Improving Metallurgical Performance & Operational Reliability at the Zhairem Pb/Zn Flotation Circuit

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Extended Abstract

1. Introduction

The Zhairem Mining and Concentrating Complex ("Zhairem") is located in the Karaganda region, north of Almaty in Kazakhstan. Historically, the ore deposit was valued for its ferromanganese and barite-polymetallic deposits of the Atasuisky ore district. The area has a long history of development that is closely linked with the extraction and processing of ferromanganese and barite ores. Kazzinc LLP, majority owned by Glencore, purchased Zhairem in 2014. In 2017, construction commenced of a new 5 Mtpa lead and zinc concentrator, which was successfully completed in early 2020. Subsequently, Zhairem embarked on a sustained effort to commission and ramp-up the plant. The ramp-up efforts were impacted by several challenges, including delayed operation of the dense medium separation circuit (DMS) and capacity limitations within the flotation circuit. In 2022, Glencore/Kazzinc entered a collaborative effort with Hatch, embarking on a joint initiative to address critical process bottlenecks and operational reliability issues, to achieve the designated 5 Mtpa design capacity and produce on-spec Pb and Zn concentrates.

This paper details the challenges impacting the flotation circuit with respect to managing changing oxide and sulphide ore feed blends, insufficient residence time and froth tenacity issues. The metallurgical and reliability improvements implemented to address these challenges are outlined. The installation of six new pneumatic (Jameson) cells in Cleaner-Scalper and Cleaner duties throughout the circuit and the pathway of assessment from concept, laboratory/pilot testwork and modelling through to design and commissioning.

2. Concentrator Flowsheet & Flotation Circuit Challenges

The Zhairem concentrator has a nameplate capacity of 5.0 Mtpa, incorporating 3-stage crushing, dense medium separation, two-stage ball milling and sequential Pb-Zn flotation. The original concentrator was designed with consideration for the variation in metallurgical performance across seven composite samples consisting of both oxide and sulphide ore zones, further characterised by high and low barite content.

An overall block flow diagram of the concentrator is shown in Figure 1.

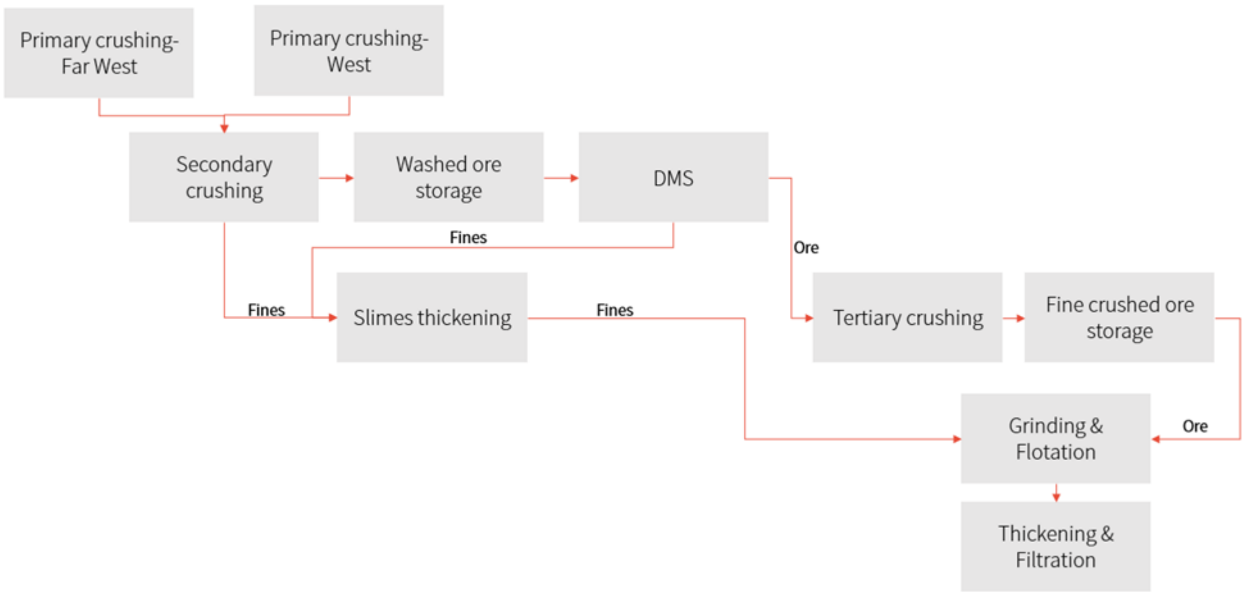

Figure 1: Zhairem polymetallic concentrator block flow diagram

The grinding and flotation circuit as built, consists of the following areas, shown by the process schematic in Figure 2:

