minimise metal losses sufficient liberation is required for a relatively clean separation. For the MRM ores this requires the feed to be -20 mm. This process therefore requires an upstream crusher plant and is typically not suitable for a SAG/AG mill plant.

For the bulk of the particles in this size range HMC (more commonly referred to in Australia as dense medium cyclone) separation is the most efficient density separation available. The efficiency of HMC separation, however, decreases significantly for particles less than 0.5 mm. A key feature of HMC plant is to removal the fine particles by wet screening prior to separation process. There is little advantage in upgrading the fines through density separation so this component (15-20% of plant feed) is dewatered and rejoins the HMC product to report to the main grinding/flotation plant. Although 0.5 mm is the nominal bottom size from HMC separation, many plants including MRM screen at 1-2 mm as it is easier to maintain high screening efficiency and minimise fines contamination of the HM cyclone feed.

Removal of waste material ahead of grinding can offer the following benefits.

- an effective increase in overall plant capacity if (as is often the case) primary grinding is the bottleneck
- a reduction in overall plant unit power consumption primarily through the removal of waste at a relatively coarse size but also potentially through a net decrease in hardness of the mill feed as the rejected silica waste is often harder than the valuable minerals
- a reduction in the volume of tailings reporting to the tails dam as the dry HM rejects can be disposed of on the mine waste dump
- a potential reduction in overall operating costs depending on percentage of HMP feed

reporting to rejects
- a reduction in water lost to evaporation in the tailings dam (this was not a factor at MRM as it is in a high annual rainfall area).

A four module HMP has been treating lead-zinc ore at Glencore's Mt Isa mine since 1982. At a loss of 5% of the contained zinc and lead the plant rejects approximately 35% of plant feed to waste however the net increase in downstream grinding capacity is 50% as the rejected silica is harder than the concentrated ore.

Installation of a heavy medium cyclone plant at MRM had been considered but rejected several times since 1995. The width of interbed material for the MRM ore is less than for than those at Mt Isa and consequently the mass split that can be rejected, at acceptable recovery, is lower. In the extraction process the ore bodies are handled in the following composites, 2-2/3 ore, 3-4 ore, 6-8 ore. The 5 ore was treated with the 3-4 ore but is now treated separately.

With the original (phase 1) underground mining operation it was decided to opt for a primary crush only of ROM ore before feeding direct to a semi autogenous grinding (SAG) mill. This simplified the comminution circuit but did not provide a sufficiently liberated product suitable for heavy medium separation. Over the years, a three stage surface crushing plant was added to increase plant throughput, thus creating the ideal feed size for heavy medium separation. With the higher tonnage phase 2 open pit mining operation, there was an inevitable increase in dilution of ROM ore thereby improving the economic justification for a heavy medium plant.

The 6-8 ore has a lower metal content that the other ores and had largely been left untreated. It did, however, form approximately 30% of future production forecasts resulting in a lower ROM grade. Partially as a consequence of this the average ROM ore hardness was also projected to increase by 15% based on core sample testwork. The existing plant was grinding and power plant capacity constrained so a reduction in feed grade would have led to a reduction in final concentrate production. Heavy medium separation (HMS) was identified as the likeliest short term option to offset this reduction in ROM grade.

Float-sink test work was performed by HRL on the three main ore body composites 2-2/3, 3-5 and 6-8 ore in 2010. For a 95% zinc metal recovery, a split to floats fraction of 19% for 2-2/3 ore, 24% for 3-5 ore and 33% for 6-8 ore was achieved. Based on 20% of plant feed bypassing HMS as fines this equated to a net reject rate (tonnes rejects/ tonnes HMP feed) of 15% for 2-2/3 ore, 19% for 3-5 ore and 26% for 6-8 ore.

Assuming similar module throughputs to the existing Mt Isa plant, a three module plant would have been required to treat all the crushed product in the Phase 3 design scenario of 5.5 Mt/a ROM. The capital expenditure could not be justified based on the reject rates for 2-2/3 and 3-4 ores. It was therefore decided to build a single module 1.8 Mt/a plant to treat all the 6-8 ore and as much of the 5 ore as was possible. Processing of the 6-8 ores had been largely avoided up until recently as it has significantly lower ROM metal grade than the 2-5 ores.

PLANT DESIGN

Flow Sheet

The HMP was designed and built on behalf of MRM by Milestone Engineers and Project Managers (MEPM). The flow sheet is shown in Figure 1 and is similar to most base metal dense medium cyclone plants. It consists of the following basic components: Plant feed, Fines Removal, heavy medium (HM) cyclone, correct medium (CM) circuit, dilute medium (DM) recovery circuit, Fines dewatering.

