Significant Potential of an IsaMill™ in Secondary Grinding Duty

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As the mineral processing industry strives to improve efficient grinding capabilities, stirred milling is becoming a more accepted technology for optimising performance and reducing carbon footprint. In the market, this has been reflected through media suppliers investing in the development of larger rolled ceramic media (up to 24 mm) and equipment suppliers releasing large stirred-mill designs (up to 12.5 MW).

When the IsaMill™ was first introduced to the market in the late 1990s, the target grind size was in the sub 10 μm range, which opened up previously un-treatable orebodies. Developments with larger ceramic media in the mid-2000s allowed the IsaMill™ to operate with a feed of up to 400 μm (F_{80}) and a top size of 1 mm using media with a top size of 6 mm. Media top size determines the appropriate F_{80} range for a stirred mill. As such, with the more recent availability of larger media (>6 mm) on the market, Glencore Technology (GT) has been investigating expanding the duties of the IsaMill™.

In October 2023, GT conducted a secondary grinding trial at Hudbay's Stall Mill in Manitoba, Canada. This trial aimed to provide proof-of-concept to demonstrate the effects of 8 mm and 10 mm ceramic media in an IsaMill™ and investigate the influence of media SG. In these trials, substantial reductions (>50%) in specific energy were observed compared to tumbling mills; this paper outlines the findings of that large-scale test work campaign and the potential for the IsaMill™ operating in this duty.

1.0 INTRODUCTION

In the mineral processing industry, communition circuits are the largest single consumers of final energy for hard rock mining operations, consuming one-quarter of the total final energy in mining (Allen, 2022). This has created several initiatives in the industry to improve efficient grinding capabilities, enabling stirred milling to become a more accepted technology for optimising performance and reducing carbon footprint in secondary grinding duties.

Some of these initiatives can be seen through media suppliers investing in the development of larger rolled ceramic media (up to 24 mm) and equipment suppliers releasing large stirred-mill designs (up to 12.5 MW and 50,000 litres in capacity). This has enabled the pathway for secondary grinding duties to be considered as part of the flowsheet.

Glencore Technology (GT) recently conducted a secondary grinding trial at Hudbay's Stall Mill in Manitoba, Canada. This trial aimed to provide proof-of-concept to demonstrate the effects of 8 mm and 10 mm ceramic media in an IsaMill™ and investigate the influence of media SG. This paper summarises the key learnings from a secondary grinding trial in an IsaMill™.

2.0 STIRRED MILLING IN COARSE GRINDING

Previously, with the ceramic media available (6 mm media), the coarsest duty accepted in an IsaMill™ was coarse particle flotation concentrate (Figure 1). This aligned with the traditional F_{80} of 400-450 µm that the IsaMill™ was advertised for. This limitation of 6 mm top size in the M4 laboratory mill and M20 pilot mill was due to the gap between the disc and shell requiring a ratio of three and a half times your media diameter to retain fluidised behaviour (Gurnett et al., 2023). Larger media diameters would require a larger mill to test.

