Paste 2023 – GW Wilson, NA Beier, DC Sego, AB Fourie & D Reid (eds)
© 2023 University of Alberta, Edmonton, and Australian Centre for Geomechanics, Perth, ISBN 978-1-55195-493-6
doi:10.36487/ACG_repo/2355_02

Case study: Brucejack paste backfill pumping system

D Balthazar *Weir Minerals, Canada*

L Fleming *Newcrest Mining, Canada*

E Vlot *Weir Minerals, Netherlands*

Abstract

Brucejack mine has been operating a paste backfill system since June 2017. In this case study, the reasons for adopting a paste backfill system will be reviewed, and actual operating conditions will be compared with the earlier envisaged design conditions. Lessons learned will be shared to provide for operational insights around the backfill system and GEHO® hydraulic piston pumps that are used for pumping paste backfill.

Keywords: *paste backfill, hydraulic piston pumps*

1 Introduction

The Brucejack mine (Figure 1) is a high-grade gold mine located in north-western British Columbia, Canada, in an area referred to as the Golden Triangle approximately 950 km northwest of Vancouver (Jones et al. 2020). At start-up in 2017, the annual permitted tonnage was 985,500 tpy (2,700 tpd on average), which was increased to 1,387,000 tpy (3800 tpd on average) in 2019. The mining method is a combination of transverse and longitudinal long hole open stoping. Paste backfill plays an important role in this mining method as backfilled stopes will be re-exposed during mining to facilitate maximum orebody recovery. Mining currently occurs between 1,050 m and 1,470 m above sea level with a vertical stope size of 30 m and a width of 15 m.

Figure 1 Brucejack

The Brucejack mine is operating a paste backfill system to increase the recovery rate of the mine and to reduce the amount of tailings stored at surface (Tailings 2022). Secondary stopes can be extracted without compromising mine safety and the environmental footprint of the mine can be reduced significantly by storing tailings underground. The tailings are mixed with a binder that enables hardening of the slurry to predefined strengths. Compared to a gravity paste backfill system, pumping allows for more flexibility and reaching remote areas of the mine.

2 Process flow sheet

The plant process flow sheet is shown in Figure 2. Ore from underground is crushed and hauled to surface where it is milled in a conventional semi-autogenous grinding (SAG)/ball mill circuit. Gold and silver are recovered through gravity concentration and bulk flotation. The gravity circuit consists of two Knelson concentrators and a gold room using a Deister shaking table to upgrade the Knelson concentrate. Table concentrate is smelted and cast into dore bars for sale. Slurry is classified through cyclones and cyclone overflow is sent to bulk flotation with 80% of material (P80) passing 100 µm. Bulk flotation recovers a pyrite concentrate which is thickened and filtered on site and sold for further smelting and refining. Tailings are discharged from the flotation circuit to the tailings dewatering circuit at a density of approximately 35% solids, where it is further thickened to about 65% solids.

