Evaluating the Integration of HydroFloat™ Coarse Particle Flotation in Copper Projects Using an Integrated Process Simulator

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Abstract

HydroFloat Coarse Particle Flotation (CPF) has garnered significant attention in the mining industry due to its potential to improve the profitability and environmental sustainability of mining projects. Despite these advantages, evaluating the integration of CPF into mineral processing circuits remains technically challenging given its interactions with preceding or succeeding flotation circuits, grinding requirements, tailings disposal, and overall plant design. This study investigates the application of Orica's Integrated Extraction Simulator (IES) as a comprehensive tool for simulating and assessing the implementation of CPF in both pre-concentration and tailings scavenging duties within a 100 ktpd porphyry copper processing plant. Through detailed modeling, this study quantifies the effects of CPF on key performance indicators, including net metal production, concentrate grade, energy consumption, and the particle size distribution of final tailings. The results highlight the value of simulation in guiding design decisions and evaluating trade-offs when integrating CPF into large-scale copper operations.

Keywords: HydroFloat, coarse particle flotation, IES, simulation, copper.

1. Introduction

In the context of the global energy transition, the mining and minerals sectors are becoming increasingly reliant upon the modernization of infrastructure and technological development. Among key commodities, copper plays a central role due to its extensive use in renewable energy systems, electric vehicles, and power-transmission networks. Multiple studies forecast a substantial increase in global copper demand over the coming decades. For example, Alejandro Tapia, president of Escondida, recently projected that copper demand will rise by approximately 70% by 2050, which is comparable to the production capacity of twenty operations the size of Escondida. Meeting this demand is expected to require cumulative industry investment of about USD 2.1 trillion over the next 25 years.

Beyond these substantial capital requirements, the copper-mining industry faces escalating technical and operational challenges. Foremost is the global decline in ore grades. According to the Chilean Copper Commission (Cochilco), from 2000 to 2016, the average copper grade at Chile's major operations fell by more than 50%. Consequently, producing the same quantity of contained copper today requires processing more than twice the ore tonnage. The combined effects of declining feed grade and rising demand have driven modern concentrator designs to unprecedented scales, with nominal throughputs frequently exceeding 100 ktpd. Operations at this scale face additional constraints, including water scarcity, tailings management, waste storage, and elevated energy consumption.

To address these challenges, the industry must adopt new policies, operational practices, and innovative processing technologies that enhance both economic performance and environmental sustainability. In recent years, several promising advances have emerged in mineral processing, including preconcentration methods such as bulk ore sorting, novel hydrometallurgical processes capable of extracting copper from low-grade sulfide ores (e.g., Jetti and Nuton), and coarse particle flotation (CPF) technologies such as Eriez HydroFloat™, which enable the efficient recovery of particles two to three times coarser than those recovered by conventional flotation.

HydroFloat Coarse Particle Flotation (CPF) has gained increasing attention in the mining industry and is regarded by several major companies as a proven, mature technology. As a result, there is a rising demand for studies that quantify the metallurgical, operational, and economic impacts of CPF implementation. These developments highlight the need for robust simulation tools to accurately assess CPF integration in both brownfield and greenfield operations.

One such tool is Orica's Integrated Extraction Simulator (IES), a comprehensive process-modeling platform that enables end-to-end evaluation of mining and mineral-processing operations, from pit to tailings disposal. This paper evaluates two case studies using IES to assess the technical and economic performance of implementing CPF circuits.

2. HydroFloat® Coarse Particle Flotation (CPF)

HydroFloat is a fluidized-bed, coarse-particle flotation machine that overcomes the limitations of conventional stirred-tank flotation cells, enabling the flotation of particles two to three times coarser in size (**Figure 1**).

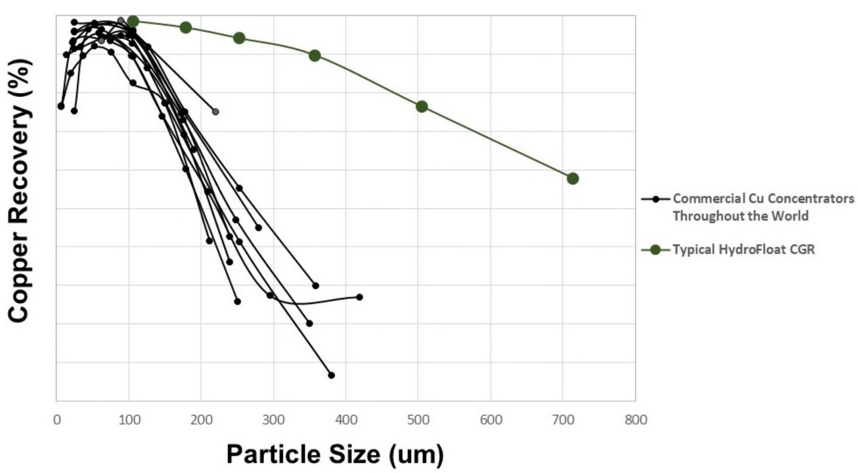

Figure 1. Size-by-size copper recovery for several concentrators versus HydroFloat CPF in a CGR application (d_{80} = 400 μm), showing the extension of flotation efficiency into the coarse size range.

HydroFloat® combines teeter-bed separation and flotation to recover coarse, hydrophobic particles. The HydroFloat fluidized-bed flotation cell is designed with two primary chambers for both separation and dewatering. The upper separation chamber comprises two zones: the freeboard and teeter bed. Feed enters the freeboard and settles against an upward flow of teeter water, which is evenly distributed through a manifold at the base of the teeter bed. This fluidization water creates a stable teeter bed that is continuously aerated through the injection of compressed air, which is dispersed into fine bubbles using a CavTube™ bubble-generation system and a small amount of frother, directly into the water prior to delivery to the cell.

Unlike conventional flotation machines, where separation is primarily governed by the buoyant rise of bubble–particle aggregates, the HydroFloat®'s upward rising fluidization current establishes a hindered-settling environment while providing an additional driving force to transport bubble–particle aggregates to the concentrate launder. In this environment, the teeter bed stabilizes and partially supports bubble–particle aggregates, promoting the selective accumulation of low-density clusters. Once these aggregates reach a critical buoyancy threshold, they then rise through the freeboard and report to the concentrate launder.