- **Grinding:** 8.4 MW primary ball mill, in closed circuit with 500 mm cyclones producing O/F with 60% passing 71µm (P80 = 130µm) and a 6.3 MW secondary ball mill, in closed circuit with 380 mm cyclones, producing O/F with 90% passing 71µm (P80 = 50µm).
- **Pb flotation circuit** : consisting of an intermediate bank processing primary grinding circuit product, followed by two lines of 38m^3 Rougher-Scavenger banks fed by secondary cyclone O/F. Pb rougher concentrate is sent to a three-stage cleaner circuit, which operates in a counter-current configuration. Pb final concentrate typically varies from 35 to 50% Pb, depending on the feed ore blend.
- **Zn-Py flotation**: consisting of two lines of 38 m^3 forced-air mechanical Rougher-Scavenger banks. Zn-Py tailings with a high pyrite content are discharged as final tailings, whilst concentrate is sent for fine grinding.
- **Zn Regrind & Zn flotation circuit**: consisting of four open circuit vertical stirred ceramic media mills, to achieve a product size P80 of 20 µm. Reground material is processed in a Zn Rougher-Scavenger line of 14 38 m^3 cells. Rougher concentrate is upgraded in 3 stages of sequential cleaning at high pH (12) using Usolmash self-aspirated mechanical cells to produce a final Zn concentrate typically ranging from 50% to 55% Zn.
- **Slimes Circuit**: A standalone rougher and cleaner circuit is installed to process the fines produced during crushing and DMS feed preparation. This stream has a high fines content and clays with poor floatability. Final slimes concentrate is ideally sent to final concentrate but often recirculated to the Zn-Py rougher due to unsuitable Zn grade and impurity levels.
- **Tailings Storage:** Final circuit tailings consist of the combined Slimes circuit scavenger bank tailings and Zn-Py scavenger tailings. These are combined and pumped to the TSF via a series of positive displacement pumps.

- **Concentrate Handling:** Final Pb and Zn concentrates are thickened separately by a two-stage thickening process, before being filtered in 4 vertical plate and fame filter presses. Filter cake is bagged for trucking or rail transport to Kazzinc in-country smelters and third-party smelters.

