



DESIGN AND IMPLEMENTATION OF AN AVC GRINDING CIRCUIT AT BHP BILLITON CANNINGTON

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ABSTRACT

Since October 2003, the BHP Billiton Cannington mill has operated a grinding circuit consisting of an AG mill, pebble crusher and a Vertimill[®] which in this paper will be referred to as an AVC circuit. What is unique about this circuit is that it utilizes a Vertimill[®] for secondary grinding rather than the conventional ball mill. The implementation of this new circuit design was based on Cannington's positive experience with Vertimill[®] technology as well as results from modelling and simulation studies. A number of complete grinding circuit surveys were carried out in order to assess the performance of the existing circuit and to evaluate circuit expansion and optimisation options. The surveys and operating data collected confirmed the exceptional grinding energy efficiency achievable using the AVC circuit. Further improvement in plant performance is expected following the installation of an online particle size analyser and an OCS expert system for process control.

INTRODUCTION

The Cannington silver, lead and zinc deposit, located in north-west Queensland, was discovered by BHP geologists in June 1990. The high

grade Cannington resource is classified at 42 million tonnes, 551ppm silver, 12.1% lead and 4.7% zinc. The Cannington mine is an underground operation with access via a decline and production from a hoisting shaft that extends to a depth of 650 metres. The main production technique is long hole open stoping. The Cannington processing plant was commissioned in October 1997 and production was gradually increased from 1.5Mtpa (180tph), to 2.1Mtpa (250tph) in 2000.

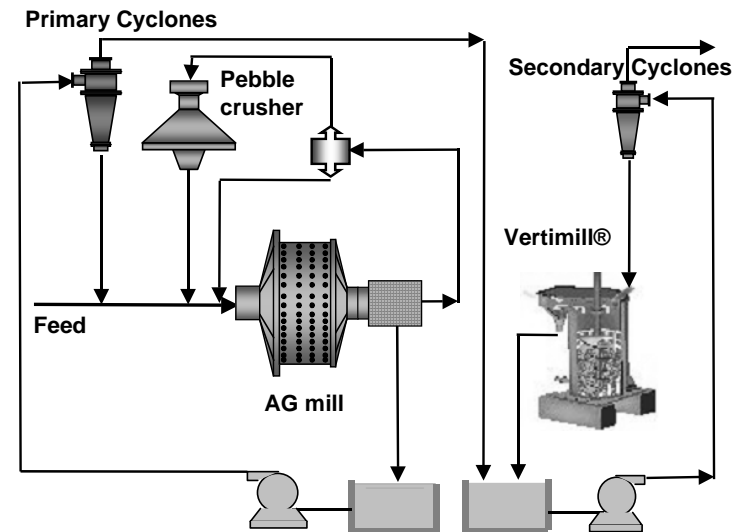


Figure 1. Two stage AVC grinding circuit flowsheet

After an initial expansion study conducted in 2002, Cannington commissioned a portable pebble crusher and started experimenting with the introduction of pebble ports in the AG mill. The number of grates with pebble ports was gradually increased and so did the amount of pebbles being discharged. By using the pebble crusher for partial (or full) pebble crushing, the circuit throughput was increased to 320tph. The pebble crusher has also added another control option for keeping the circuit throughput stable during variations in feed ore hardness and size. After confirming the positive effect of the pebble crusher on throughput, a permanent Metso HP300 pebble crusher was installed. With greater pebble crusher capacity and more pebble ports in the discharge grates, throughputs in excess of 350tph were achieved but could not be sustained due to coarse flotation feed and the associated recovery losses. In order to reduce the flotation circuit feed size and reduce the circuit product variations, a grinding circuit expansion project was undertaken.