This dual mechanism, fluidization-assisted hindered settling combined with bubble–particle flotation, creates a highly selective separation environment that enhances coarse-particle recovery while maintaining high throughput and low entrainment. Meanwhile, hydrophilic or unattached particles move downward through the teeter bed into the dewatering cone, where they are discharged as a high-solids underflow (typically >55% w/w solids) through an underflow control valve. This valve responds to a control signal from a float target mounted at the top of the separation chamber. The HydroFloat system also includes side-mounted pressure transducers that measure the differential pressure across the fluidized bed. These measurements are used to estimate and maintain a consistent effective bed density.

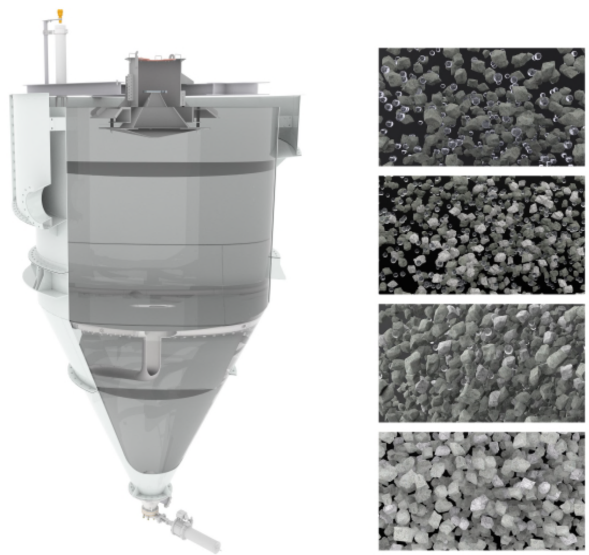

Figure 2. HydroFloat® CPF

2.1 Applications

In the base-metals industry, HydroFloat CPF has been deployed primarily in two applications: Tailings Scavenging (TS) and Coarse Gangue Rejection (CGR).

2.1.1 Coarse Gangue Rejection (CGR) Flowsheet

A generalized configuration of the CGR circuit is shown in **Figure 3**. Although several circuit variations are possible, the fundamental concept is to divert a classified stream from the mill circulating load and process it via HydroFloat™ CPF at a particle size significantly coarser than that treated in conventional flotation. The HydroFloat underflow forms an effectively barren, coarse tailings stream, which is removed from the flowsheet prior to conventional flotation. This early gangue rejection reduces downstream processing loads and improves overall circuit efficiency.

In some operations, early removal of approximately 30–40% of coarse gangue via the HydroFloat™ tailings stream can deliver substantial metallurgical benefits. In particular, rejecting deleterious or complex gangue minerals, such as talc, clays, and other naturally floatable or sliming components, at coarse sizes can markedly improve flotation selectivity, froth stability, and overall recovery in the conventional circuit.

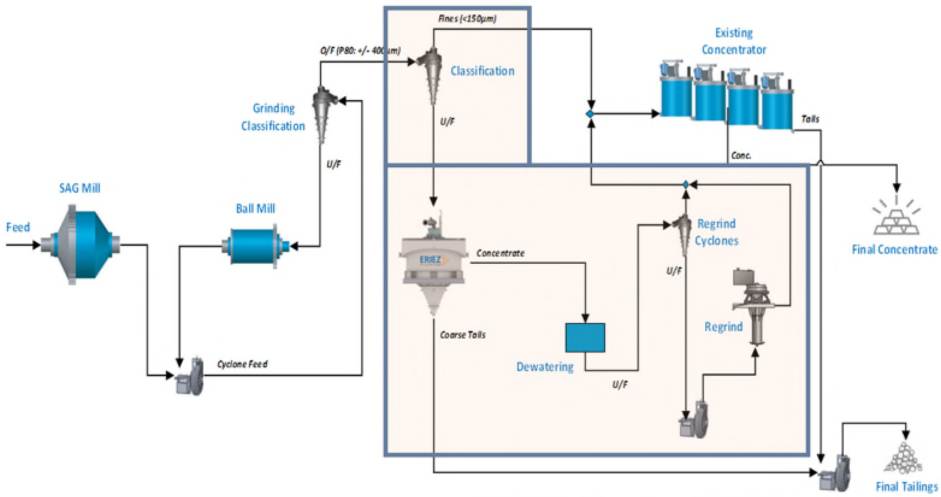

Figure 3. HydroFloat ™ CPF **-** Coarse Gangue Rejection simplified flowsheet.

Evaluation of CPF circuits typically begins with a desktop analysis, followed by successive stages of laboratory and pilot-scale test work (**Figure 4**). At each project stage, it is essential to define the expected outcomes and the potential benefits that CPF can deliver. Although the primary focus is often the metallurgical and operational impact within the concentrator, the analysis should extend across the entire value chain, from mine design through tailings storage facility (TSF) performance. This holistic approach is critical: implementing coarser grinding not only affects concentrator performance and OPEX but also enables more stable, sustainable, and cost-effective TSF configurations.

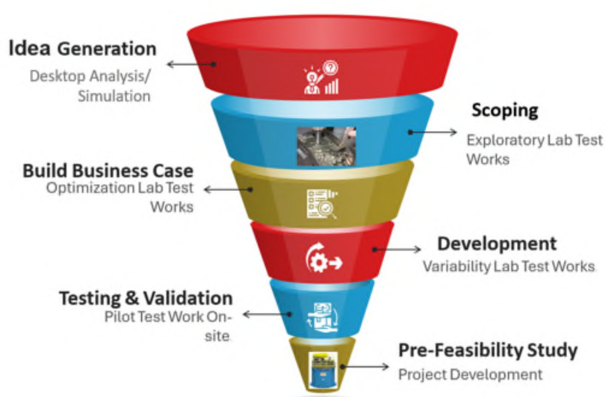

Figure 4. Eriez Roadmap for projects development

Figure 5 summarizes the metallurgical responses of different copper ore types evaluated in the HydroFloat™ CGR configuration. Several studies show that inherent preconcentration can occur in Coarse Gangue Rejection (CGR) circuits as a direct result of the classification stage. After classification, the fine fraction (<150 µm) typically exhibits a copper-grade increase of about 30–50%, depending on the feed grade and the grinding-product P_{80}. For example, in a recent South American copper operation, the fine fraction's grade increased from 0.45% Cu (head grade) to 0.69% Cu (<150 µm) after classification, consistent with trends reported elsewhere. Conversely, the copper grade in the coarse fraction (HydroFloat™ feed) decreased to an average of about 0.30% Cu, reflecting effective mineral separation during classification.