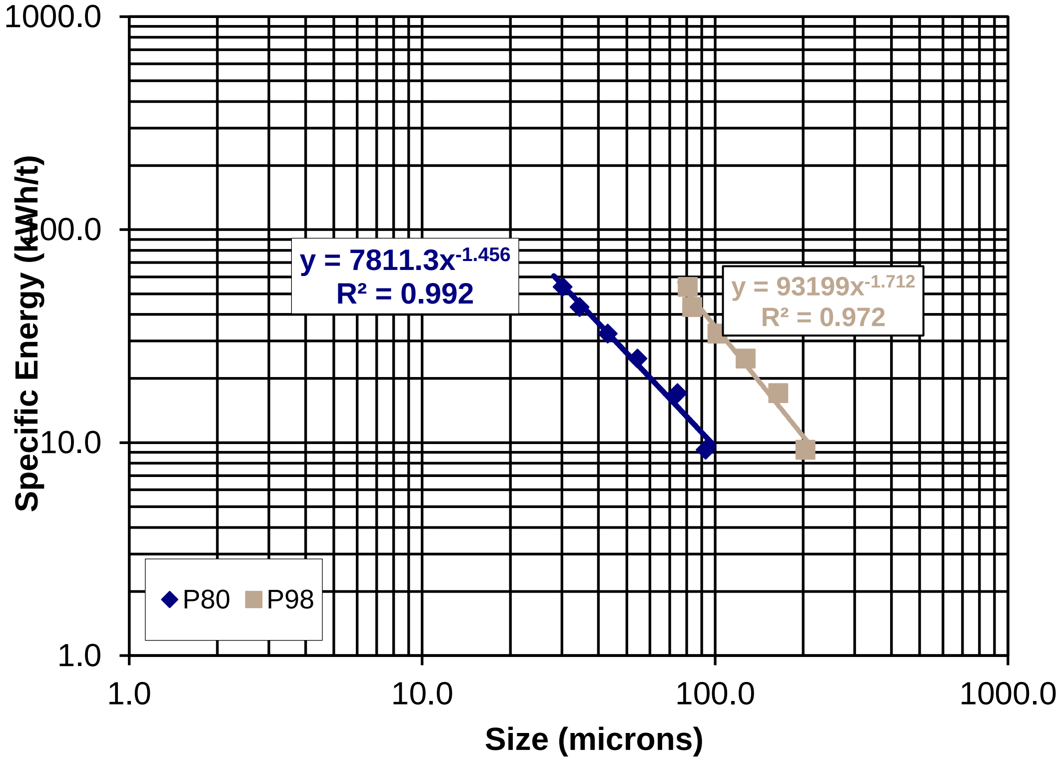

FIGURE 1: HYDROFLOAT CONCENTRATE (F_{80} 330 MICRONS, TARGET P_{80} 30 MICRONS) – SINGLE STAGE GRIND (GURNETT ET AL., 2023)

The IsaMill™ is a widely accepted and well-established stirred mill option for tertiary and pre-leach grinding, as well as flotation regrind. As the industry progressively works towards more energy-efficient grinding and milling technologies, the stirred mill has continued to evolve, and secondary grinding trade-offs with ball mills are now being examined.

Glencore Technology has previously conducted flotation regrind ball mill replacement studies (F_{80} < 200 μm) in which energy savings of 29 % (not including the ball mill cyclone feed pump) were achieved (Larson et al., 2015). It was hypothesised that these savings could be translated to secondary grinding duties with larger-sized media.

The top size of a stirred mill feed is defined by the media top size; this is why there is an emphasis on ceramic media availability as the driving force behind coarse grinding applications. Larger, cost-effective, diameter media sizes are readily available; an example of this evolution in ceramic media can be seen in Figure 2. It shows the size available when originally developed (~2 mm in 2001) and the rolled ceramic media up to 24 mm (2023).

FIGURE 2: EVOLUTION OF CERAMIC MEDIA (2 MM, 5 MM, 10 M AND 24 MM)

Once the implications for larger media sizes are evaluated in stirred milling, there is potential to significantly save on specific energy requirements and footprint considerations from the IsaMill™'s higher energy intensity per unit area, as demonstrated in Figure 3. In the future, there may even be communition circuit designs that utilise inert grinding media. This would result in improved chemistry from the absence of Fe^{2+}/Fe^{3+} ions in solution from no steel grinding media in an HPGR-IsaMill™ or AG Mill – IsaMill™ circuit (Gurnett et al., 2003).

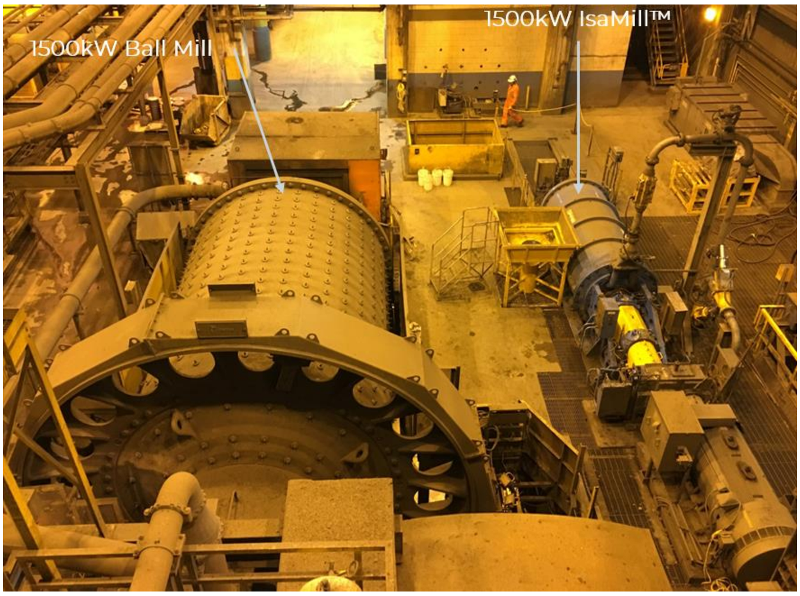

FIGURE 3: FOOTPRINT REDUCTION BETWEEN BALL MILL AND ISAMILL™ FOR THE SAME 1500 KW MOTOR (GURNETT ET AL., 2023)

Currently, the largest supplied IsaMill™ is a 5.5 MW M20,000, with designs up to 12.5 MW in an M50,000. With designs now available for higher volumetric flow duties, the next logical step will be to move the IsaMill™ into the secondary grind territory with this newly available ceramic media. The paper summarises the start of this journey, with an initial proof of concept trial at Hudbay's Stall Mill in Manitoba, Canada.