During the design and engineering stage of the expansion project, a two stage AVC grinding circuit flowsheet was developed. The AVC circuit is shown in Figure 1 and consists of a pebble crusher and AG mill in closed circuit with primary cyclones. The secondary stage of the grinding circuit consists of one Vertimill® VTM 1500 WB (1.1MW) in closed circuit with secondary cyclones. After consultation with the cyclone suppliers regarding the size, operating pressure and cut point for the primary cyclones, guarantees were obtained that a coarser than simulated primary cyclone overflow could be obtained. Based on positive experience with the 250mm Cavex cyclones in the existing circuit, 400 CVX Cavex cyclones were chosen for the primary duty. A perfect mixing population balance Vertimill® model was developed for Cannington in the process design stage. Grinding circuit simulation results (Jankovic et al, 2001, 2002) indicated that throughputs of 350tph could be achieved with the introduction of pebble crushing and a final product size P80 = 95 microns should be achieved with the introduction of one VTM 1500 WB Vertimill®.

COMMISSIONING OF THE AVC GRINDING CIRCUIT

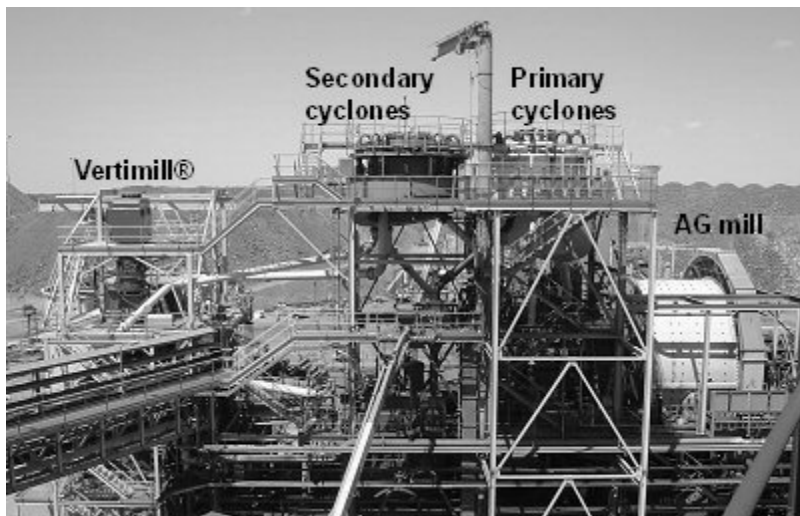


Figure 2. Cannington Grinding Circuit

The new AVC grinding circuit was commissioned in late October and early November 2003. Figure 2 shows a photo of the Cannington grinding circuit minus the pebble crusher. Metso Minerals Process Technology Asia-Pacific (MMPT-AP) was part of the commissioning team providing process and optimisation support. Low grade ore was

processed during the commissioning period that resulted in flotation tailing thickener and auxiliary equipment capacity problems. The grinding circuit throughput had to be restricted to 330tph due to the flotation tail handling limitations (Jankovic et al, 2003, 2004).