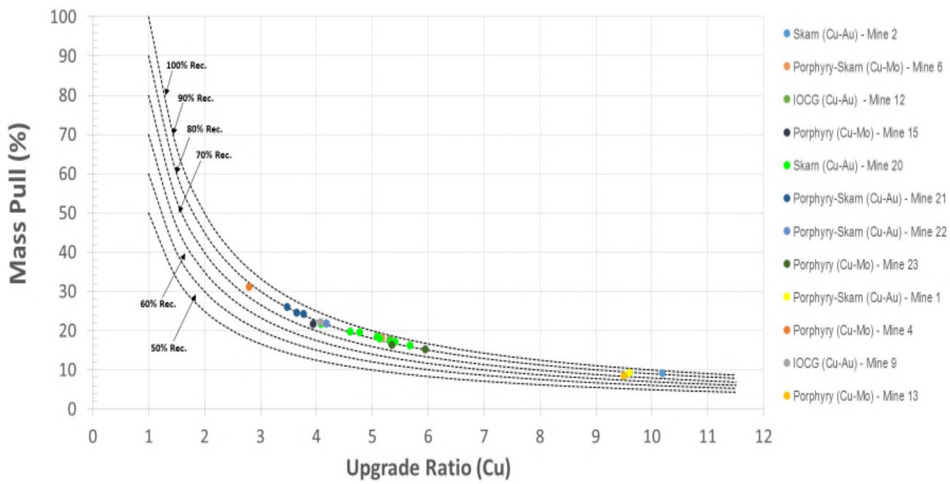

Figure 5. HydroFloat™ CPF performance in coarse gangue rejection (CGR)—copper ores.

The CGR (pre-rougher) application is not new. Early adopters of HydroFloat™ CPF used CGR flowsheets in phosphate and potash industries, where the benefits of fluidized-bed flotation for coarse-particle recovery were first demonstrated. In the base-metals sector, Anglo American pioneered this flowsheet at its El Soldado operation in Chile. At El Soldado, feed to the CPF plant is taken directly from the SAG-mill product, with particle classification achieved via a two-stage cyclone arrangement. The project has delivered substantial operational benefits, including increased net metal production without additional power consumption (Arburo *et al.*, 2022). Furthermore, the coarse and fines ridden tailings generated by the HydroFloat at El Soldado have been used to construct a demonstration plant for Anglo American's patented hydraulic dewatered stacking (HDS) tailings-disposal technology, an approach that exemplifies the integration of CPF with innovative, sustainable tailings-management solutions.

2.1.2 Tailings Scavenging (TS) Flowsheet

The earliest base-metals applications of HydroFloat™ were implemented in Tailings Scavenging (TS) circuits. Cadia Valley Operations pioneered the use of HydroFloat to recover coarse copper and gold particles from rougher tailings. This configuration was considered lower risk and more straightforward to integrate into existing brownfield operations. Beyond improving overall plant recovery via enhanced recovery of coarse copper in the rougher tailings, the TS application also enabled an increase in plant throughput. This improvement is achieved by targeting a coarser primary grind while maintaining efficient recovery of coarse particles in the CPF circuit.

Figure 6 shows a simplified flowsheet for the Tailings Scavenging (TS) application. In this configuration, rougher or final tailings are classified by cyclone, from which the coarse fraction is treated by HydroFloat™. Through close collaboration with mining companies and continued optimization of the HydroFloat design, the classification stage within the CPF plant has been progressively simplified. Currently, most CPF installations employ cyclone classification only.

Recent research, development, and site testing indicate that the CPF flowsheet could be further streamlined. In certain applications, feed preparation can be achieved with a single stage of conventional cyclone classification, thereby reducing capital and operating costs. In TS circuits, the HydroFloat concentrate is typically dewatered and then reground to improve mineral liberation before the cleaning stage, where a final concentrate is produced. The most recent CPF installations have incorporated dedicated cleaning circuits for the CPF concentrate, enabling greater operational flexibility and metallurgical accountability.

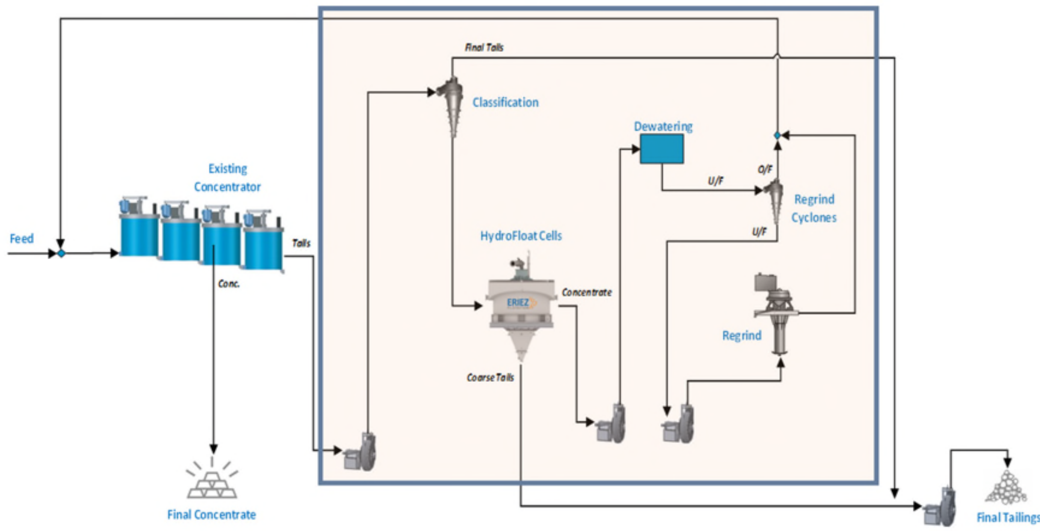

Figure 6. HydroFloat™ CPF—tailings scavenging (TS) simplified flowsheet.