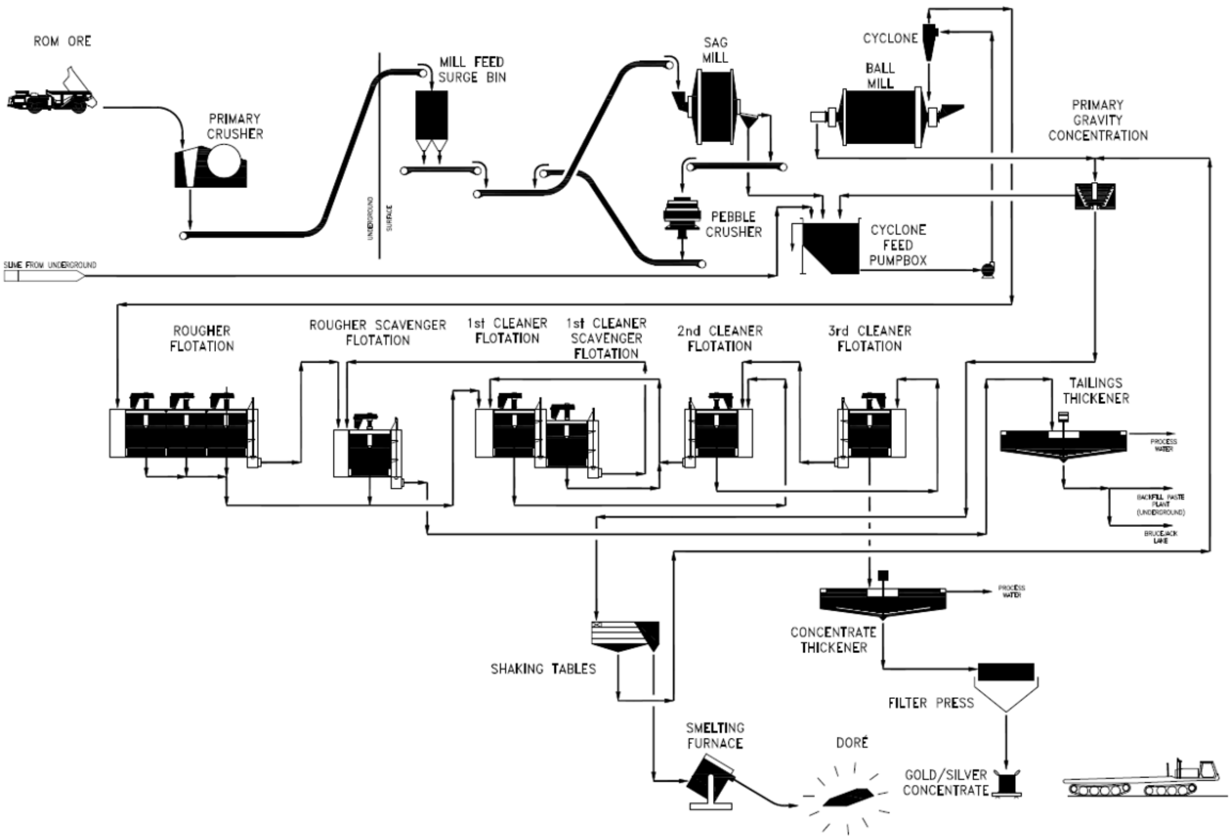

Figure 2 Process flow sheet

3 Paste backfill circuit

The tailings are thickened in an 18 m diameter deep cone thickener to a density of 64–65% solids; tailings underflow is discharged either to the waste rock and tailings storage facility or sent to the paste stock tank for paste backfill (approximately 30–40% of the total tailings volume). A horizontal belt filter was originally installed to increase paste density if needed, but the filter was removed in 2021 as it was not used. The tailings stock tank can hold 1,100 m^3 of tailings to continue paste backfill during mill outages. Thickened tailings are then mixed with binder in a paste mixer before being pumped underground (Figure 3). The binder used is TerraFlow® 90 which is a premixed product containing 90% slag and 10% general usage limestone cement sold by LaFarge Canada. Typical binder additions range between 3 and 11% depending on whether the backfill will be re-exposed and depending on different specifications for sill and main body pours.