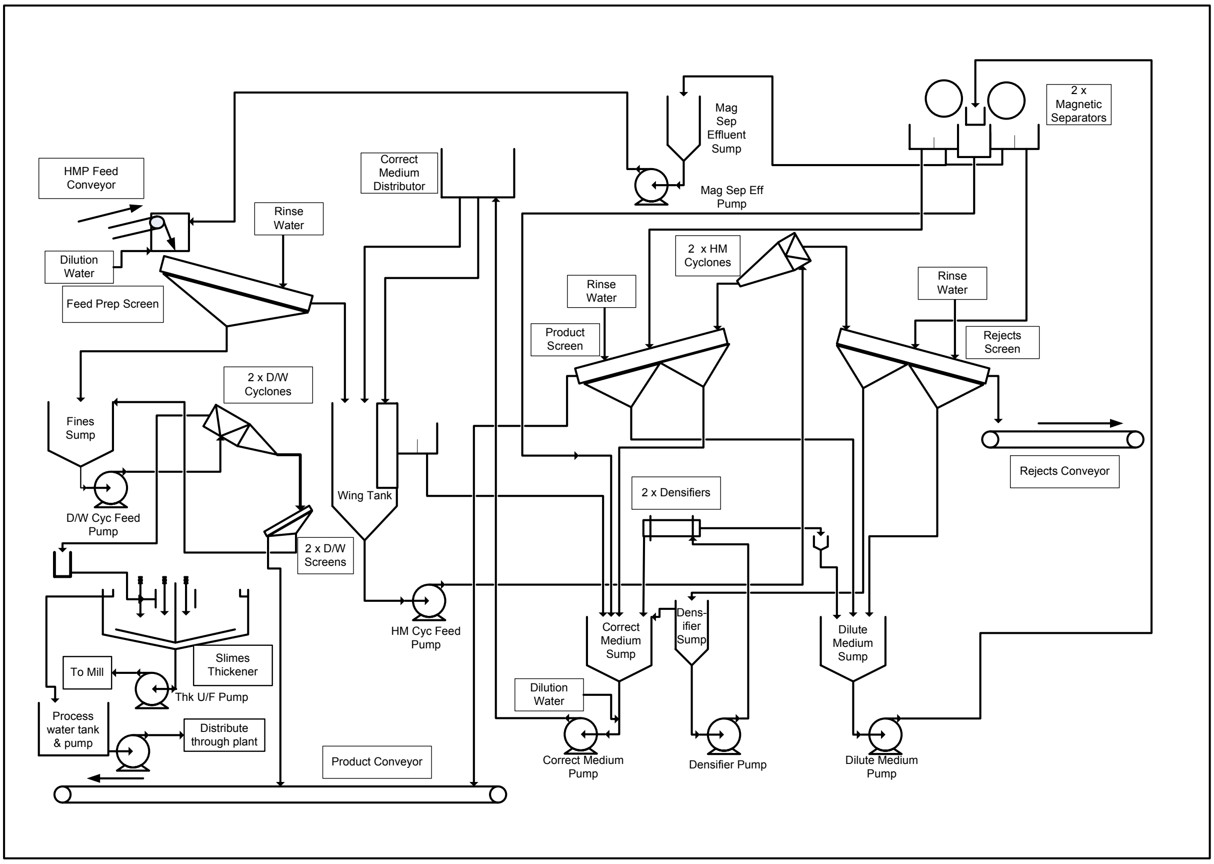

Figure 1 HMP Flow Sheet

Ore is drawn from the live ore stockpile via two feeders (one vibratory; one belt) on to the HMP feed conveyor which conveys the feed up to the top floor of the HMP module. There it is turned to a slurry using recirculating process water and wet screened on the feed prep screen to remove the fines (−1.6 mm). The screen oversize is mixed with ferrosilicon medium in the discharge chute and drops in the wing tank main compartment. A second portion of medium is added to the seal leg of the wing tank that continuously overflows back to the correct medium tank. This design allows the wing tank to operate under a constant head regardless of ore feed rate.

The medium is pumped from the correct medium sump to an overflow weir type distributor on the top floor where is can be split at the target ratio between the primary and seal leg compartments of the wing tank. The medium is controlled to the target density by injecting water into the suction pipe of the correct medium pump. The control loop measures the density on the nuclear gauge on the pump discharge line and adjusts the control valve on the water injection line.