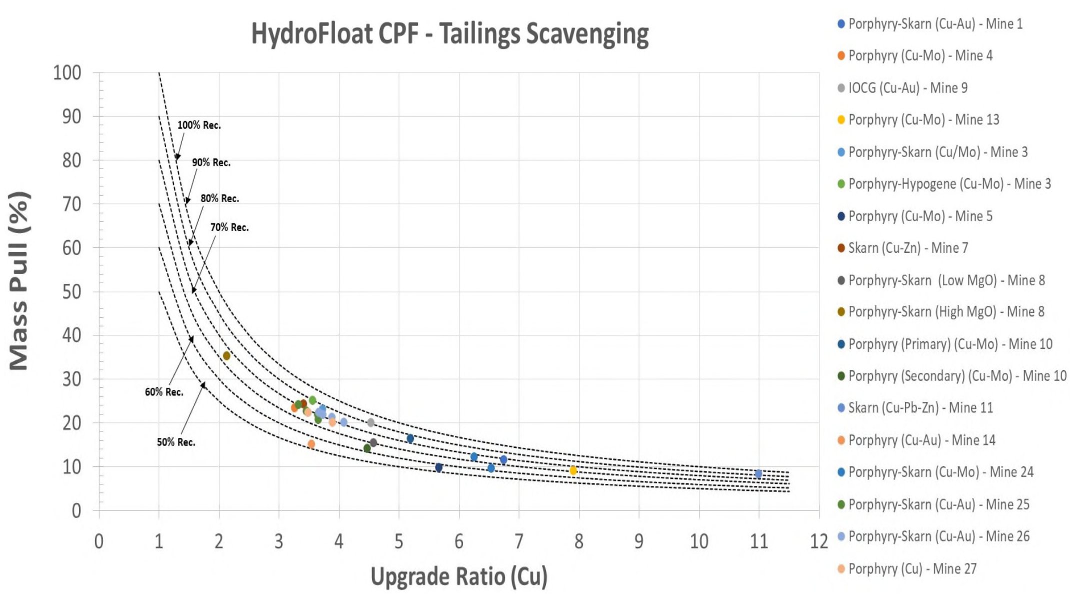

Figure 7. HydroFloat™ CPF performance in tailings scavenging (TS)—copper ores.

3. IES Simulation

The Integrated Extraction Simulator (IES™) is a cloud-based platform for modeling, simulation, and optimization in mineral processing. It enables rapid evaluation of processing scenarios across the value chain and combines physics-based equipment models with neural-network-based models and customized models from third-party sources or vendors. IES supports large datasets, multicomponent modeling, and rapid configuration of alternative flowsheets, enabling large-scale simulation runs.

The origins of IES lie in an industry-sponsored research program led by the Australia-based Cooperative Research Centre for Optimizing Resource Extraction (CRC ORE) (Cooperative Research Australia, 2014). Established in 2010, CRC ORE's government-funded term ended in June 2021, after which a competitive selection process assigned commercialization rights to Orica.

3.1 Flowsheet development

A representative process model for a large-scale porphyry copper operation was developed and simulated using IES. Process data were sourced from the Orica and Eriez databases.

The base-case flowsheet included an SABC comminution circuit—one SAG mill, two ball mills, and one pebble crusher—followed by a conventional flotation circuit. The flotation circuit comprised a rougher stage, regrinding of the rougher concentrate, and a two-stage cleaner circuit with a cleaner-scavenger stage. **Figure 8** illustrates the flowsheet configuration described above (Base Case) as **Figure 9** exemplifies the Flowsheet considering CPF.

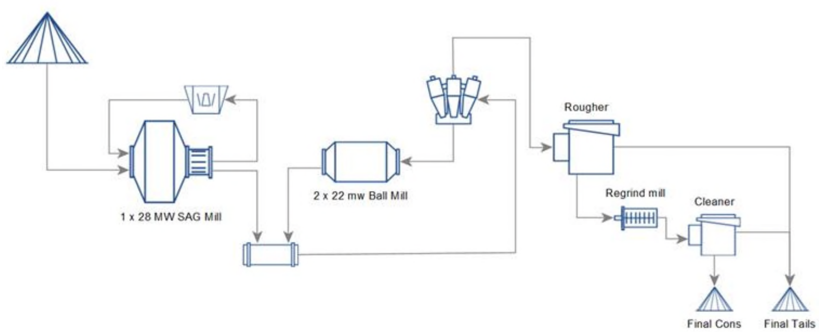

Figure 8. Base case simplified flowsheet simulated in IES

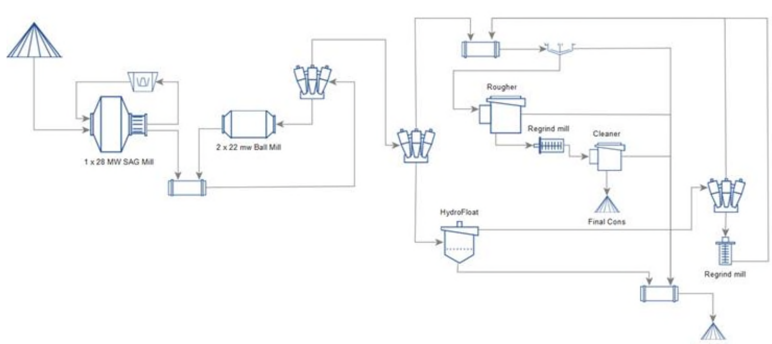

Figure 9. CGR CPF simplified flowsheet simulated in IES

After establishing the base case, two circuit configurations using HydroFloat® Coarse Particle Flotation (CPF) were evaluated:

1. Coarse Gangue Rejection (CGR): Pre-concentration through rejection of coarse gangue within the milling circuit and prior to conventional flotation means.
2. Tailings Scavenging (TS): Recovery of additional valuable material from Tailings.