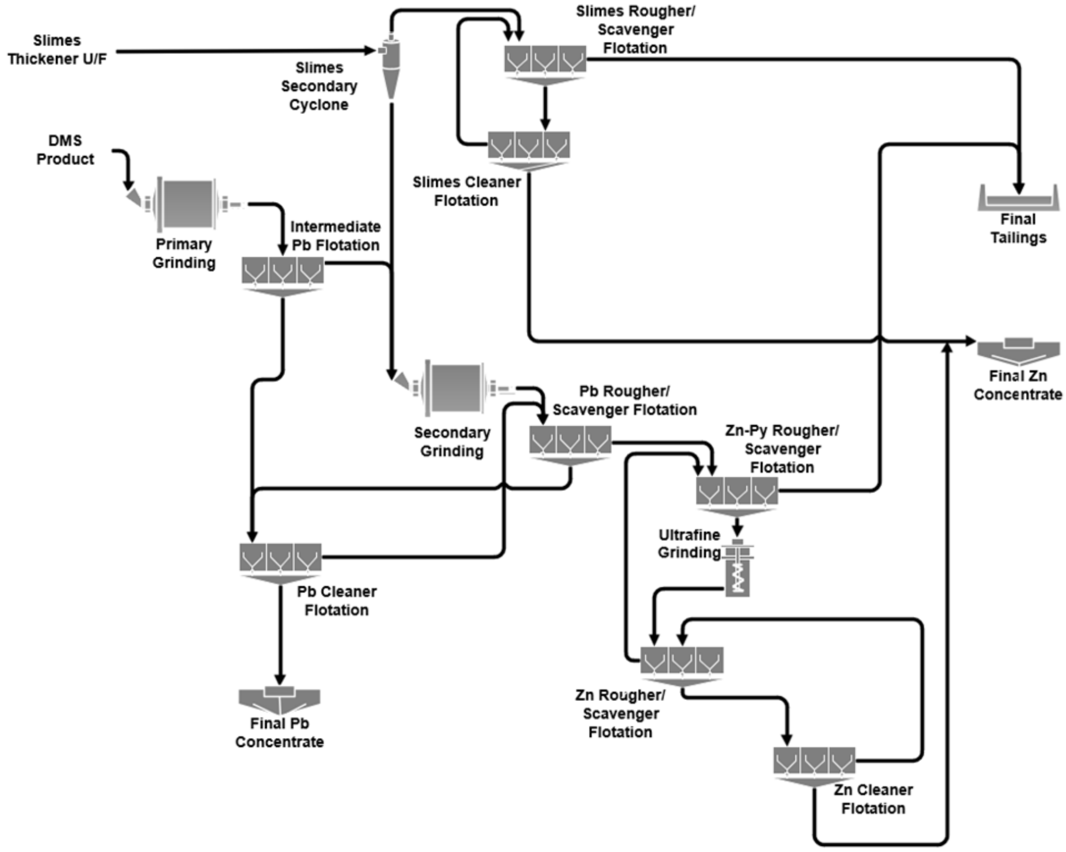

Figure 2: Grinding and flotation circuit process schematic

Since commissioning, the grinding and flotation circuit had been unable to consistently achieve the design throughput and metallurgical performance specified in original process design criteria, due to a range of factors both within the flotation circuit and due to upstream crushing and DMS circuit limitations. Table 1 provides a comparison of the baseline plant performance – captured as part of the diagnostic assessment completed by Hatch at the commencement of the project, against design targets

Table 1: Key flotation circuit performance criteria and project baseline

Parameter	Design		Baseline
	Oxide Ore Blend	Sulphide Ore Blend	
Throughput, t/h	465	430	366
Pb Concentrate Grade, % Pb	36	54.6	33
Pb Rec. to Pb Conc, %	60	85	34
Zn Conc Grade, % Zn	52	55	49
Zn Rec. to Zn Conc, %	78	86.7	52

As part of that 3-month diagnostic assessment, Hatch specialists completed a plant runtime assessment and a gap analysis of the plant design, reviewed operations and maintenance routines, and evaluated operator capabilities and staffing adequacy. This assessment highlighted the focus areas for improvement:

Capacity Constraints:

1. Insufficient Zn rougher/scavenger and cleaner capacity, operating at high feed percent solids.
2. Pb cleaner cells lacked residence time and selectivity.
3. Highly viscous and immobile froths resulting in spillages and overloading in Cleaners.

Ore Blend Variability: oxide ores blends reduced Pb recovery and concentrate grade; ore blends changed quickly e.g. weekly.

Operational Strategy Misalignment: Inconsistent KPIs and control strategies between shifts.

Following the diagnostic assessment, a flotation circuit model was developed in collaboration with Glencore – XPS to investigate the identified capacity constraints. Laboratory flotation tests were performed to establish Pb & Zn flotation kinetics, as inputs to the XPS HSC Sim model, calibrated with plant and shift production data for sulphide ore. Due to the complexity of the flotation circuit and lack of flow and density meters within the circuit as well as intermediate OSA (Courier) sampling points, model development was heavily guided by spot samples and shift data.

3. Improvement Initiatives

Considering the above circuit challenges, the site identified several initiatives to expand Zn circuit capacity with additional mechanical cells as follows:

1. Addition of Tufekcioglu 38 m^3 forced air flotation cells to the Zn-Py Rougher and Scavenger banks

3. Addition of 10x 50m^3 forced air flotation cells as an additional Zn Scavenger bank in series

4. Addition of 2x Zn Rougher and 2x Zn Scavenger, 38m^3 cells to the existing Zn Rougher & Scavenger banks (space was provided in the original plant layout but the cells were not installed at the time).

3. Slime Cleaner 2 & 3 stages consisting of 2x and 1x 5m^3 tank cells respectively, to improve slime concentrate grade and impurity rejection.

The mechanical cell expansions identified above were incorporated into the flotation circuit model which indicated that, although beneficial, the full value of these upgrades could not be realised, due to the continued recirculating loads from closed circuits and high solids loading in the Zn cleaner circuit.