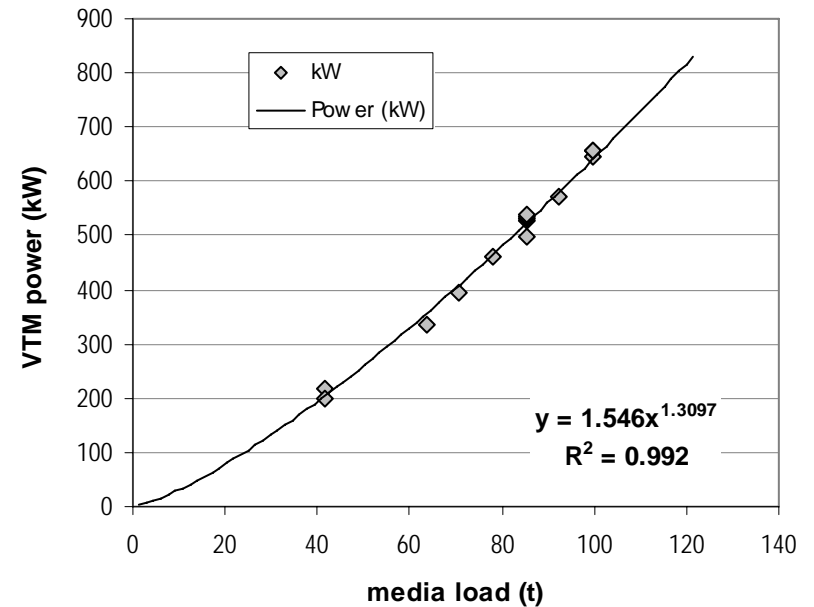


Figure 3. Vertimill® VTM 1500 power draw increase with media load

Data from the Vertimill® grinding media loading operation were collected to study the mill power response with load. Figure 3 shows the mill power as a function of media load in water. It can be seen that the power equation accurately fits the mill power trend. Using this function, it was calculated that 150 tonnes of grinding media is required to reach the full power draw of 1.1MW.

As the part of the commissioning effort, MMPT-AP and Cannington conducted six grinding circuit surveys. The first two surveys were conducted around the primary and secondary cyclones and the Vertimill®.

The third and fourth surveys were full circuit surveys and the last two surveys were conducted around the Vertimill® and secondary cyclones only.

Table 1: Summary of surveys conducted during commissioning

Survey number	1	2	3	4	5	6
Fresh feed (tph)	319.9	320.5	329.8	319.3	335.2	337
AG mill power(kW)	4569	4561	4527	4544	4921	4849
Vertimill [®] power (kW)	640	631	614	619	685	754
Primary cyc O/F (µm)	100	146	150	150	133	131
Secondary cyc O/F (µm)	76	106	94	109	100	93
Operating Wio (kWh/t)	14.6	17.3	15.6	17.6	17.4	16.7

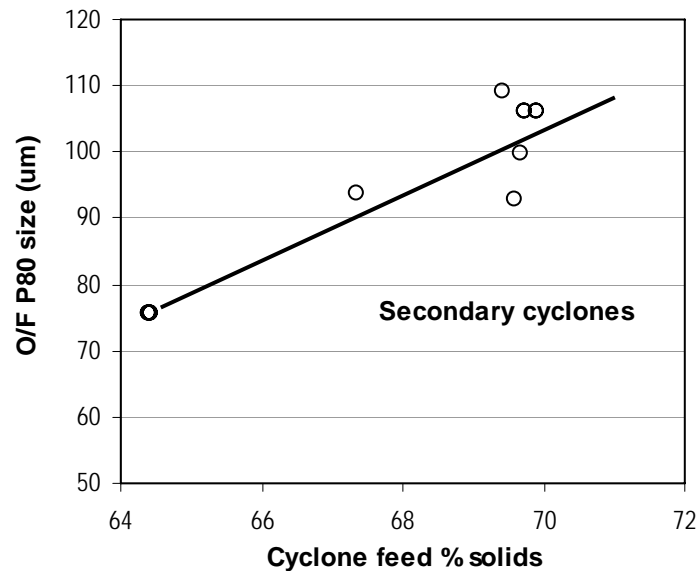


Figure 4: Secondary cyclone overflow P80 versus feed % solids

Table 1 shows that the operating work index measured for the overall circuit during these surveys ranged from 14.6kWh/t to 17.6kWh/t. The Bond ball mill work index for the ore samples collected from surveys 3 and 4 was 17.2 and 18.7kWh/t, respectively. The fact that the operating work index is lower than the Bond work index indicates the circuit is achieving exceptional energy efficiency. This confirms the observation that Vertimills[®] outperform, at low reduction ratios (<1.5), conventional ball mills when used for a similar duty.

Figure 4 shows the effect of the secondary cyclone feed density on overflow product size. A finer product was obtained at a lower cyclone

feed density (64.5% solids by weight). A similar trend was observed with the primary cyclones. This suggested that cyclone feed density was an important variable for product size control.