The simulation used the following inputs:

- Assay-by-size analysis, including valuable elements and primary gangue minerals.
- Baseline plant flowsheet and metallurgical balance.
- Comminution properties.
- Major equipment characteristics and capacities.
- Flotation kinetics data.
- Operational limitations (e.g., mining capacity, comminution energy, water availability, equipment capacity, footprint constraints).
- Copper price (USD/lb).

Key performance indicators (outputs) tracked in each simulation case included:

- Throughput.
- Copper recovery.
- Final concentrate grade.
- Net metal production.
- Energy consumption.
- Tailings particle size distribution (PSD).
- Revenue.

3.1.1 Coarse Gangue Rejection (CGR) Simulation

The initial case examined was the CGR circuit. This configuration effectively demonstrates the primary advantages of CPF; however, for existing operations, this option must consider the footprint and integration with those operations. Conversely, for greenfield projects, the circuit can be designed with all applications in mind from the outset, resulting in a more streamlined and optimized circuit. For this evaluation, a greenfield scenario was considered, with a nominal and fixed plant throughput of 100 ktpd. To align with a conventional flowsheet, a baseline primary grind size (P_{80}) of 200 µm was employed.

To assess the impact of incorporating CPF, overall circuit performance was evaluated with and without the use of CPF for a total of three primary grind sizes, including P_{80} of 200 µm (Base/Case 1), 300 µm (Case 2), and 400 µm (Case 3).The following sections summarize the main simulation findings, highlighting Cases 2 and 3, which were considered the most attractive in terms of net metal production and environmental benefits.

Across all cases, plant throughput was fixed at 100 ktpd. CPF benefits were assessed primarily in terms of optimizing the grinding energy required to reach a size that provides the most favorable balance between capital (CAPEX) and operating (OPEX) expenditures, while maintaining metallurgical recovery and throughput comparable to the base case.

Grinding circuit

For the CGR case, three calculations were performed for the specific energy of the SAG, ball, and regrind mills: (I) the Morrell/Bond method (Morrell, 2008) for SAG-mill specific energy; (II) the Bond method for ball-mill specific energy (Bond, 1961); and (III) the jar-mill method for regrind specific energy, using jar-mill reference data and an efficiency factor to estimate Vertimill specific energy. The details of SAG, ball, and regrind milling are summarized in Table 1, 2, and 3, respectively.

Table 1. IES scenarios simulated – SAG mill

Case	Grind Size (μm)	Axb	SAG Mill SE (kWh/t)	SAG Mill Motor (kW)	SAG Mill Diameter (ft)	SAG Mill Length (ft)
Base/Case 1	200	34	5.42	27,285	40	26
Case 2	300	34	5.24	26,358	40	26
Case 3	400	34	4.96	24,960	40	25

Table 2. IES scenarios simulated – ball mill

Case	Grind Size (μm)	Bwi (kWh/t)	Ball Mill SE (kWh/t)	Ball Mill Motor Power (kW)	Ball Mill Diameter (ft)	Ball Mill Length (ft)	Number of Mills
Base/Case 1	200	14.6	8.64	43,454	28	42	2
Case 2	300	14.6	7.05	35,477	26	42	2
Case 3	400	14.6	6.20	31,200	26	38	2

Table 3. IES scenarios simulated – regrinding mill

Case	Grind Size (μm)	Regrind Mill Tonnage (t/h)	Regrind Mill F80 (μm)	Regrind Mill P80 (μm)	Jar Mill SE (kWh/t)	Regrind Mill SE (VTM) (kWh/t)	Regrind Mill Power (kW)	Regrind Mill Model	Number of Mills
Case 1	200	190	384	75	7.6	5.32	1011	VTM 1500	1
Case 2	300	280	440	75	8.7	6.09	1705	VTM 1000	2
Case 3	400	321	518	75	9.7	6.79	2180	VTM 3000	1

Figure 10 shows the simulated relationship between grind size (P_{80}) and total specific grinding energy for copper production, comparing the base case with and without HydroFloat® CPF. In both scenarios, energy consumption decreased as P_{80} increased, consistent with the expected reduction in comminution intensity. This trend aligns with process-design principles and has been reported in previous studies (Arburo *et al.*, 2020; Pyle *et al.*, 2021).

As summarized in **Table 1** and **Table 2**, the primary grinding circuit (SAG and ball mills) showed a reduction in specific energy across all CPF cases. The magnitude of this reduction increased at coarser target grind sizes, reflecting lower ore-breakage requirements when coarse gangue is rejected early in the circuit. In contrast, the regrinding circuit showed a moderate increase in energy use in the CPF scenarios, attributable to the higher mass flow reporting to this stage from the HydroFloat concentrate.

Overall, total specific grinding energy per unit ton of copper concentrate decreased by 2.9%, 11.6%, and 15.1% at P_{80} = 200 μm, 300 μm, and 400 μm, respectively, when a CPF circuit was incorporated. These results reinforce the potential of CPF integration to deliver substantial energy savings at coarser grind sizes, maintaining or even improving the global metallurgical recovery. Moreover, the simulations indicate that operating at coarser grinds (Cases 2 and 3) could reduce the required installed mill capacity (see **Table 1** and **Table 2**), offering additional CAPEX and OPEX advantages.