3.0 THE HUDBAY STALL MILL

The comminution circuit at HudBay's Stall Mill is described as follows. Fine ore bins convey crushed ore to two independent circuits, Stall and Chisel. The Stall circuit processes approximately two-thirds of the mill feed through a 3.2 m x 4.9 m rod mill and a 3.8 m x 5.5 m ball mill. The Chisel circuit processes the remaining one-third through a 2.1 m x 3.0 m rod mill and a 3.2 m x 4.0 m ball mill (Marion et al., 2020).

Each rod mill discharges into a dedicated cyclone feed pump box, combined with the ball mill discharge and dilution water. Each cyclone underflow returns to its respective ball mill. The cyclone overflow from each circuit combines and discharges into the cyclone overflow pump box. The product reports to a copper conditioning tank through a trash screen. The grinding circuit data is detailed in Table 1 and the layout given in Figure 4.

TABLE 1: GRINDING CIRCUIT PARAMETERS (REPRODUCED FROM MARION ET AL., 2020)

Rod Mill	**Stall Circuit**	**Chisel Circuit**
Rod mill work index	9.9 kWh/t	9.9 kWh/t
Rod diameter	86 mm	93 mm
Rod mill speed	21.1 rpm	16.6 rpm
	70 % of critical	68 % of critical
Rod mill motor	200 hp	800 hp
Ball Mill		
Ball mill work index	15.0 kWh/t	15.0 kWh/t
Ball diameter	38 mm	38 mm
Ball mill speed	16.6 rpm	16.8 rpm
	69 % of critical	76 % of critical
Ball mill motor	800 hp	1600 hp

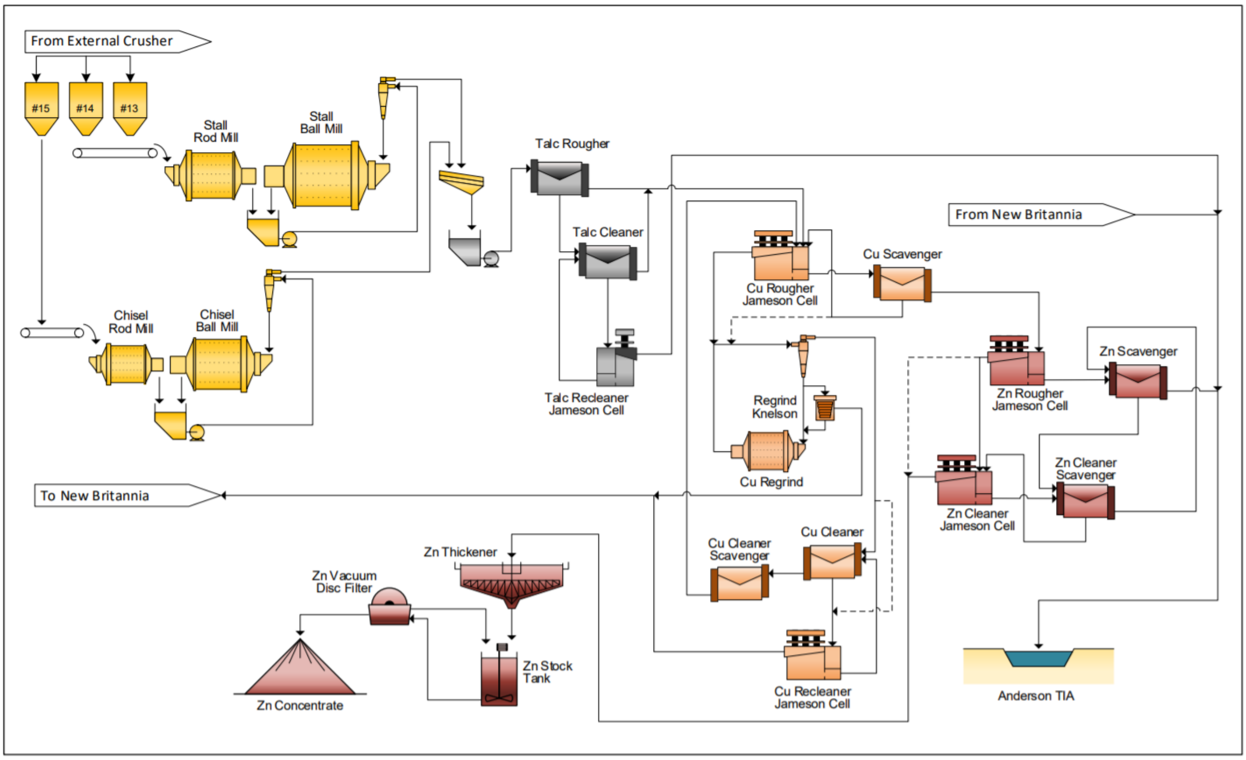

FIGURE 4: STALL FLOTATION CIRCUIT (TAVCHANDJIAN, 2021)

4.0 COARSE GRINDING TRIAL SET-UP

For the Coarse Grinding proof-of-concept trial, an M100 IsaMill™ (75 kW – 100L IsaMill™) was installed on the ground floor of the Stall Mill to treat the Stall circuit rod mill discharge; the location of the sample point in the flowsheet is outlined in Figure 5 with an X.