The combined ore and medium is drawn from the bottom of the wing tank and pumped up to the two HM cyclones configured in parallel. The heavy ore product reports to the cyclone underflow as the sinks fraction and the rejects to the cyclone overflow as the floats fraction. The medium in both streams is removed from the product and rejects on drain and rinse screens. These screens have twin underpan compartments. The medium is allowed to drain through the first portion of the screen (drain section) without being diluted. Residual medium sticking to the ore/rejects is then recovered by washing the solids firstly with recycled magnetic separator effluent and then with process spray water. The rinsed product discharges from the product screen on to the product conveyor and is directed to the mill feed stockpile. The rinsed rejects discharge on to the rejects conveyor and then on to the rejects stacker which can slew 90^0 to form a 6000 t rejects stockpile. The rejects are back loaded to the main mine waste dump in trucks every night shift by the mining department.

The action of the HM cyclones has a dewatering effect on the medium so the portion reporting to the product screen has a slightly higher density than the correct medium whereas the portion reporting to the reject screen is slightly lower.

Product screen medium reports directly to the correct medium sump and reject screen medium reports to a smaller densifier sump. This continuously overflows to the correct medium sump with a variable portion removed from the base of the sump and pumped to the pipe densifiers. These remove a low density stream to the dilute medium sump and concentrated medium stream to the correct medium sump. The degree of medium densification can be controlled by the densifier pump speed.

The diluted medium stream is collected in the rinse section underpan of both screens and gravitates to the dilute medium sump. The dilute medium is pumped up to two counter rotating magnetic separators that recover the magnetic ferrosilicon (mags). The recovered 'mags' gravitates to the correct medium sump. Effluent containing non-magnetic solids is distributed both to the drain and rinse screen wash boxes and the magnetic separator effluent sump. From this sump the effluent is transferred to the HMP feed mixing box to slurry the incoming feed.

The feed prep screen undersize slurry (-1.6 mm) reports to fines sump and is pumped to the dewatering cyclones. The cyclone underflow reports to the inclined high frequency dewatering screens with screen oversize reporting to the product conveyor. Screen undersize recycles back to the fines sump. The cyclone overflow slimes with a P_{80} of 20-25 um reports to the slimes thickener where flocculant is added and the solids thickened to approximately 30% solids w/w. The clarified thickener overflow reports to the process water tank for reuse in the plant.

The main components and their purpose are shown in Table 1.

Table 1 Flow Sheet Components and Purpose

Section	**Main Components**	**Purpose**
Plant Feed	500t live ore stockpile Feeders (1vib+1belt feeder) Feed conveyor	Buffer storage Draw from stockpile Feed ore into HMP
Fines Removal	Feed mixing box Feed prep screen	Slurry ore feed Remove fines (-1.6 mm) prior to HM separation
HM circuit	Wing tank HM cyclone feed pump HM cyclones Product screen Sinks screen	Mix ore with correct medium Feed HM cyclones Separate product from rejects Recover medium from product Recover medium from rejects
CM Circuit	Correct medium sump Correct medium pump Correct medium distributor Densifier sump Densifier pump Densifiers	Storage for CM circulation Pump CM to distributor Split medium to wing tank compartments Take drain medium from rejects screen Feed densifiers Dewater medium to >correct medium density
DM	Dilute medium sump	Receive dilute medium from D&R screens

Circuit	Dilute medium pump	Transfer dilute medium to magnetic separators
	Magnetic separators	Separate medium from ore slimes
	Mag separator effluent pump	Transfer effluent to feed box to slurry new feed
Fines Circuit	Fines sump	Receive feed prep screen u/s
	D/W cyclone feed pump	Feed D/W cyclones
	D/W cyclones	Cut at 30um particle size
	D/W screens	Dewater -1.6+0.03 mm material to 88% solids w/w
	Slimes thickener	Thicken -30 um slimes to 30% solids w/w
	Slimes thickener u/f pump	Transfer slimes to mill circuit
Products handling	Product conveyor	Transfer product to main stockpile feed conveyor
	Rejects conveyor	Transfer reject to stacker conveyor
	Rejects stacker conveyor	Stack rejects stockpile
	6000 t rejects stockpile	Storage for rejects prior to removal by truck to mine waste stockpile

Prior to the MRM plant the existing base metal HM plants in Australia, which are generally more than 25 years old, are all based on gravity fed heavy medium cyclones. These plants are much taller, and have a correspondingly higher capital cost, compared to pump feed cyclone plants standard in the coal industry. For the MRM plant, it was decided to leverage off modern coal preparation plant design as much as possible. Due to the much larger number of coal heavy medium separation operations worldwide, compared to those in base metal, there appears to have been significantly more innovation and design optimisation in the coal industry. The main differences between the MRM plant and a typical coal HMC plant are

- the medium used is ferrosilicon (6.7 SG) to achieve a correct medium separating density of 2.7-2.9 SG depending on ore type. Coal plants use magnetite (5.1 SG)
- in coal plant the magnetic separators are used to both recover and densify the medium from the dilute stream. For ferrosilicon an additional densifier cyclone circuit is required to sufficiently dewater the circulating medium
- there is no fines separation circuit as this is effectively done in the downstream grinding-flotation plant.