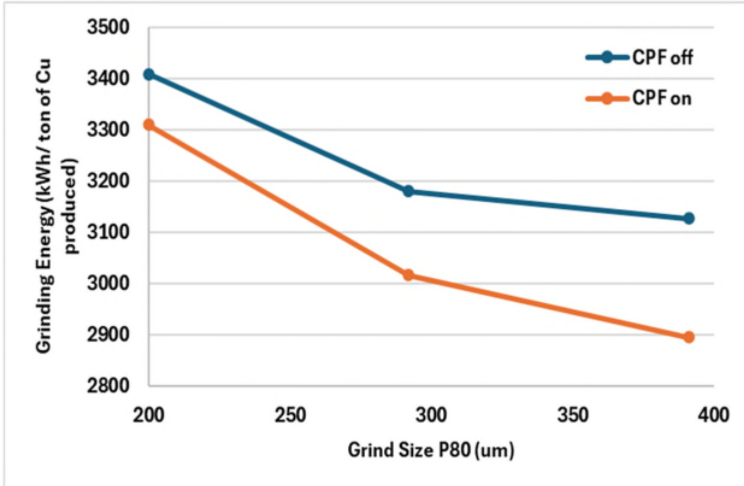

Figure 10. Specific grinding energy versus grind size (P_{80}) to produce one ton of copper, with and without HydroFloat™ CPF.

Flotation circuit

In the base case, the rougher stage was modeled with a size-by-size grade/recovery model using conventional cells, with a flotation feed P_{80} = 200 µm and copper grade of 0.45%, yielding 91.3% copper recovery and a 6.32% Cu rougher concentrate grade. The cleaner stage was also modeled using size-by-size grades and recoveries, as classification cyclone performance was represented with an efficiency-curve model.

This calibrated rougher/cleaner model was applied to both CPF applications (CGR and TS). For the CGR circuit application, the cyclone efficiency-curve model was recalibrated using Weir Cavex DE data. For the TS application, the cyclone overflow (O/F) cut was set to 100 µm. The regrind mill was represented with a size-reduction model. It is worth noting that IES enables integrated evaluation of comminution and flotation circuits within a single flowsheet canvas.

Figure 11 illustrates the simulated relationship between grind size (P_{80}) and overall copper recovery for both the base case (CPF OFF) and HydroFloat® CPF in a CGR configuration. At the base case P80 (200µm), the introduction of the CPF in the process improved recovery by 3.7 percentage points while also reducing specific power consumption, indicating the significant potential of CPF in enhancing production and lowering specific power usage. As grinding sizes coarsened, there was a reduction in recovery due to liberation; however, with CPF, overall recoveries remained higher compared to scenarios without CPF in the circuit and at finer grind sizes.

At a grind size of P_{80} = 200 µm, the copper recovery in the simulated conventional flowsheet plant was approximately 91%, compared to 95% when using CPF. When the grind size increased to P_{80} = 400 µm, copper recovery in the conventional circuit declined to about 83%, while the CPF-enabled circuit maintained a recovery of approximately 92%. These findings suggest that HydroFloat integration can enhance recovery and reduce energy consumption, which in turn reduces CO_2 emissions. Moreover, when grinding size increases, HydroFloat can mitigate the recovery losses typically linked to coarser grinding and may even boost overall concentrate production in existing operations, once increasing the grinding size can alleviate limitations in the grinding circuit, enabling higher throughput. Subsequently, it is necessary to examine the downstream circuit for any bottlenecks that may be addressed by adding extraction capacity, for example, in the flotation process. This trend aligns with prior studies on coarse particle flotation in porphyry copper systems (Arburo *et al.*, 2020; Pyle *et al.*, 2021), which similarly reported enhanced recovery at coarser grind sizes due to improved coarse-particle collection efficiency.

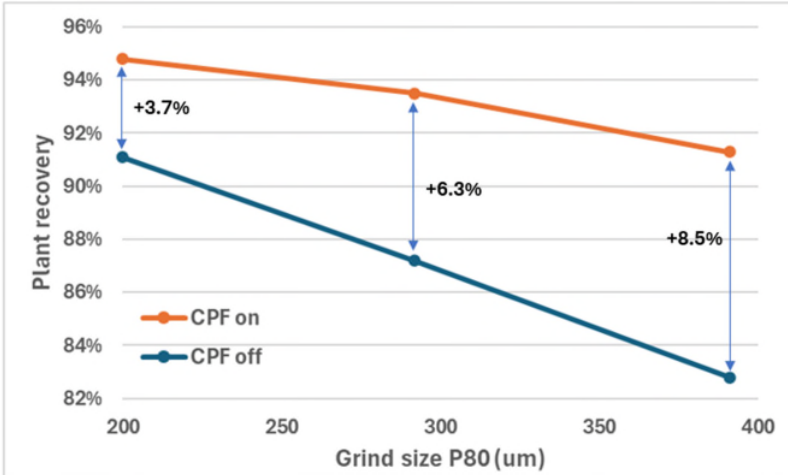

Figure 11. Overall copper recovery versus grind size (P_{80}), with and without HydroFloat™ CPF.

Net Metal Production

Figure 12 summarizes simulated copper-production rates across grind sizes (P_{80}) for a conventional circuit (CPF off) versus HydroFloat® CPF in a CGR configuration. The inclusion of CPF in the process enhanced overall copper production across all evaluated grind sizes. As noted, while increasing the grind size typically results in reduced recovery, the presence of CPF in the process led to higher production when compared to scenarios where CPF was not utilized within the circuit. For instance, at P_{80} = 200 µm, copper production with CPF was approximately 19.9 t/h, compared with 19.1 t/h for the base case. The gap widened at coarser grinds. For example, at P_{80} = 400 µm, CPF-enabled production remained near 19.2 t/h, whereas production declined to nearly 17.4 t/h in the absence of CPF. These results illustrate HydroFloat CPF's ability to sustain metal recovery under coarser-grinding conditions, offering potential operational and economic advantages.