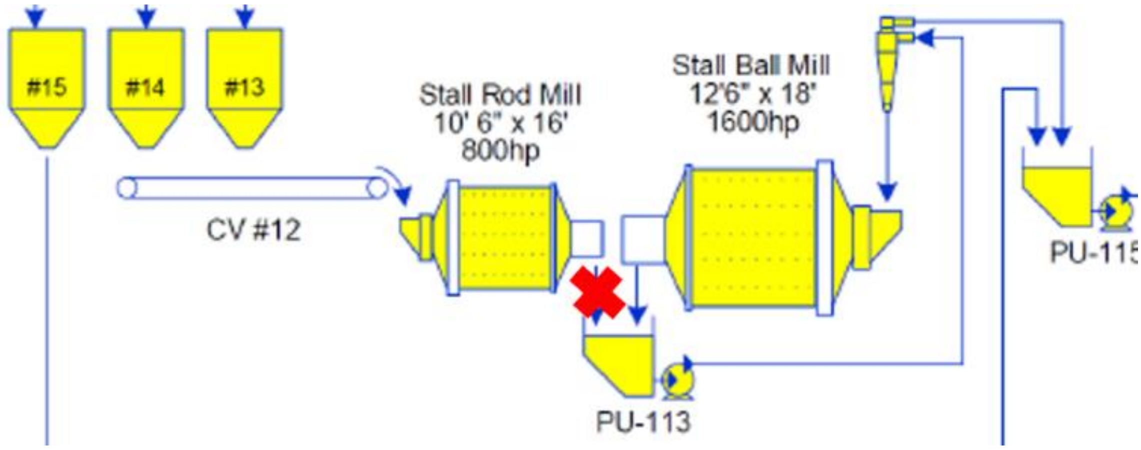

FIGURE 5: M100 SAMPLE LOCATION

4.1 Test work Matrix

Glencore Technology then executed a test work matrix (Table 2) using the M100:

TABLE 2: TESTING MATRIX

Test	Sample Point	SG	Media Size (Top Size)	Test objective	Analysis
1	Rod Mill Discharge – 50 Hz - Supplied Density	3.8	8 mm	Determine Proof of Concept	kWh/t - inferred by media loading in the mill. Particle Size - analysed by Screen & Malvern
2	Rod Mill Discharge – 40 Hz - Supplied Density	3.8	10 mm		kWh/t - inferred by media loading in the mill. Particle Size - analysed by Screen & Malvern
3	Rod Mill Discharge – 40 Hz - Supplied Density	4.5	8 mm		kWh/t - inferred by media loading in the mill. Particle Size - analysed by Screen & Malvern
4	Rod Mill Discharge – 30 Hz - Supplied Density	3.8	8 mm	Determine Tip Speed Effect	kWh/t - inferred by media loading in the mill. Particle Size - analysed by Screen & Malvern
5	Rod Mill Discharge – 30 Hz - Supplied Density	3.8	10 mm		kWh/t - inferred by media loading in the mill. Particle Size - analysed by Screen & Malvern
6	Rod Mill Discharge – 30 Hz - Supplied Density	4.8	8 mm		kWh/t - inferred by media loading in the mill. Particle Size - analysed by Screen & Malvern

Additional tests were initially requested by looking at the increased tip speed and operating density. The reason for this was due to:

- When the IsaMill™ Signature Plot Test is undertaken in a laboratory, it is conducted with a feed condition of 18 to 20 % solids (v/v) to maximise the efficiency (Figure 6). This aims to limit the viscosity impacts on grinding efficiency for particle surface area exposure. Theoretically, when larger particles are treated, the mill can be run more dense as fewer surfaces will be exposed. Theoretically, the operating density could no longer become a limiting design issue for secondary grinding duties.