Key Component Design Basis

Heavy Medium Cyclones

The Heavy Medium Cyclones are used to separate low density reject material from the higher density product. Traditionally 400 mm diameter cyclones have been used as the standard for base metal separation with a feed driving head equivalent to 15-40 times the diameter of the cyclone (i.e. 6-16 m). For a 200-300 t/h module this would require 4 x 400 mm cyclones in parallel. This is based on the theory that smaller cyclones operating at higher inlet pressure have a lower particle size at which the separation efficiency starts to drop off quickly (known as the 'breakaway' size). For a 400 mm cyclone the theoretical breakaway size is 1mm compared to 3 mm for an 800 mm cyclone (Napier-Munn 2009). In practice this relationship is less obvious as coal wash plants now use cyclones up to 1300 mm in diameter. A review of coal heavy medium cyclone in 2002 concluded 'there is no significant effect on Ep for all size fractions greater than 1mm using cyclones of 700-1300 mm in diameter (Clarkson 2002). 610 mm cyclones have also been used in the South African diamond industry for many years.

Smaller cyclones are also susceptible to blockages in the feed inlets. A 400 mm cyclone has an inlet diameter of 80 mm compared to the largest nominal a feed particle of 25 mm. Prior to the design of the MRM plant an 800 mm cyclone had been installed one of the modules at the Mt Isa plant to replace 4x400 mm cyclones. It reportedly reduced downtime for blockages and improved cyclone life although attempts to measure differences in separation efficiency were inconclusive at the time.

Based on the available data at the time 2 x 610 mm high capacity heavy medium cyclones were selected. This selection was based on required spigot capacity as well as cyclone efficiency considerations. For base metal heavy medium separation the product reports to the cyclone underflow. Allowing for a worst case split of 85% cyclone feed reporting to underflow 245 mm spigots were required to conform to standard DSM capacity guidelines. The MRM cyclones were designed for a nominal feed driving head of 9.5 D (9.5 x cyclone diameter) based on standard coal design and the Mt Isa 800 mm DM cyclone but with the variable speed pump capacity to deliver up to 14 D if required. The typical coal style wing tank was used to mix medium and feed prep screen oversize and a Warman 250MCR pump with 315 KW motor selected.

Screens

Multislope ('banana') screens were selected for the feed prep and drain and rinse (product and reject) screen duties in line with current coal plant design practice. The feed prep screen was sized at 19 t/h/m^2 (115 t/h/m width) for a 95% screening efficiency at the original target cut point of 1.2 mm (1 mm aperture) based on vendor experience. This resulted in a 2.4 m wide by 6.1 m long Metso multislope screen being selected. The drain and rise screens were sized on standard drainage rates of 50 m^3/h/m^2 for a 0.8 mm aperture similar to those used in coal plants. For commonality of spares, 2.4 m wide x 6.1 m long Metso multislope screens were also selected for both product and reject screens. Since start up the feed prep screen has been operated with a 1.4 mm aperture (1.6 mm cut point) to allow for the increased feed rates.

Magnetic Separator

Two 'back-to-back' 1.2 m diameter x 3 m long Eriez counter-rotating magnetic separators were selected as primary magnetic separators. Space allowance was made for a secondary magnetic separator if needed however this proved unnecessary. The two units provided a reasonably conservative volumetric loading of 40 m^3/hr/linear m.

General

The DM cyclone feed, correct medium and densifier feed discharge pipes were sized for a nominal velocity in the range of 3.0-3.5 m/s. Ceramic tiled steel pipes were used for the pump suction and discharge pipes and for the gravity pipes from the drain sections of both drain and rinse screens. All other slurry pipes were lined with 6 mm natural rubber. HDPE was used for the process water and slimes thickener underflow lines.

The Wing tank and large sumps were based on ceramic lined coal designs.

A list of the main equipment used in the plant is shown below in Table 2.