GRINDING CIRCUIT OPTIMISATION

After removing the flotation tailing handling capacity limitations, the plant throughput was increased to 380tph at the beginning of 2004. New production targets were then set to over 400tph. In order to achieve this target, Cannington and MMPT-AP conducted additional circuit optimisation work (Jankovic and Valery, 2004).

AG Discharge Grate Design

The Cannington AG mill discharge grate design has been modified throughout the life of the circuit in order to increase throughput. Figure 5 shows the effect of increasing the % of open area which is pebble ports on relative scats production. It can be observed that the pebble production increased from 20% for the grate without pebble ports to over 100% for the grate with all openings being 65mm pebble ports. Although the total open area of the grate was increased from 5.6% with no pebble ports to 7.6% with all pebble ports, it can be concluded that the fraction of openings that are pebble ports dictate the amount of material discharged as these larger openings allow coarser material to leave the mill. An optimal grate design with pebble ports at 65% of the open area was used to achieve over 400tph circuit throughput but limit pebble production below the pebble conveyor capacity.

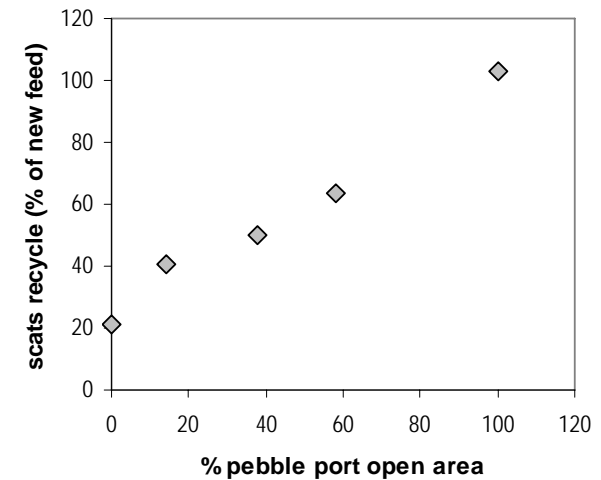


Figure 5: Scats production versus fraction of open area comprised of pebble ports (65mm pebble ports and 17mm grates)

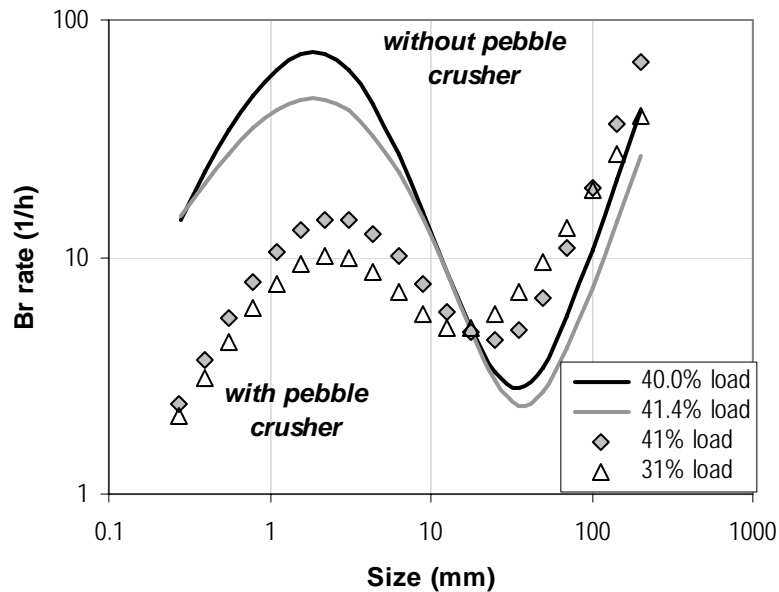


Figure 6: Cannington AG mill breakage rates

The AG mill operation has changed significantly since 2002. AG mill throughput in 2004 was in excess of 410tph compared to a maximum of 280tph in 2002. The product size from the closed AG circuit was around 160 microns in 2004 compared to 90 microns in 2002. This shift in operation is reflected in the breakage rates of the AG mill model. The fitted breakage rates for surveys done in 2002 (before the introduction of the pebble crusher) and surveys conducted in 2004 are presented in Figure 6. It can be observed that there is a significant drop in breakage rates in the fine, -5mm range and a significant increase in the +20mm size range. This is due to a change in composition of the AG mill rock charge because of the removal and crushing of the pebbles. The overall result is an increase in AG mill throughput and product size.