Pneumatic flotation cells were proposed to be installed in six locations throughout the circuit to improve cleaner circuit capacity. These locations & the selected Jameson Cell models are shown in Table 2. Jameson Cells were selected for this duty due to the generation of small bubble size for improved fines recovery, along with froth washing of concentrate to reduce entrainment. (Huynh, Araya, Seaman, Harbort, & Munro, 2014) Although there are several flotation cell technologies that offer similar advantages (Pyle, Tabosa, Vianna, Sinclair, & Valery, 2022), Jameson Cells were selected based on their proven performance in Pb/Zn applications, including at Glencore's own McArthur River operation, amongst others (e.g. Red Dog, Stall, Dugald River). This was coupled with a robust scale-up methodology allowing the Kazzinc operations team to examine cell performance at lab and pilot scale prior to committing to the full installation.

Table 2: Jameson Cell duty, model and objective

Circuit	Location	Cell Model	Objective
Pb	Cleaner-Scalper	E2532/6	Relieve Pb Cleaner I duty; produce saleable Pb conc.
	Cleaner III	E3432/8	Replace third bank of self-aspirated cells; improve selectivity against Zn.
Zn	Cleaner-Scalper	B4500/12	Relieve overloaded Cleaner I duty; produce saleable Zn conc from rougher conc.
	Cleaner III	E3432/8	Improve final cleaning stage and replace self-aspirated cells; reduce entrainment of SiO_2/Fe/K.
Slimes	Scavenger II	E2532/6	Recover Zn from slimes scavenger tails to reduce metal losses.
	Cleaner II	Z1200/1	Upgrade slimes cleaner feed to high-grade Zn conc (≥45% Zn) suitable for blending into final concentrate.

A thorough testwork program was undertaken to investigate the suitability and potential performance of the cells in each of the above duties. Dilution cleaning testwork as recommended by Glencore Technology was conducted at the on-site lab on fresh plant samples utilising various ore blends. A pilot testwork campaign was carried out to validate the dilution cleaning testwork results for the various duties, and to allow operators to further understand the cell operation.

Key outcomes from this testwork were:

- The final Zn cleaner was able to achieve excellent concentrate grades above the target of 52% (Figure 3) and consistent K rejection with 0.1–0.2% K in concentrate (Figure 4)
- Slime Cleaner Jameson cell upgraded Slimes Cleaner I conc to ≥45% Zn from 30% feed grade when operated non-aggressively (low air to pulp ratio, high froth depth) to maximise Zn/SiO2 selectivity.