Table 2 Main Process Equipment

Equipment	**Qty**	**Make & Model**	**Design sizing**	**Actual capacity**
DM Cyclones	2	Multotec 610m	100 t/h/cyc	200 t/h/cyc
Feed Prep Screen	1	Metso 2461 MS	19 t/h/m^2 (115 t/h/m width)	34 t/h/m^2
Product Screen	1	Metso 2461 MS	50 m^3/h/m^2	In line with design
Rejects Screen	1	Metso 2461 MS	50 m^3/h/m^2	In line with design
Magnetic Separators	2	Eriez CLIMAXX 1.2mx3.0m counter rotating	40 m^3/h/lin. m	In line with design
Dewatering cyclones	1dty 1stdby	Warman 400CVX	200 m^3/h/cyc	Now running both cyclones
Densifier cyclones	2	Multotec 200mm	75 m^3/h/unit	In line with design
Dewatering screen	2	Metso 1.2x3.6HF (originally 1 x 0.9x3.0HF)	40 t/h/m width	30 t/h/m width
Slimes Thickener	1	Outotec 9m HRT	3.0 m/hr rise rate	In line with design

PLANT PERFORMANCE

Feed ramp up and de-bottlenecking

The design feed rate of 250 t/h(dry basis) was reached relatively quickly after commissioning in August 2012, as was target reject rate and acceptable metal recovery. It was then decided to ramp the feed rate up as far as possible to maximize plant utilisation. Up to 450 t/h(dry basis) was achieved without loss of metallurgical performance before reaching the limit of the single vibratory, feed conveyor power, dewatering screen and slimes transfer line to the mill. Upgrades were installed in September 2013 to add a second feeder, upgrade the feed conveyor power from 30 to 45 KW, replace the existing 0.9x3.0 m dewatering screen with two 1.2x3.6 m units (to allow for an expected future increase in fines) and install a large slimes transfer line. The initial vibratory feeder had been problematic in terms of hard fines build up which required regular cleaning. It was decided to install a 640 t/h belt feeder as the second feeder. This has proven much more reliable and tends to be used as the duty feeder with the original as a standby unit.

After these upgrades were completed, plant feed rates of up to 600 t/h became possible though only for short periods as the capacity for the existing contract crusher plants was limited to a steady state of around 350 t/h. Density tracer surveys conducted on the HM cyclones showed a drop in cyclone efficiency above 500 t/h however this did not appear to translate into a decrease in metal recovery. This is attributable to relatively clean separation for the ore and interbed material at the plant feed size resulting in minimal ore/silica composite material with a relative density close to the separation density (known in density separation processes as ‘near gravity’ material).

As part of the Phase 3 expansion, a new owner-operated 5.5 Mt/a crusher plant was commissioned in May 2014 to replace the existing contract crusher plants. The HMP could then be operated as it maximum capacity. Based on survey and wear data it was decided to limit the maximum throughput to 540 t/h (dry basis). Figure 2 shows the average feed rate in dry t/h per quarter.

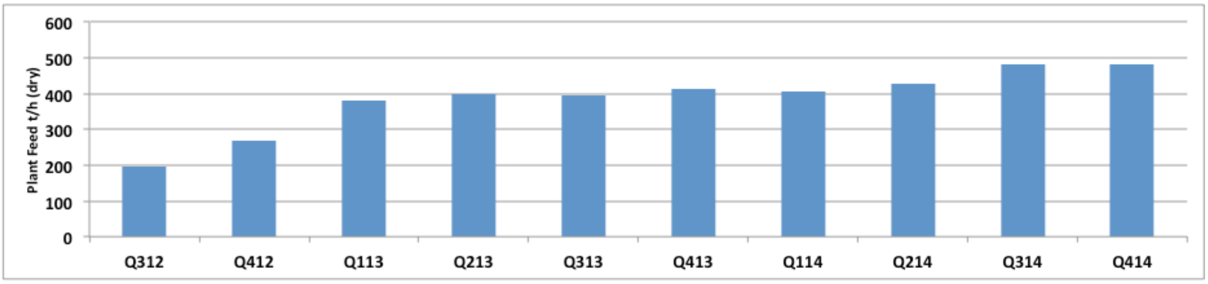

Figure 2 Average Plant Feed Rate t/h per Quarter

As a result of changes to feed rate, the annualised plant capacity has risen from the design 1.8 Mt/a to a current average rate of 2.5 Mt/a as shown in Figure 3 together with annualised reject throughput.