Pebble Crusher Operation

Initially the use of the pebble crusher was not optimal at Cannington as the performance of the crusher and its effect on the circuit were not well understood. To assess the performance at different crusher gaps and feedrates, testwork was carried out on the pebble crushing circuit. The pebble crusher was operated at three different closed site settings (CSS) to determine the effect on operating throughput. Crusher feed-rate (through a change in the percentage of pebbles diverted to the feed conveyor) was increased during each test until the crusher vibration limit

was reached. Figure 7 shows changes in circuit tonnage at different CSS.

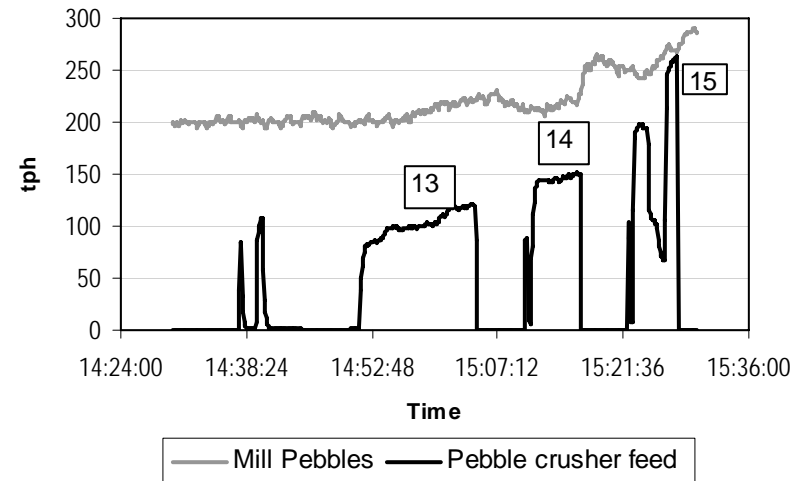


Figure 7: AG mill new feed, scats and pebble crusher feedrate during the crusher testwork at different crusher gaps (13, 14 and 15mm)

A summary of the pebble crusher test results is given in Table 2. It can be observed that both crusher feedrate and power is increasing with increasing CSS, which indicates that the crusher was operated more efficiently at larger gaps. This is confirmed by the specific energy input (kWh/t) which is also increasing with gap size. A higher kWh/t means more energy is being used for crushing, which should result in a finer product. Crusher product sample sizing indicated only small differences in the crusher product size. At higher throughputs, the operation is approaching the “choke fed” condition that is considered a preferable operating strategy. Note that the pebble crusher power draw was significantly lower than the motor rated power (220kW). This is due to the relatively soft ore and the low motor power factor.

Table 2: Summary of the pebble crusher testwork results

CSS (mm)	Crusher Feedrate (tph)	Power (kW)	Specific Energy (kWh/t)
13	119.3	54.3	0.45
14	146.2	78.2	0.53
15	195	116	0.59
15*	240	150	0.62

* indicates crusher overload

Evaluation of Grinding Circuit Performance

A summary of the full grinding circuit surveys carried out in 2004 is given in Table 3. Similar to the commissioning surveys, the operating work index for the overall circuit ranged from 16.2 to 17.5 kWh/t although the throughput was increased compared with 2003. The Bond ball mill work index for the feed ore samples collected from survey 11 was 17.1kWh/t. Thus it can be concluded that the overall circuit operating index is close to the bond ball mill work index which indicates its an energy efficient circuit. Although solids flow through the Vertimill[®] has increased to 1000 t/h, no deterioration in performance was observed. This is proof that the Vertimill[®] can be successfully used for high throughput applications.