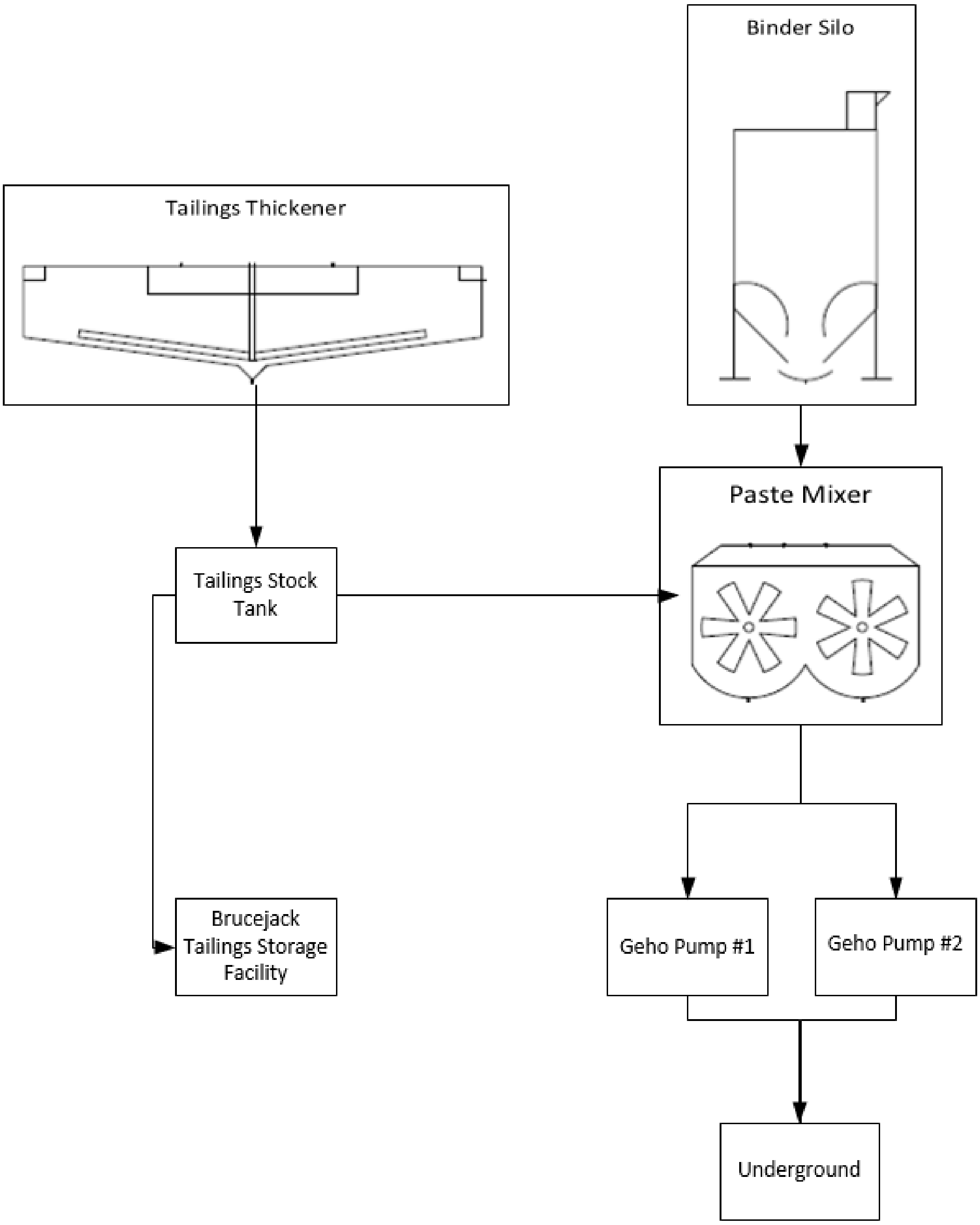

Figure 3 Paste plant flow sheet

A total of four silos are maintained on the Brucejack mine property to store and transport binder, one 750 tonne silo, two 200 tonne silos and one 100 tonne day silo. Paste is pumped from the mill underground in one of two 8" API 5 L X52 paste lines that connect to schedule 80 piping on each level to deliver the paste to the respective stope. Historic paste flowrates have been 60–100m^3/h. Utilisation of the system is 50% with 70% of the downtime associated with stope availability, curing and stope switching.

4 Paste pumps

For pumping the backfill paste, Brucejack mine is operating three GEHO® hydraulic driven piston pumps. The paste is distributed to different paste zones in the underground mine (Figure 4). Two pumps are located in the mill at surface level (1,385 m) while the third pump is located at the 1320 level underground. The third pump functions as a booster pump to pump paste backfill to the levels above 1,350 m. Pumps #1 and #2 have been operated for 7,844 and 9,204 hrs respectively. Pump #3 (which is the booster pump) has been operated for 4,667 hrs.