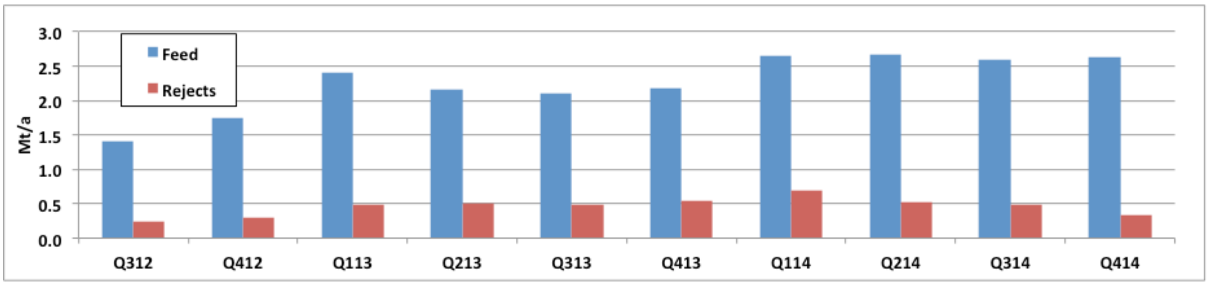

Figure 3 Annualised Plant Feed Rate Mt/a per Quarter

Metallurgical Performance

Plant design was based on 95% zinc and lead recovery at the following reject rates for the different ore composites

2-2/3 - 16%, 3-5 – 20%, 6-8 - 26%.

Figure 4 below shows the comparison of actual zinc recovery to that predicted by reject rate and average ore composition by quarter. As can be seen target recoveries have continued to be met with no net change since start-up despite an increase in feed rate from 250 to nearly 500 t/h.

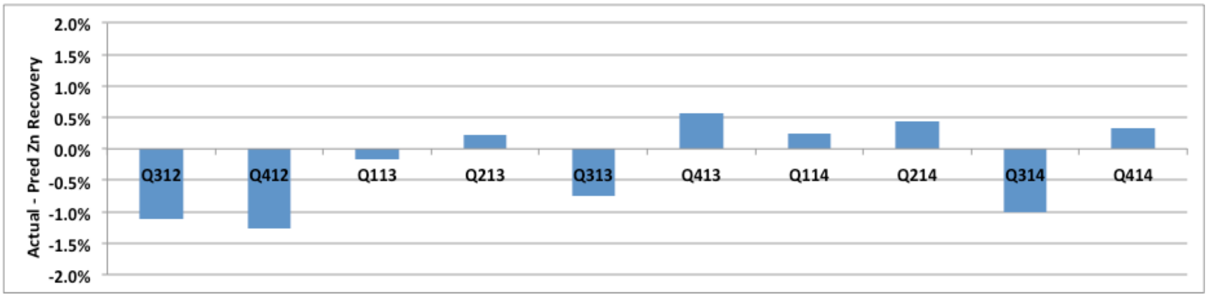

Figure 4 per Quarter Actual - Predicted Zinc Recovery

Medium consumption

Budget ferrosilicon (FeSi) consumption was 0.25 kg/tonne of plant feed. Based on historical Mt Isa performance data rates as low as 0.20 kg/t are achievable. Periods of high consumption were mainly the result of major loss events resulting from plant crash stops. A modification to drain and rinse screen panel design in the first quarter of 2014 also seems to have reduced FeSi losses. Since then the average consumption is around the 0.2kg/tonne of plant feed as shown on Figure 5.

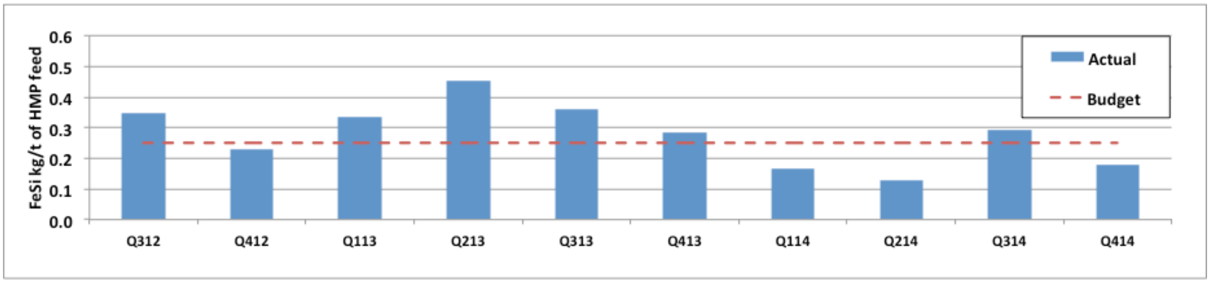

Figure 5 FeSi Medium Consumption Rate per Quarter

Improvement in ore characteristics

Samples of plant feed, product and rejects while operating on both 3-4 ore and 5 ore were collected during plant operation in December 2012 and sent to SGS for Bond rod and ball mill work index testing. The results showed an average increase in hardness from feed to rejects of 11-12% for both rod and ball mill bond work index and an average decrease in hardness from feed to product of 9.5%.