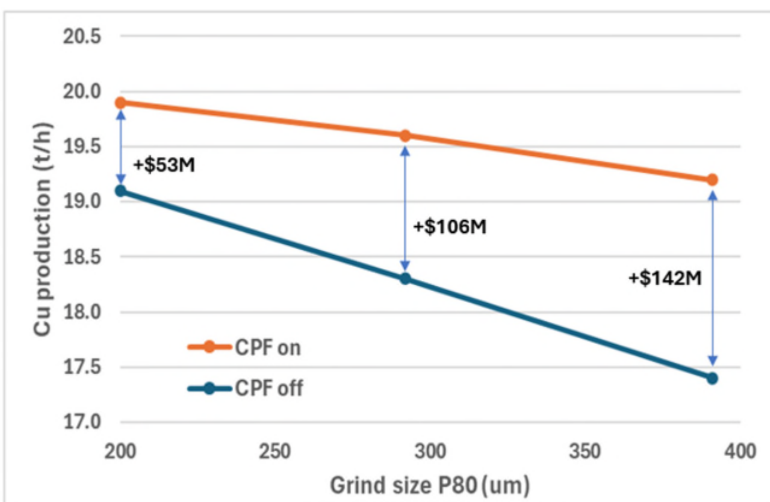

Figure 12. Net metal production and revenue versus grind size (P_{80}), with and without HydroFloat™ CPF.

An approximate estimate of additional revenue from incorporating HydroFloat® CPF in a CGR configuration at increasing primary grind sizes was calculated from the associated copper recoveries and incremental copper production (see **Figure 12**). The analysis was performed at a copper price of ~USD 7,900 per ton. Considering the copper price as of October 27, 2025, the estimated revenues are expected to increase by ~35%, further differentiating the economics of conventional and CGR circuit configurations at increasing grind sizes.

Tailings Management

As expected, coarsening the grinding product increases the proportion of coarse tailings, which in most cases improves water recovery and overall tailings management. A notable aspect is the characteristics of the HydroFloat™ tailings, as shown in **Figure 13**. The HydroFloat tailings exhibit a steeper particle-size distribution (PSD) curve, with almost no material below 75 µm. This yields tailings with excellent hydraulic conductivity that can enhance the performance of novel disposal technologies such as Anglo American's patented hydraulic dewatered stacking (HDS) process.

Use of Coarse Particle Flotation (CPF) generates a larger volume of coarse material (sands), which are particularly beneficial in early project stages of tailings-dam construction. In the case studied, the fraction coarser than 74 µm increased from 46% in the base case to 60% with CPF ON at a grinding product size of P_{80} = 400 µm.

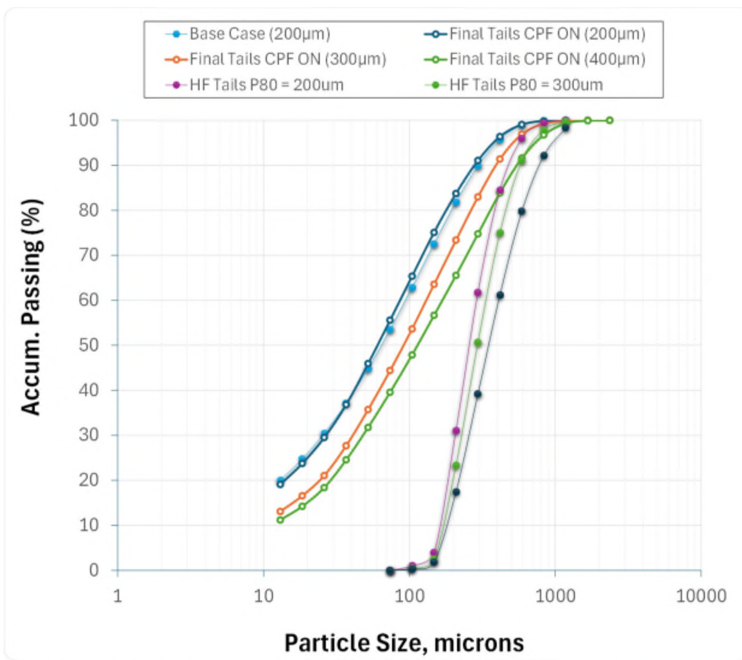

Figure 13. Particle-size distribution (PSD) of final tailings for all evaluated cases, including HydroFloat™ tailings.

Table 4. Tailings characteristics of the different scenarios simulated

Case	Grind Size (μm)	CPF	HydroFloat Tailings P80 (μm)	Final Tailings >74 μm (%)	Final Tailings P80 (μm)
Baseline	200	OFF	N/A	46	196
Case 1	200	ON	393	44	180
Case 2	300	ON	468	55	266
Case 3	400	ON	594	60	361

3.1.2 Tailings Scavenger (TS) Simulations

The tailings-scavenging configuration has been the preferred application of HydroFloat™ in base-metals operations. Several studies (Vollert *et al.* 2019; Haines *et. al.*, 2024) show that the most significant benefit of Coarse Particle Flotation (CPF) is its ability to enable coarser grinding, which, in turn, increases plant throughput while maintaining, or even improving, metallurgical recovery.

For the simulation study, an operating plant was used as the reference case. Under this scenario, operational constraints were incorporated into both the grinding and flotation circuits. In the base comminution circuit, the evaluated plant throughput was 4,680 t/h. Three CPF-integration cases were analyzed:

- **Base case:** P_{80} = 200 µm; feed grade 0.45% Cu. No HydroFloat employed.
- **Case 1:** Base-case grinding product (P_{80} = 200 µm) without increasing throughput, but with HydroFloat CPF; CPF benefit is additional metallurgical recovery.
- **Case 2:** Primary grind coarsened to P_{80} = 250 µm; CPF enables higher throughput and improved recovery.
- **Case 3:** Primary grind coarsened to P_{80} = 300 µm; as in Case 2, CPF delivers higher throughput and improved recovery.

As shown in **Table 5**, plant throughput increased with coarser grind size up to a point, beyond which the semi-autogenous (SAG) mill became the limiting factor. As such, further increases in grind size did not raise throughput.