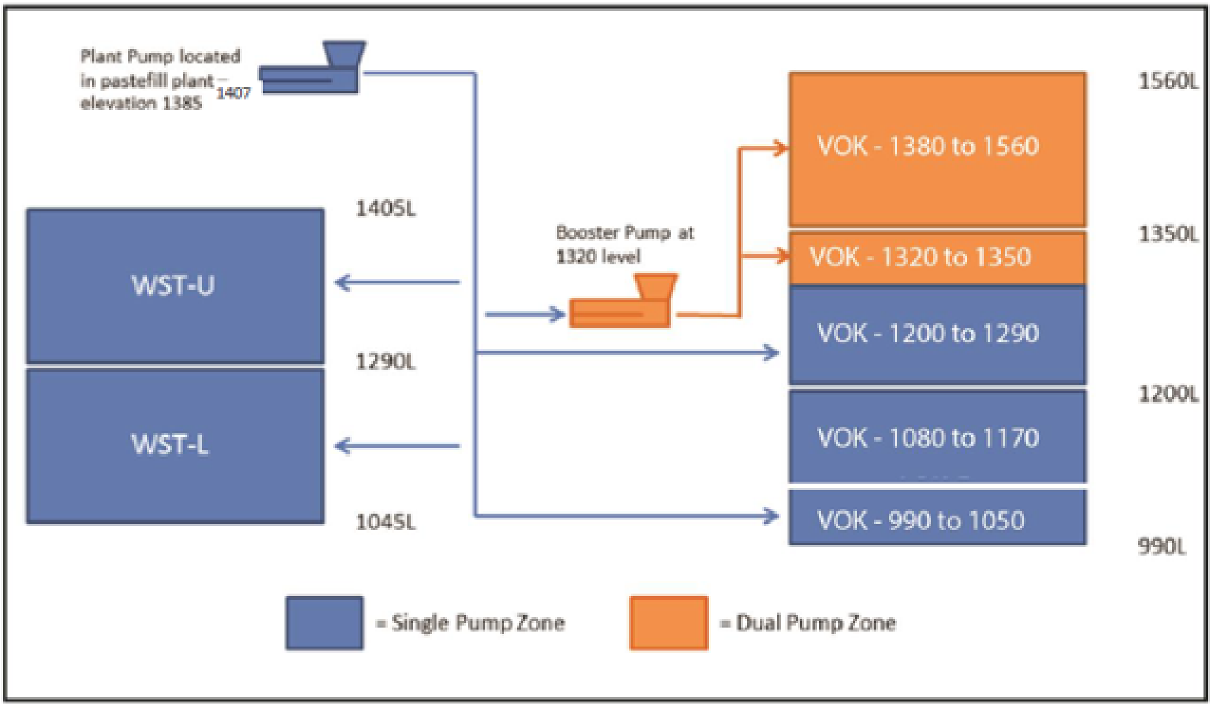

Figure 4 Paste zones (Jones 2020)

A hydraulic driven piston pump is typically a two-cylinder, single acting, positive displacement pump, consisting of a pump unit and a hydraulic power unit (HPU). The HPU drives one or more hydraulic pistons that are connected to the slurry pistons. When a piston moves backwards (suction stroke), the cylinder space in front of the slurry piston is filled with slurry. When the piston moves in the opposite direction (discharge stroke), the slurry is discharged from the cylinder into the main slurry line (Vlot & Keijers 2018).

The pump cylinders are connected to a valve box, also referred to as the pump liquid end. This pump type is utilised for handling slurries that are highly viscous, such as paste backfill. Pump operation is sequence controlled by a programmable logic controller (PLC). Refer to Figure 5 for a typical cross-section of a valve pump.