The removal of the slimes from the mill live ore stockpile (these are pumped direct to the mill) has also reduced stockpile angle of repose and increased live ore capacity. These two factors, which were not taken into account at feasibility stage, have increased the motivation to process as much of the ROM ore as possible through the HMP prior to milling.

PLANT ECONOMICS

All electrical power at MRM is generated on site by gas-fired generators. At the time of the HMP construction, the 22 MW power plant was operating at capacity for the plant throughput of 2.4 Mt/a run of mine ore. The existing primary grinding circuit was also operating at maximum capacity. The main driver for the HMP was to increase ROM capacity to 2.8 Mt/a in the short term ahead of the larger Phase 3 expansion, which would involve increasing the capacity of both these areas. Even with the subsequent Phase 3 expansion, the presence of the HMP allowed for a more flexible and efficient selection of equipment for the power station and primary grinding upgrades.

Capital Cost

The capital costs to build the HMP in 2012 were as shown in Table 3. To reduce site costs the main plant was built in pre-assembled modules floor by floor in Darwin and trucked to site.

Table 3 HMP Capital Costs

Item	**$M**
HMP Module Incl. feed, product and reject conveyors	35
Live Ore Stockpile	3
Stockpile Feed Conveyors and feed diversion system	2
Total	40

Operating Costs

The operating costs for 2014 were as shown in Table 4. A significantly smaller portion of the HMP costs are variable with throughout when compared to a grinding plant. The flow rate and density on the large pumps is independent of feed rate so there is only a marginal increase in overall power consumption (mainly attributable to conveyors) with increased throughput. As a result plant power consumption only varies between 700-800 KW for feed rates of 0 up to 590 t/h (dry basis).

Table 4 HMP 2014 Operating Costs

Item	**Cost $M/a**	**$/t Plant Feed**	**% of Total**
Labour	1.87	0.75	44%
Ferrosilicon	1.00	0.40	24%
Power	0.57	0.23	13%
Maint. consumables	0.50	0.20	12%
Other	0.30	0.12	7%
Total	**4.24**	**1.70**	100%

Impact On Downstream Costs

At the current HMP throughputs the plant is operating at a plant feed of 2.5 Mt/a and producing 0.5 Mt/a of rejects at a recovery loss of 5% of the zinc. This rejected material is, on average, 11% harder than the HMP feed so in terms of savings in grinding power and steel consumables it is equivalent to removing 0.56 Mt/a of mill feed. Cost savings are shown in Table 5.

Table 5 Downstream Operating Cost Savings

Item	**Cost $/t milled**	**Saving $M/a**
Primary Grinding Power (incl. pumps)	3.6	$2.0
Primary Grinding Steel Ball & Liner Consumption	3.8	$2.2
Primary Grinding Consumables (incl. liners)	1.4	$0.8
Rougher feed, tails and final tails pumping	0.2	$0.1
Total	**9.0**	**$5.1**

Net operating cost and power savings

As the HMP operating costs are relatively fixed, the net saving in operating costs is dependent on the amount of rejects. The net reduction in operating costs in relation to reject rate and plant throughput is shown in Figure 6 based on MRM costs. At the current plant throughput of 2.5 Mt/a and reject rate of 20% there is only a marginal saving in overall costs. Figure 6 shows the comparative saving in operating costs (Downstream savings – HMP costs) for MRM as a function of reject rate and plant throughput. Figure 7 shows the net saving in plant power for the same parameters. Clearly the more material rejected at the HMP the more the costs and power savings however this must be balanced with increased metal recovery loss with increasing reject rate.