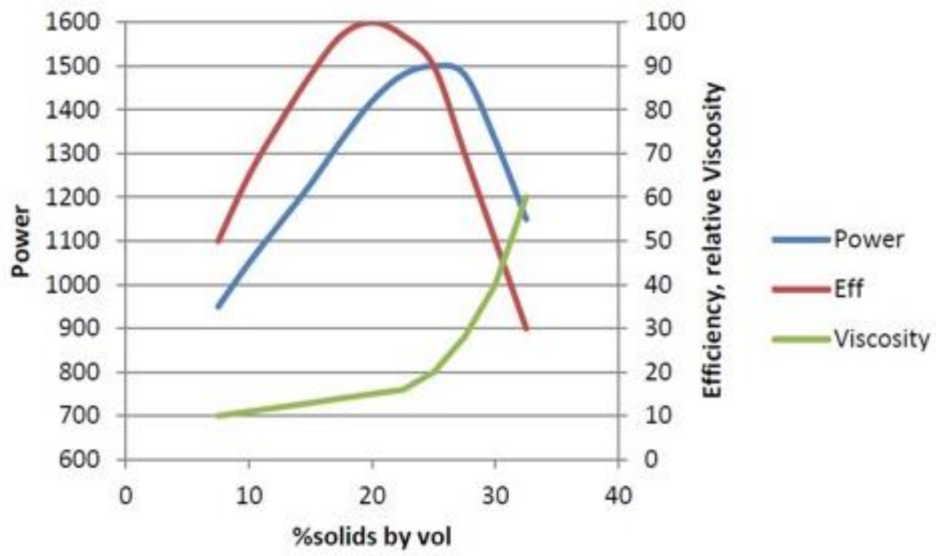

FIGURE 6: EFFECT OF DENSITY ON THE GRINDING EFFICIENCY WITHIN THE ISAMILL™(GURNETT ET AL., 2022)

- The increased tip speed was to investigate the stress intensity mechanism of the media within the IsaMill™. The stress intensity is proportional to the media diameter cubed, media velocity squared and media density (Gurnett et al., 2023). It was theorised that improved breakage of coarse particles would be seen within the mill at higher tip speeds.

Due to limitations on the M100 arrangement and sample location, GT found that the M100 was limited to operating at motor outputs less than 45 Hz. As the unit was fed via gravity, the flow from gravity could not overcome the 'back-pumping' effect of the rotor. Variability in feed density coming through the overflow pan made feed density dilution challenging to manage.

4.1 Trial Layout

Figures 7 to 9 demonstrate the pipework and sampling arrangement utilised throughout the trial. A line was tapped into the Rod Mill discharge pan, and a knife gate was installed at the bottom of the pan to draw the sample for the M100. The knife gate fed a Saunders valve (with a flushing port on either side of the valve) to control the flow to M100. Water lines were connected to flush the mill, dilute the feed, and help the coarse feed flow to the mill if required. This arrangement is shown in Figure 7.

FIGURE 7: SAMPLE COLLECTION POINT

The connected plant sample feed line was a 2 in rubber line suspended from the hanger bars over 3-4 m to the M100 (Figure 8). Before connecting to the M100, a sample point was installed to measure density and collect feed samples under each of the nominated conditions in the test work matrix (Table 1). Part of the challenge with this arrangement is that the coarse material started to pool, at times lost its laminar flow, and occasionally built up in the line. Without flushing ports, this arrangement would not work. For future trials, a peristaltic pump will supply the mill.

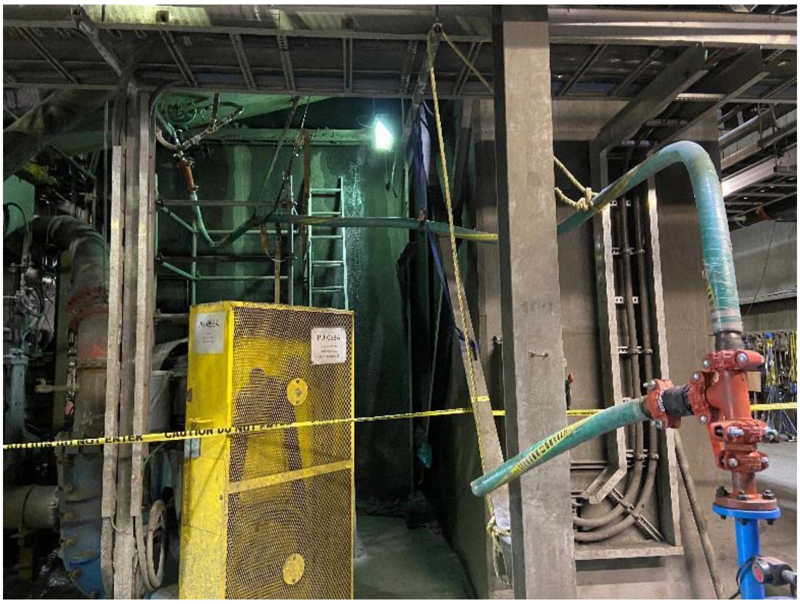

FIGURE 8: FEED ARRANGEMENT TO M100 ISAMILL™

Once the material passed through the mill, the discharge was dropped to the floor directly in front of a spillage sump pump. This was done to limit spillage to the floor and allow for an accessible sample location, as shown in Figure 9.