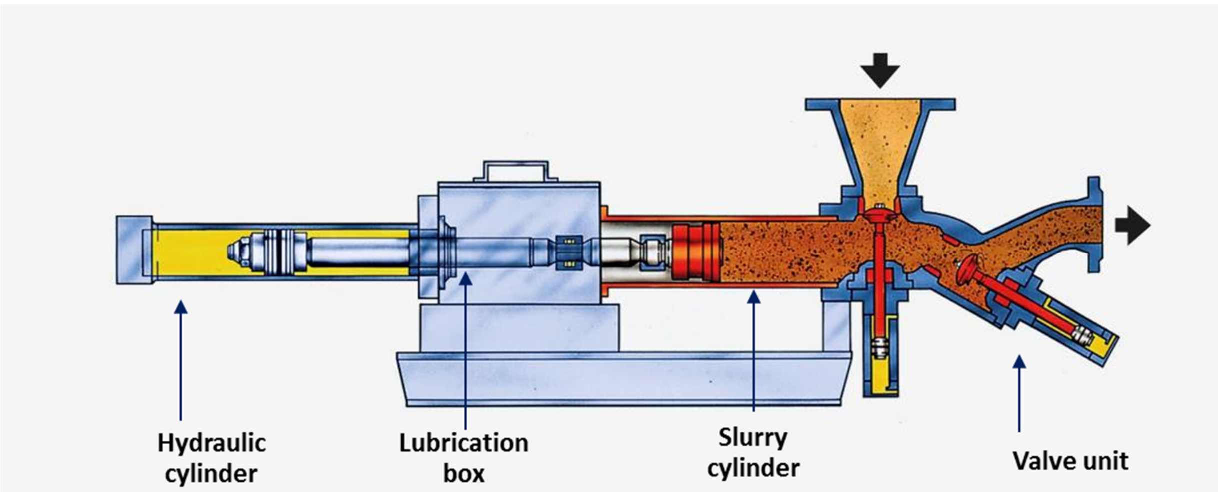

Figure 5 Typical cross-section of hydraulic driven piston pump with cone valves (Vlot & Keijers 2018)

The most effective way of dealing with the phenomenon of pressure pulsations is to avoid generating them. This can be done by creating a discharge flow that is continuous despite the reciprocating motion of the pistons. In a two-cylinder pump, this can be achieved if both pistons are driven independently of each other.

Figure 6 shows a schematic of this hydraulic concept. Using this concept, the pump is divided into two single-cylinder pumps each driven by its own hydraulic system. The technology behind the pulsation free system comprises of pre-compression of the piston chamber that has completed its suction stroke up to the level of the discharge pressure before the discharging piston chamber has reached it end position. The PLC controls the respective piston speed profiles (Figure 7) so that the total net discharge flow is constant, resulting in a constant discharge pressure.