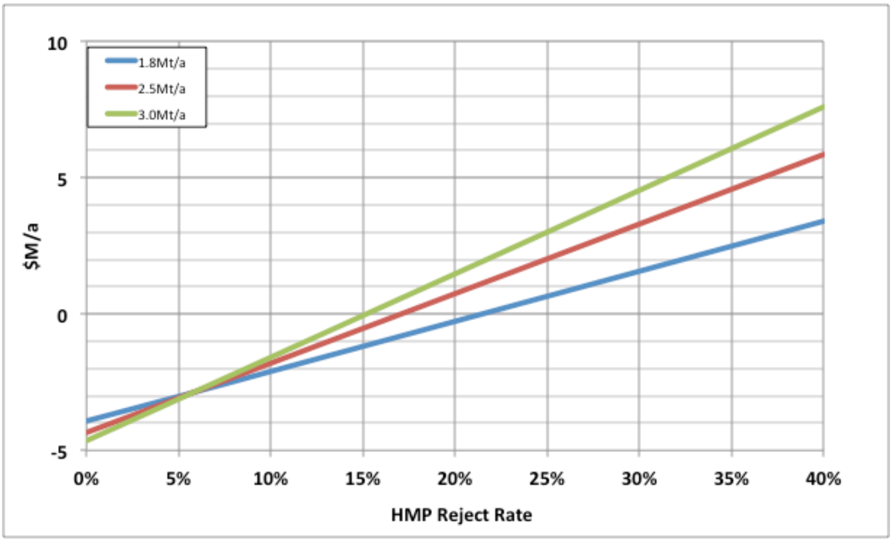

Figure 6 Net OPEX Savings vs. HMP Feed and Reject Rates

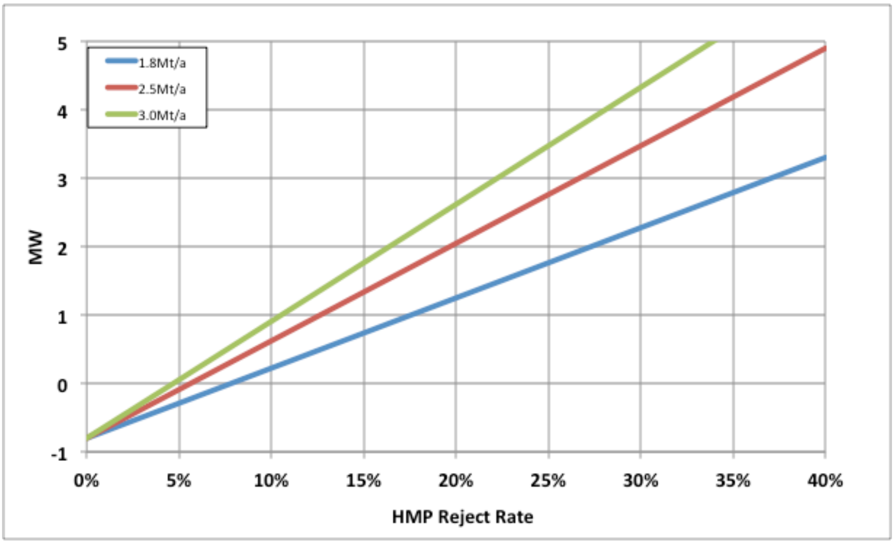

Figure 7 Net Power Savings vs. HMP Feed and Reject Rates

Water and tails dam capacity savings

The installation of the HMP has resulted in 0.5 Mt/a of gangue being disposed of as dry solids at the mine dump that would otherwise have been fine tailings pumped to the tails dam at 52-55% solids w/w. In addition to the reduction in tailings deposited in the dam each year this equates to 460-410 ML/a less water being pumped to the tailings dam.

MRM is located in a relatively high rainfall area by Australian standards. Apart from occasional dry years there is typically a positive water balance surplus. Water evaporation losses at the tails dam are therefore not usually a significant issue however the water lost on tails dams in more arid areas (such as Mt Isa) can be very high making this a significant potential benefit.

CONCLUSIONS

Although the plant was designed for a capacity of 1.8 Mt/a, it has been able to achieve 2.6 Mt/a for 2014. The plant should be capable of >3.0 Mt/a once the target plant utilisation of 80% is achieved. This experience would appear to validate the assertion that traditional design parameters from base metal heavy medium cyclone plants are too conservative in light of advances made in the equivalent design parameters for coal DMC plants.

Use of the more compact and lower capital cost pump fed HM cyclone layout has been validated for base metals.

At the time of justification the HMP capital cost of $40M was the lowest capital cost and most expedient option to increase the ROM capacity by 0.4 Mt/a prior to construction of a larger on site power plant. At current plant throughput rates the HMP provides a net increase of 0.56 Mt/a in downstream capacity for no increase in operating cost and 2 MWh reduction in power usage.

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REFERENCES

Clarkson C.J, Edward D.J, Davidson J, Lahey A.E, 2002, "Analysis of Large Diameter Cyclone Plant Performance", *Proceedings of the Ninth Australian Coal Preparation*, pp 107-124.

Creswell G.M, 2001 "Pre-concentration of Base Metal Ores by Dense Medium Separation" SAIMM Copper, Cobalt and Zinc Recovery Conference, Zimbabwe. Section: Mineral Processing

Napier-Munn T.J., Gibson G., Bessen B. 2009, "Advances in Heavy Medium Cyclone Plant Design", *Tenth Mill Operators Conference*, Adelaide, SA. Pp 53-61.

Wallace J, Strohmayr, S, Cameron K, Mathewson D, 2014, "McArthur River Mine Heavy Medium Plant - Differences and Similarities with Coal Dense Medium Cyclone Plants", *Proceedings of the Fifteenth Australian Coal Preparation Conference*, Gold Coast, QLD. Pp 39-54.

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