Table 5. IES scenarios simulated – SAG/Ball mill circuit in TS application

Case	Axb	Wi (kWh/t)	Throughput (t/h)	Grind Size (um)	BM CL %	Total Grinding Power (kW)	Total Grinding Specific Energy (kWh/t)	Constraint
Base/Case 1	34	14.6	4680	200	293	57627	12.13	Ball Mill
Case 2	34	14.6	5280	250	281	58059	10.81	Ball Mill
Case 3	34	14.6	5340	300	247	58098	10.69	SAG Mill

Figure 14 shows that the CPF process can compensate for the loss in metallurgical recovery associated with coarsening the grinding product. While a 3.1% copper recovery improvement was simulated at the baseline primary grind size through incorporation of CPF, global copper recoveries also improved by nearly 1-2% while coarsening the primary grind size from 200 to 300 µm. **Figure 15** presents the corresponding impact on metal production and revenue resulting from coarser grinding, increased plant throughput, and CPF integration. As discussed above, coarser grinding and higher throughput positively affected both the project's economic performance and its environmental KPIs. For example, in this case, CO_2 emissions were simulated

to decrease by greater than 10% because of reduced milling energy consumption per unit ton of copper concentrate.

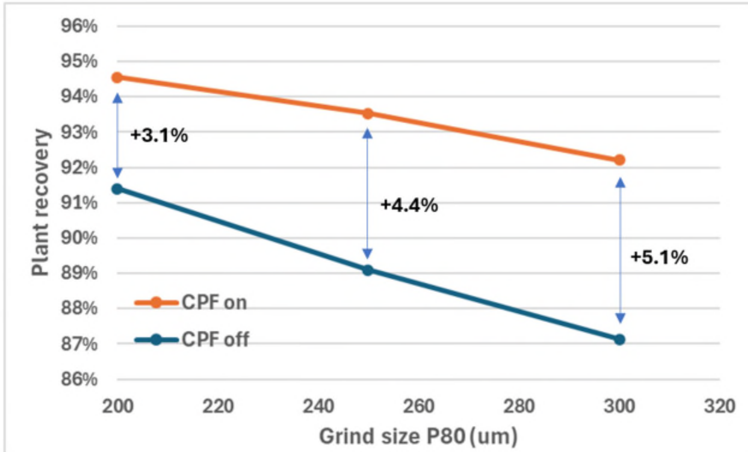

Figure 14. Net metal production and revenue versus grind size (P_{80}), with and without HydroFloat™ CPF.

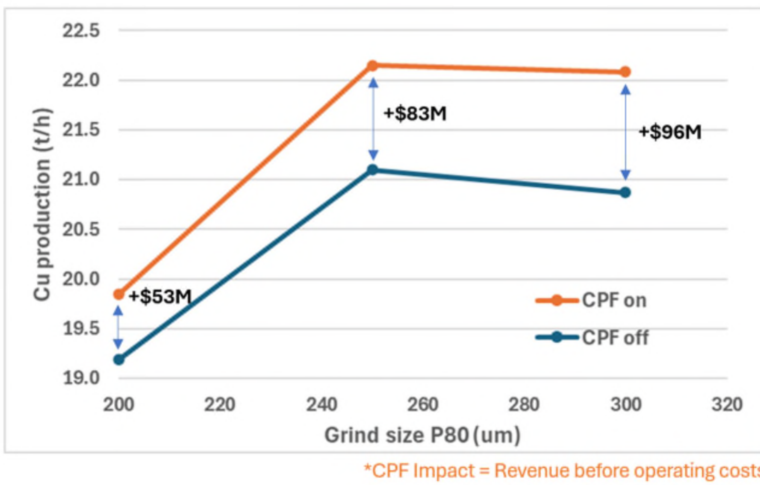

Figure 15. Net metal production and revenue versus grind size (P_{80}), with and without HydroFloat™ CPF.

4. Conclusions

HydroFloat® utilizes a combination of teeter-bed separation and flotation to recover coarse, hydrophobic particles. By introducing air bubbles into the fluidized bed, the HydroFloat merges the attributes of hydro classifiers with flotation. These features, coupled with the absence of a traditional froth phase, establish an optimal environment for the recovery of coarse particles.

Using Orica's IES software, implementation of HydroFloat CPF was simulated within both greenfield Coarse Gangue Rejection (CGR) and brownfield Tailings Scavenging (TS) copper porphyry applications. In both scenarios, the performance of baseline conventional flowsheets, without use of CPF, was evaluated to demonstrate improvements in throughput, copper recovery, and net metal production, as well as reductions in grinding energy consumption, through use of HydroFloat CPF.

The integration of a Coarse Gangue Rejection (CGR) circuit within a greenfield application enhanced overall copper production across all assessed grind sizes. Although an increase in grind size typically reduces recovery, the inclusion of Coarse Particle Flotation (CPF) in the process flowsheet consistently increased production levels compared to the baseline scenario at a finer grind size and without CPF. Additionally, there was a notable reduction in total specific grinding energy, amounting to approximately 15.1% at a P_{80} of 400 µm, in contrast to the conventional flowsheet primary grind size of 200 µm. These findings suggest that the incorporation of a Coarse Particle Flotation (CPF) circuit can facilitate considerable energy savings at coarser grind sizes, alongside production increases. Furthermore, simulations revealed that operating at coarser grind sizes (P80=300 µm and 400 µm) may lower the necessary installed mill capacity, thereby providing additional advantages in terms of capital expenditure (CAPEX) and operational expenditure (OPEX).

The coarsening of the grinding product resulted in an increased proportion of coarse tailings. The HydroFloat tailings demonstrated a coarser particle-size distribution (PSD), with a minimal presence of material finer than 75 µm. Such tailings possess favorable hydraulic conductivity and can improve the efficacy of innovative disposal technologies, such as Anglo American's patented hydraulic dewatered stacking (HDS) process.

By comparison, Tailings Scavenger (TS) simulations utilizing HydroFloat within a brownfield application demonstrated an increase in the overall plant copper recovery of up to 3.1 percentage points. However, more intriguing was the improvement in net metal production and reduction in grinding energy consumption per unit ton of copper concentrate upon increasing the primary grind size from 200 to 300 µm. Although the SAG mill was proven to constrain the maximum achievable throughput in this brownfield application, increases in throughput of more than 10%, in addition to coarse copper recovery gains, netted improvements in annual copper production revenue of up to $US 230M.

5. References

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