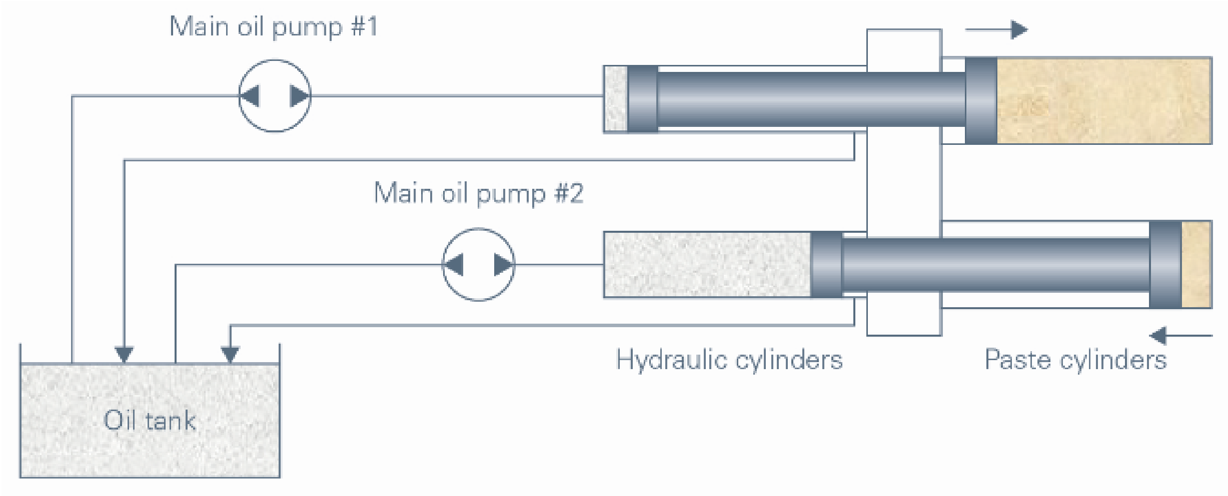

Figure 6 Hydraulic concept of individual controlled pistons (Vlot & Keijers 2018)

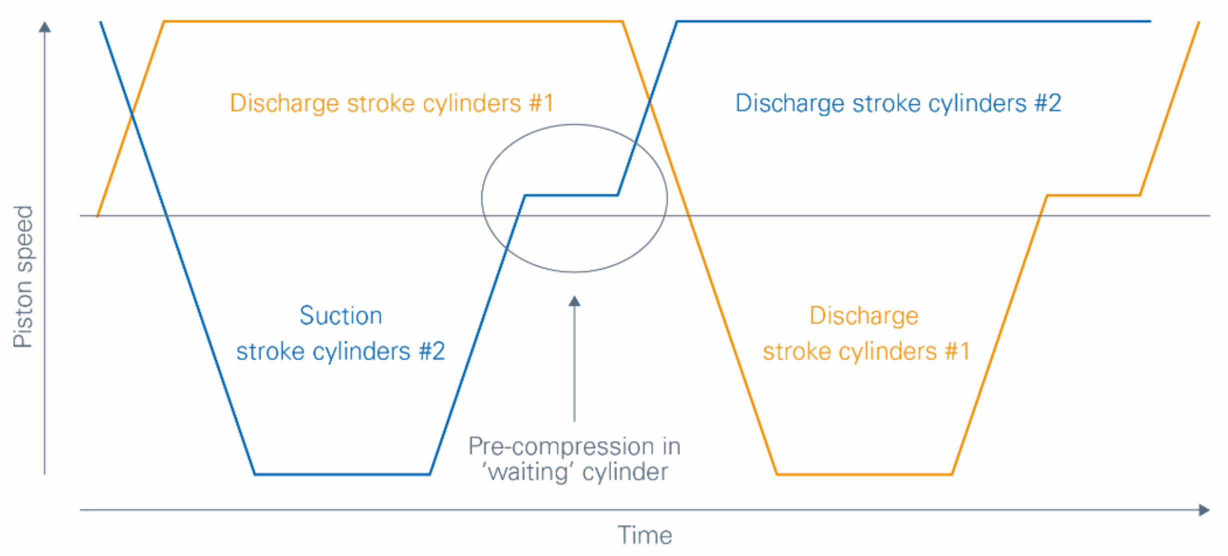

Figure 7 Piston speed profile of pulsation free system (Vlot & Keijers 2018)

The pumps at Brucejack mine are of type dual hydraulic cone (DHC) 26300 (Figure 8), are dual single acting, and rated for a continuous duty of 145 m^3/h at 125 bar pressure. The pumps are equipped with a pulsation free system, or a so called Versnelde Zuigslag (VZ) system.

The pumps are equipped with hydraulic actuated cone valves, size API 15 and have a 2,600 mm stroke length.

In the case of a hydraulic piston pump, the valves and seats, cylinder liner and piston are in direct contact with the slurry (Figure 5). These parts are, therefore, also considered wear parts and have to be replaced periodically.

Figure 8 GEHO® paste pump #2

5 Paste plant and pump operation

Since the initial commissioning, the paste plant has handled a total of 1.8 M m^3 of paste (Table 1).