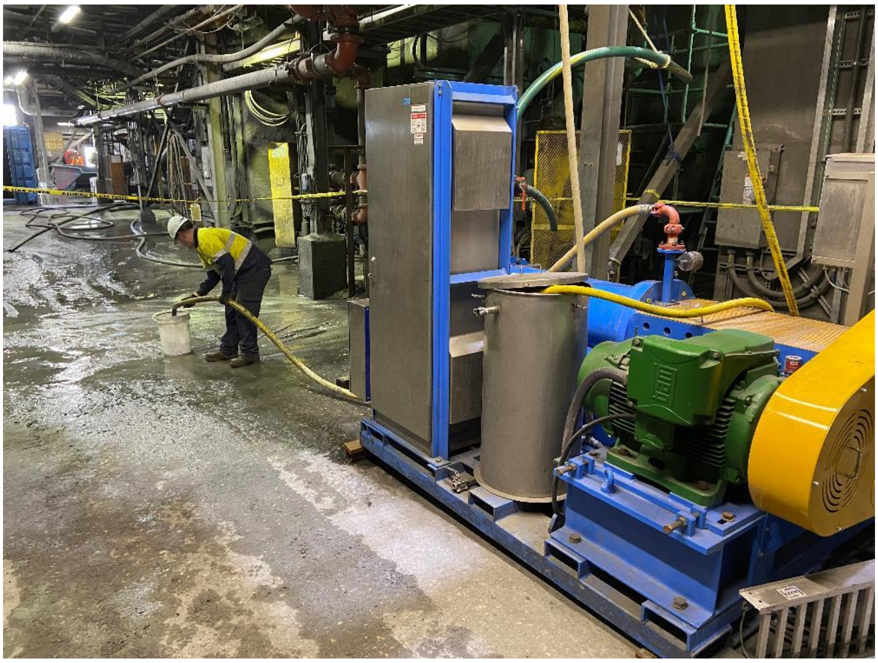

FIGURE 9: MILL DISCHARGE TO SUMP

5.0 M100 COARSE GRINDING TRIAL RESULTS

The first test conducted on the M100 was the 3.8 S.G 8 mm media comparison, as there were initial concerns that the 10 mm media might damage the mill due to the limited gap between the rotor and discharge screen.

There were several learnings associated with the first test conditions. The higher the tip speed at which the mill was operated, the less visually efficient the mill appeared. However, this was not the case. Instead, the rotor was cutting finer (at higher rotation speeds). After getting the setting dialled in and gaining familiarity with operating the mill from the sampling point, a comparison was made to the existing ball mill discharge.

5.1 8 mm Media Trials

Using the 3.8 SG 8 mm media, a sharper size distribution at the same power draw was produced by the M100 compared to the existing ball mill (Figure 10). The sharper size distribution allows a more uniform product. Theoretically, a product with less ultrafines and coarse oversize should produce a better flotation response. As the trial progressed, it was believed that if the discharge of the M100 fed into a flotation cell, an improvement of the size-by-size recovery would have been seen versus the existing ball mill discharge in the plant due to that sharper product from the IsaMill™.

Another area of interest is the variability in the feed F_{80}, which was derived from the sampling location. As more coarse grind test work trials occur, this feed variability will likely be encountered more readily versus a flotation regrind mill. Therefore, future coarse grinding designs will need to accommodate greater flexibility in the feed F_{80}.