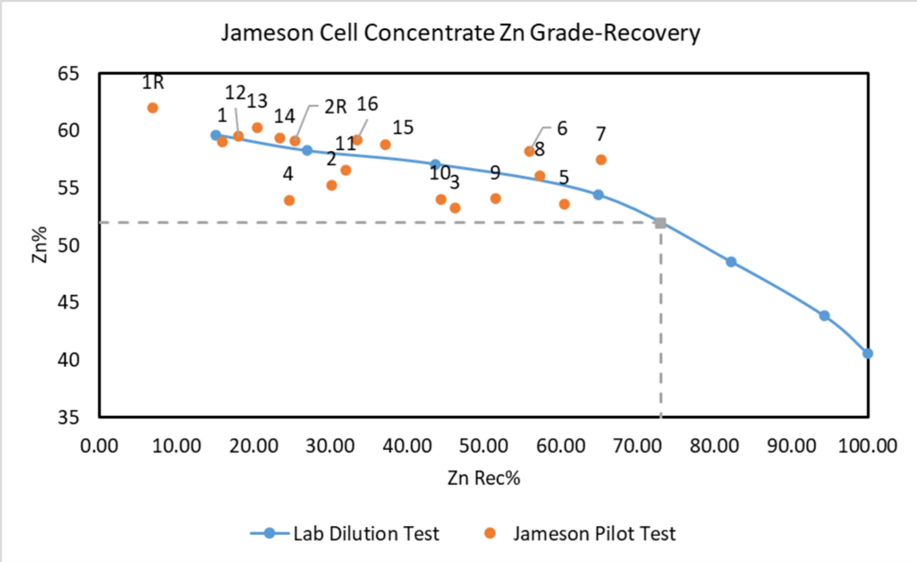

Figure 3: L-500 pilot grade-recovery curve for Zn final cleaner duty

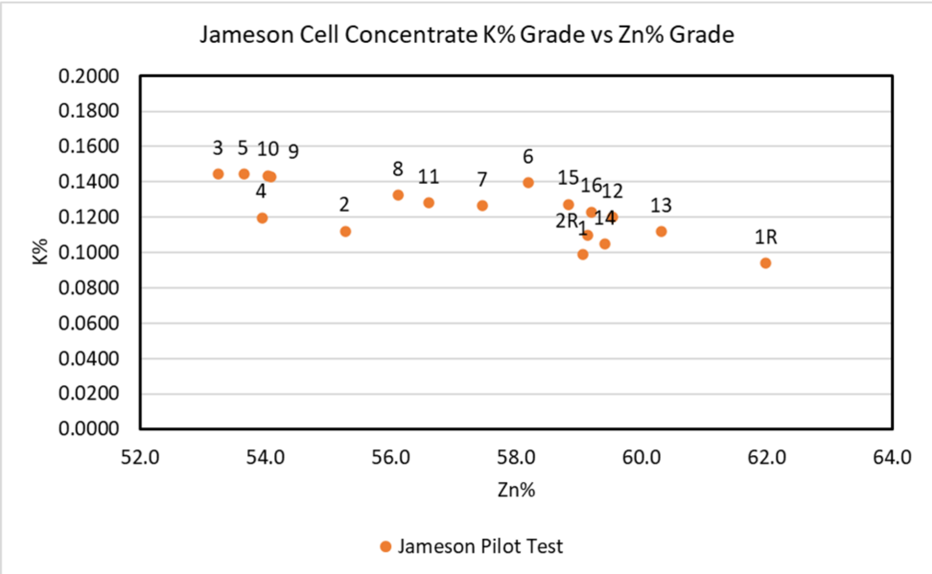

Figure 4: K grade in pilot L-500 concentrate across range of test conditions.

In parallel with the pilot testwork, Hatch undertook an initial pre-feasibility study to determine the plant layout, key tie-ins, project schedule with a focus on procurement timelines and CAPEX. This was caried forward into detailed design, procurement and execution by a local design institute with Hatch providing local site-based support and technical guidance, as the Jameson Cell technology was a new technology to the in-country design team. The overall upgraded circuit configuration incorporating mechanical cell expansions and Jameson Cell installations is shown in Figure 5.