It can also be observed in Table 3 that the final circuit product size was finer at higher throughputs and this is due to the AG mill power being significantly higher. This higher power draw is due to the AG mill operating with a higher rock load. This clearly demonstrate the crucial role of AG mill operation on the circuit final product size and suggests that the AG mill should be run with the highest charge possible (i.e. highest power draw). The increase in the circuit operating work index was a result of changes in feed ore composition (hardness) and size, as well as changes in circuit operation.

Table 3: Full grinding circuit surveys conducted in 2004

Survey number	8	9	11
Fresh feed (tph)	380.3	394.2	410
AG mill power(kW)	4,228	4,780	4,927
Vertimill [®] power (kW)	840	730	967
Primary cyc O/F (µm)	179	207	201
Secondary cyc O/F (µm)	135	128	121
Operating Wio (kWh/t)	16.2	17	17.5

CURRENT OPERATION

In addition to the grinding circuit expansion, other parts of the plant (flotation and thickeners) have been subsequently upgraded. The improvements since the expansion have been incremental and have resulted in the plant being de-bottlenecked downstream. These improvements have included removal of the Mozzley small diameter cyclones in the split flotation section, bypass of the preflotation stage and a thickener capacity upgrade. The higher throughputs have resulted in a much coarser grind (P80 above 150µm) and this has resulted in slightly reduced flotation recoveries. However, the revenue from the extra

tonnage has outweighed losses due to the drop in mineral recovery and thus the changes have had an overall positive effect.

BHP Billiton Cannington and MMPT-AP are in the process of installing Metso Mineral's OCS[®] expert control system in the grinding circuit and it is expected that this will result in an improvement in overall circuit performance. During several trial periods, the plant has been able to run at over 480tph whilst under OCS[®] expert control. An on-line particle size analyzer is being installed to provide the data required to enable better grind size control by the system.

Cannington management is currently in the early stages of planning to achieve additional grinding/flotation circuit improvements. The aims are to achieve higher mineral recoveries at throughputs of 450tph and a significantly finer grind-size. In order to achieve a finer grind, options related to reducing the amount of material being ground are being considered. These include the installation of a flash flotation circuit and the removal of low grade pebbles from the grinding circuit.

CONCLUSION

In October 2003, the BHP Billiton Cannington mill commissioned an AVC grinding circuit consisting of an AG mill, pebble crusher and a Vertimill[®]. Laboratory and industrial scale data, modelling and simulations were used during the design and subsequent optimisation. The objective of the Vertimill[®] circuit was to maintain the flotation feed size below P80=100 microns as the throughput rate was increased to 350 t/h. The design targets were quickly achieved and circuit performance was found to be exceptionally energy efficient. This confirms the common perception that Vertimills[®] outperform, at low reduction ratios (<1.5), conventional ball mills when used for a similar duty. It also shows that the Vertimill[®] can be successfully used for coarser grind, high throughput applications.

New production targets were set to over 400tph at the beginning of 2004. To achieve this target, optimisation of the discharge grate design and pebble crusher operation was performed. The fraction of open area that consists of pebble ports was found to control the pebble discharge rate. A pebble port fraction of 65% was found to be sufficient to achieve high throughputs but not exceed the capacity of the pebble return conveyor. Pebble crusher operation was found to be more effective at larger CSS enabling higher crusher feed throughputs.

Currently the plant is operating at around 450 t/h and over several periods, the plant was operating consistently around 480 t/h whilst under OCS expert control. There is no indication that grinding circuit energy efficiency has changed although high throughputs have resulted in a significantly coarser flotation feed size and recovery loss. Cannington management is currently considering different strategies for further grinding/flotation circuit optimisation aimed at reducing the grinding circuit product size.

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