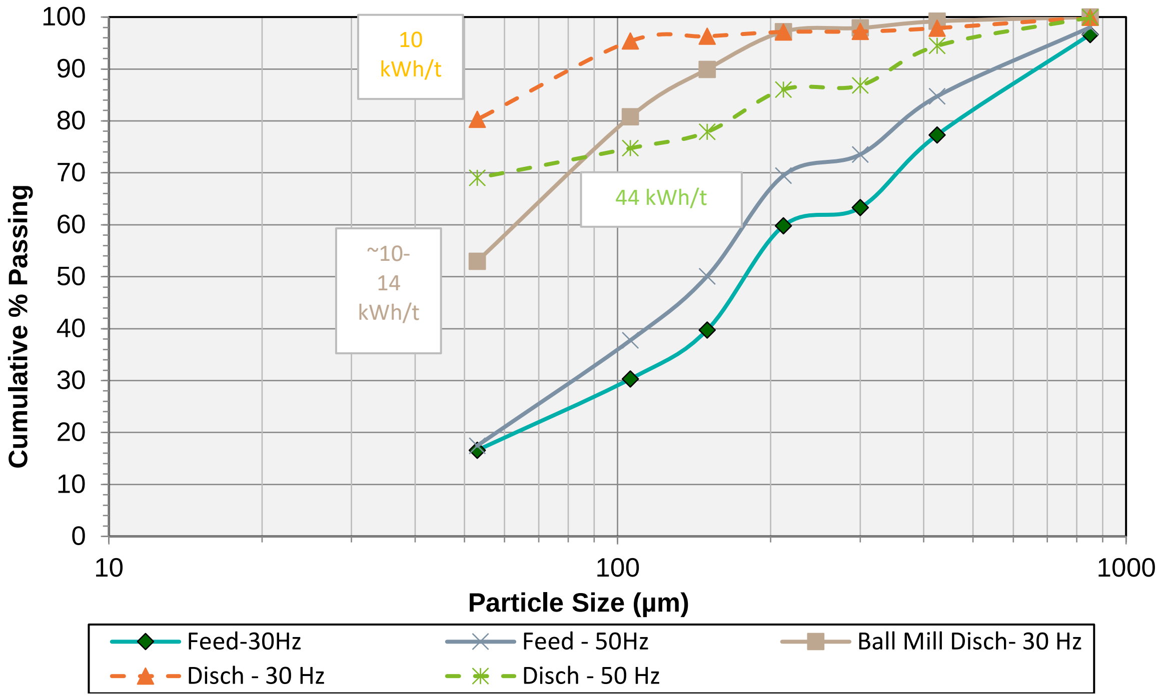

FIGURE 10: .3.8 S.G 8 MM MEDIA COMPARISON

The test using 4.5 SG 8 mm media did not achieve successful results; with evidence of coarse particle build-up within the mill It is hypothesised that the media was too heavy to be fluidised in a slower, coarser grinding application, and these findings were supported by inefficiencies evidenced in previous work using a smaller laboratory scale, IsaMill™ (M4). It is recommended that higher SG charges be removed from future coarser grinding test work trials.

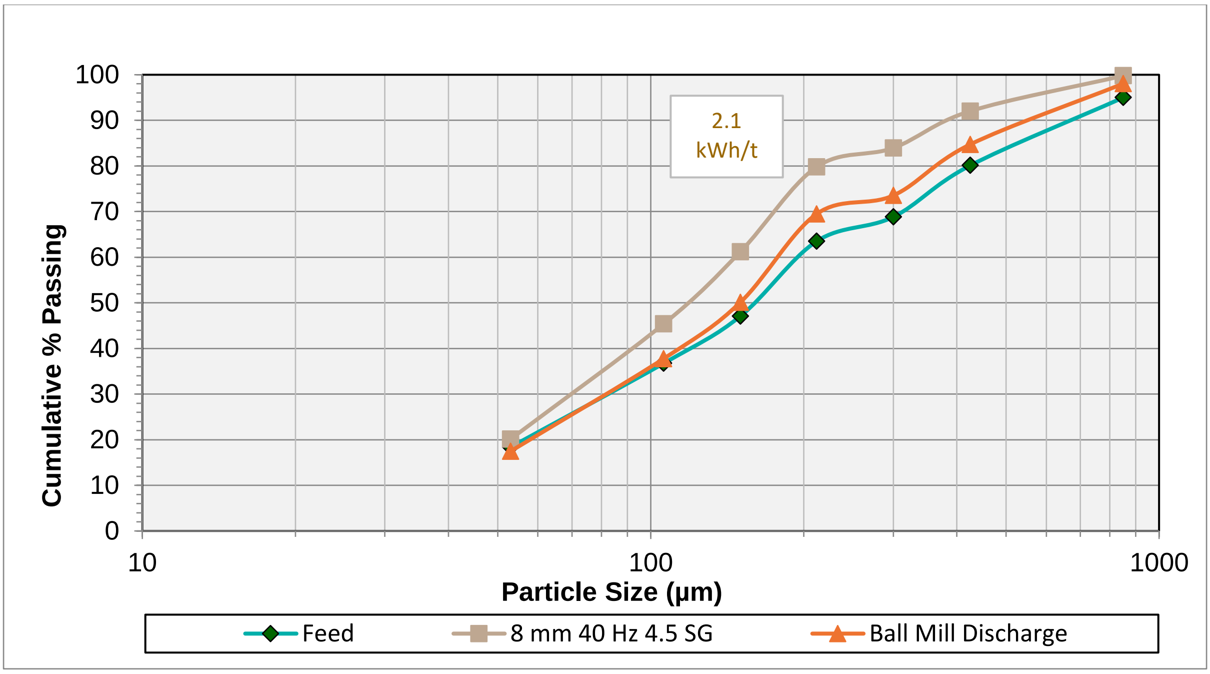

FIGURE 11: 4.5 S.G 8 MM MEDIA COMPARISON

5.2 10 mm Media Trials

The results of the 3.8 SG 10 mm media trials were considered a success. The M100 achieved a PSD comparable to that of the existing ball mill (Figure 12). Additionally, in producing the same particle size distribution approximately 80 % less energy was required.

Mechanical constraints, specifically the gap between the shaft end cap and non-drive end line, limited the amount of 10 mm media that could be charged to the IsaMill™. However, the results still indicate excellent potential for coarser grinding applications. In response to the limitations of the amount of coarse media that can be charged, new discharge screen/rotor concepts are being developed. They must be subsequently trialled to ensure it is not a limitation to developing full-scale operating mills that use coarser media.