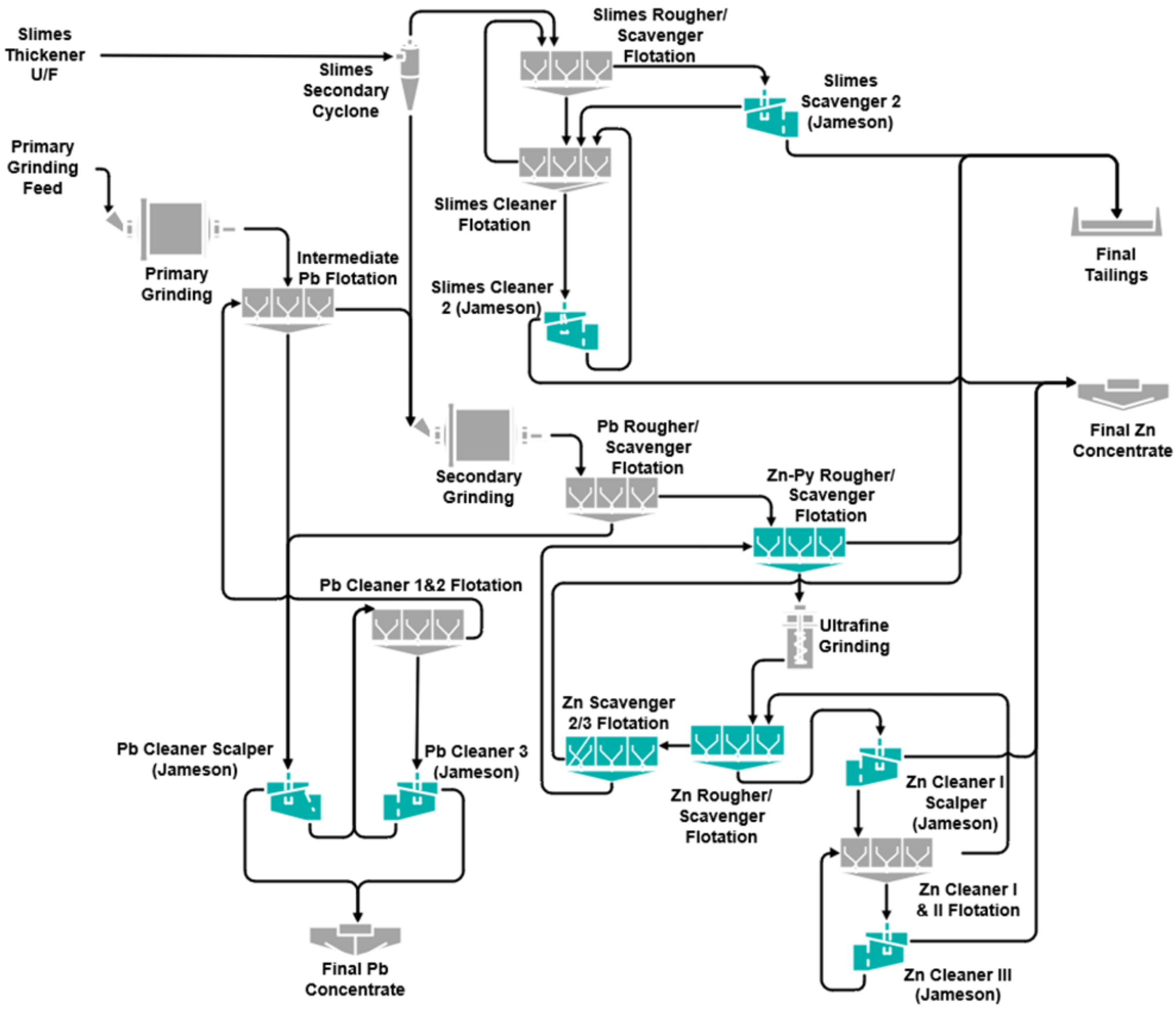

Figure 5: Flotation circuit schematic post expansion

4. Jameson Cell Metallurgical Performance & Overall Plant Improvement

The Jameson Cells were commissioned sequentially in a collaborative effort between Kazzinc operations staff, Hatch and Glencore Technology. The cells underwent sequenced dry, wet and slurry commissioning stages over a period of 6 months, whilst each operational cell was then the subject of further reagent and operational parameter tunning to obtain optimal performance. The challenge of commissioning multiple cells in a short timeframe was compounded by changing feed blends, and the interaction between each successive cell and those that preceded it. Managing the overall circuit process water balance as wash water streams were introduced was a particular challenge.

Since the commissioning of the Jameson Cells there has been improvements in the overall performance of the flotation circuit as summarized in Table 3 below. While the average zinc concentrate grade was steady, there has been ~2% improvement in Zn recovery at a higher throughput. It is also important to note that this improvement has been realised at the time while the cell operating parameters and reagent addition were still being optimised.

Table 3: Comparison of Zn circuit performance pre and post circuit upgrades

Key Parameters	Performance post Mechanical Expansion	Performance post Mechanical + Pneumatic Cell Expansion
Time Period	*Jan - Sep ‘24*	*Jan – Mar ‘25*
Zn Conc. Grade, % Zn	49.0	49.0
Zn Recovery, %	67.9	69.3

5. Conclusions

This project has identified the challenges and circuit constraints encountered during the ramp up of the Zhairem polymetallic flotation circuit, treating a highly variable ore blend with complex mineralogy, undersized self-aspirated cleaner cells and an extremely tenacious froth impacting concentrate transport and cell hydrodynamics.

The installation of six pneumatic flotation cells (Jameson Cells) to upgrade the circuit, provided effective debottlenecking in combination with mechanical cells to recover slow floating minerals. The collaborative approach between Hatch, Kazzinc and Glencore has delivered a more reliable flotation circuit with consistent metallurgical performance, providing experience that can be carried across to similar polymetallic operations globally.

Constructability and operability were an essential consideration from early in the design. Hands-on operator training on the pilot cell, combined with training sessions for each shift prior to wet commissioning, was invaluable to ensure the cells were well understood and operated effectively, given the Jameson Cell technology was new to the Zhairem site.

It was also evident that to secure a sustained overall flotation circuit recovery uplift, the interactions between each mechanical or Jameson Cell upgrade must be considered, including changing recirculating loads and process water requirements. Considering upgrades in isolation, or failing to consider interim configurations during a staged implementation, will complicate the commissioning journey and negatively impact project value.

6. Acknowledgements

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7. References

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