Year	Paste produced m^3
2017	13,136
2018	375,484
2019	426,797
2020	423,370
2021	380,513
2022 YTD as of 30 June	199, 438
Total	**1,818,738**

Table 1 Paste quantities

The pumps are operating with varying pressures (Table 2). The average values of 2022 (YTD to 30 June) indicated operating pressures of up to 57 bar. In earlier years, pressures of up to 80 bar were recorded. Pumping pressures depend mainly on pump flow, pumping distance, height difference and slurry properties, and can be used as valuable process information.

Table 2 2022 Pump operating pressures

	Pump #1	Pump #2	Pump #3
Maximum pressure (bar)	57	54	40
Average pressure (bar)	19	20	5

The main wear parts in a DHC pump are the valves and seats, the piston (cup) and the cylinder. The lifetime of these parts depends on the pump operating hours, speed, pressure, and slurry consistency. For example, the wear of a valve and seat is normally linear in relation to the speed of the pump. With respect to slurry consistency, this plays an important role when, for example, larger particles are present in the slurry and get trapped between the valve and the seat. This can lead to a shorter than expected lifetime of the parts. The average lifetime of the piston cup, valve and seats at Brucejack mine is 2,000 hours. The lifetime of the cylinders is around 8,000 hours. The lifetime of the wear parts is consistent with industry for this application.

After plant start-up, in 2018, knocking sounds to the pipeline became apparent. The root cause was investigated and was found to be a poorly performing pulsation free function of the DHC pumps. During the investigation, it was noticed that problems with the grounding of an MCC cabinet were causing transient electrical currents, which caused the pump controls to respond poorly to the field sensors. To overcome these issues the electrical system was modified and upgraded, after which the pump was tuned again and functioned properly from the beginning of 2020 onwards. The troubleshooting took more time than expected due to the remote location of the site and during that time, additional wear to the piston cups had been experienced.

Another problem that has been experienced at Brucejack mine was leakage in the water cooler of the HPUs. These water to oil coolers offer very efficient cooling in a small unit, but in this case, if leakage in the system is undetected, the oil gets polluted with water and components can fail quickly. The system had to be cleaned twice and as an intermediate solution the leaking coils were plugged to resume operation on a short-term basis. The coolers were later replaced and a regular inspection program was launched to prevent reoccurrence. One of the features offered by Weir for future projects is the installation of a water sensor in the oil system just downstream of the cooler for early water detection, and a retrofit for Brucejack mine is advisable.

Brucejack mine has also implemented an annual checkup of the HPU by the OEM, so any deviations from the new state will be detected and can be adjusted in the pump controls.

6 Conclusion and recommendations

From the Brucejack mine project, the following recommendations can be taken:

- Sufficient attention should be given to possible failure modes and the detection of each type of failure, even when they would normally not occur or not occur frequently.
- It is advised to implement a paste production scheme that logs pumping distance, height, flow and slurry properties for operational learning and monitoring purposes.
- Annual preventative checkups should be part of a normal operating and maintenance procedure, as this will allow for a healthy predictable machine condition.

Acknowledgement

We kindly acknowledge mill manager Michael Yakimchuk of Brucejack mine for all of his support in writing this case study.

References

Jones, IWO, Huang, J, Phifer, M, Coleman, T, Ghaffari, H, Herrera, M, … & Findlater, L 2020, *Technical Report on the Brucejack Gold Mine, Northwest British Columbia, NI 43-10*, prepared for Pretium Resources Inc.

Tailings 2022, *Backfill of Tailings to Underground Workings*, https://www.tailings.info/storage/backfill.htm, accessed at 19/12/2022

Vlot, E & Keijers, R 2018, 'Pulsation-free hydraulic-driven swing tube piston pump', in RJ Jewell & AB Fourie (eds), *Paste 2018: Proceedings of the 21st International Seminar on Paste and Thickened Tailings*, Australian Centre for Geomechanics, Perth, pp. 195-204, https://doi.org/10.36487/ACG_rep/1805_15_Vlot