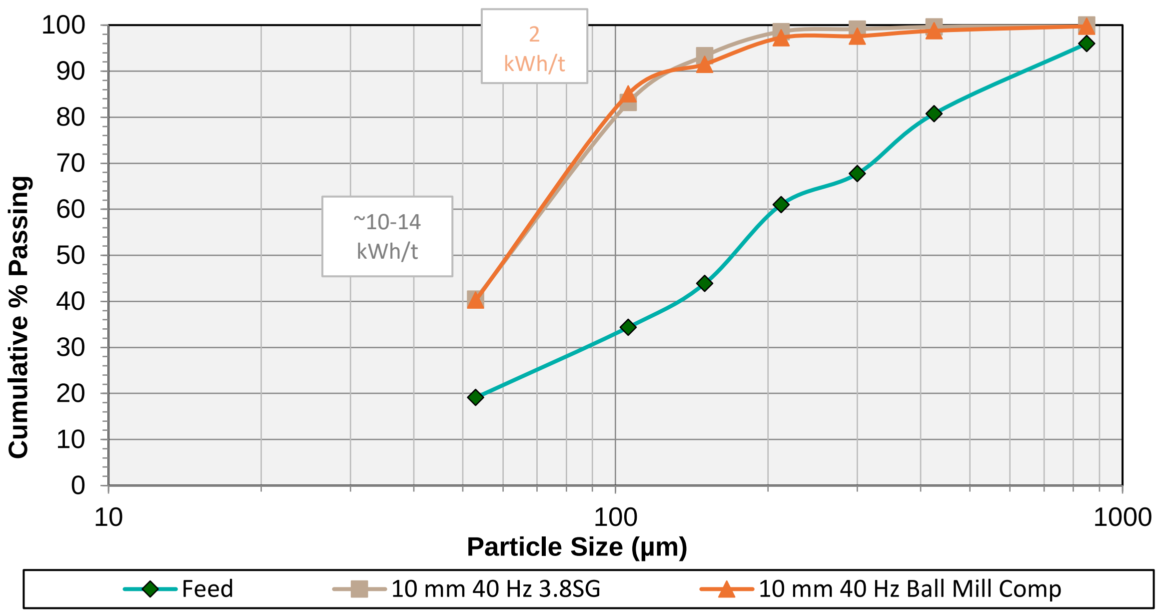

FIGURE 12: 10 MM MEDIA COMPARISON

6.0 CONCLUSION

The proof-of-concept trial identified that the IsaMill™ can operate with coarse media and that a coarse grinding pathway of 2 mm to 3 mm feeds may be achievable with few minor modifications to the mill. The evaluation of the performance of 3.8 SG 8 mm Media, 4.5 SG 8 mm media and 3.8 SG 10 mm media was undertaken, and limitations of the coarser media in the IsaMill™ were understood.

The higher density and more costly 4.5 SG 8 mm media was evaluated; however, it did not work for coarser grinding duty. The 3.8 SG 10 mm media was the most energy efficient for coarser grinding duty, replicating the ball mill particle size distribution with a significantly reduced energy (measured up to 80%). As expected, the IsaMill™ can produce a sharper particle size distribution than a ball mill.

Another coarse grinding trial on a site offering a coarser feed with a P_{80} minimum of 1 mm is recommended.

7.0 ACKNOWLEDGEMENTS

Glencore Technology would like to thank Conor Blayney (Stall Mill - Assistant Manager) for supporting the coarse grinding trial and allowing the test work to occur at the Stall Mill. GT would also like to thank Kings Beads for providing media and technical assistance during the trial.

8.0 REFERENCES

Allen, M.,2022. Mining Energy Consumption 2021 – a high-level study into mining energy use for the key mineral commodities of the future. CEEC International: Coalition for Minerals Efficiency.

Gurnett, I., Martin, C., Stieper, G., 2023. Coarse Grinding on a IsaMill?. Canadian Mineral Processors Conference 2023, Ottawa, Canada.

Gurnett, I., Swann, A., Stieper. G, and Collier, L., 2022. Stirred Milling Design – Incorporating the IsaMill™ into the Jameson Concentrator. IMPC Asia Pacific, Melbourne, Australia.

Tavchandjian, O., 2021. NI 43101 Technical Report Lalor & Snow Lake Manitoba, Canada. Hudbay Minerals Inc.

Larson, M., Anderson, G., Mativenga, M., Stanton, C., 2015. The Arrium IsaMill from design through commissioning and optimisation, MetPlant Conference 2015, Perth, Australia.

Marion, C., Taylor, M., McTaggart, K. Amelunxen, P., 2020. Hudbay Minerals Inc. – Snow Lake Concentrators, in Canadian Milling Practice 2020 Edition, CMP/CIM.