CHALLENGES OF TAILINGS TRANSPORT PUMPING SYSTEMS IN NEGATIVE STATIC HEAD APPLICATIONS

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ABSTRACT

Gravity-driven fluid transport systems, whether operating under pressurized conditions or as open-channel flow, provide an efficient and robust solution for most applications. However, in tailings transport, it is essential to maintain minimum flow velocities to prevent solids from settling. When the natural elevation difference is insufficient to provide the energy required to overcome the pressure gradient associated with these minimum transport velocities, a pumping system must be incorporated. This article addresses the operational challenges of tailings pumping systems in pipelines with negative static head and explores alternative solutions that may offer greater robustness and efficiency under these conditions.

Keywords: tailings transport, pumping, negative static head, sedimentation, energy efficiency.

INTRODUCTION

Knight Piésold's Mechanical Division, in collaboration with its international offices, conducted a prefeasibility-level hydraulic evaluation for an 8.5 km mine tailings transport system. The initial pipeline design was developed under constraints related to the pipeline corridor location, as well as the elevations and positions of the process plant and the TSF. Although tailings pipelines are often excluded from the early decision-making matrix for these high-cost components of mine operations, the reliability and robustness of the tailings transport system are heavily influenced by decisions made during the initial stages of the project. As a critical element of mine infrastructure, a well-designed pipeline system is essential for the long-term success and operational continuity of the mine. The objective of this article is to demonstrate that reliable and efficient systems can still be achieved through feasible modifications to the initial conceptual design.

METHODOLOGY

- **Transport Stability Analysis:** The transport stability analysis was conducted using the Paste Stability Diagram (PSD) developed by Dr. Donald Hallbom (1). The transition from laminar to turbulent flow was determined based on the intersection of the Buckingham models and the Tomas & Wilson model (2). The sedimentation rate was analyzed using the Durand model, modified by JRI, with six different models evaluated as part of a sensitivity study.
- **Determination of Pressure Drops:** Pressure losses were calculated using the "Warman" model for heterogeneous slurry and Buckingham and Tomas & Wilson models for non-Newtonian homogeneous slurries.
- **Rheology:** Rheological characterization was performed by third parties for various tailings concentrations. These tests determined both fluid parameters and confirmed that the Bingham Plastic model is the most appropriate representation for the concentration range under study, providing Bingham Yield Stress and plastic viscosity for a range of concentrations. Details of pre-shearing, true yield stress, rheomalaxis and/or thixotropy behavior are not included on the report.

Table 1 System parameters

Parameter	Symbol	Value	Unit
Solids Density	SG	2,65	-
Average particle size	D_{50}	62	μm
Concentration Range by Weight	$Cw_{\%}$	56 – 59	-
Tailings Production Range	T	61115 – 82685	TPD
Rheology – Yield Stress	Ys	14.1 – 25.2	Pa
Rheology – Coefficient of Stiffness	μ_b	10.91 –11.17	mPa.s

ANALYSIS

The evaluation of the selected pipeline size begins with an assessment of transport velocity limits, taking into account both the thresholds for turbulent sedimentation and the transition from laminar to turbulent flow. The Paste Stability Diagram, developed by Dr. Donald J. Hallbom, is a powerful tool for evaluating and selecting pipeline sizes for tailings transport. Figure 1 illustrates the selected Ø30 DR9.3 HDPE pipeline, which falls within the stable zone for both the nominal design point and the entire operating range.

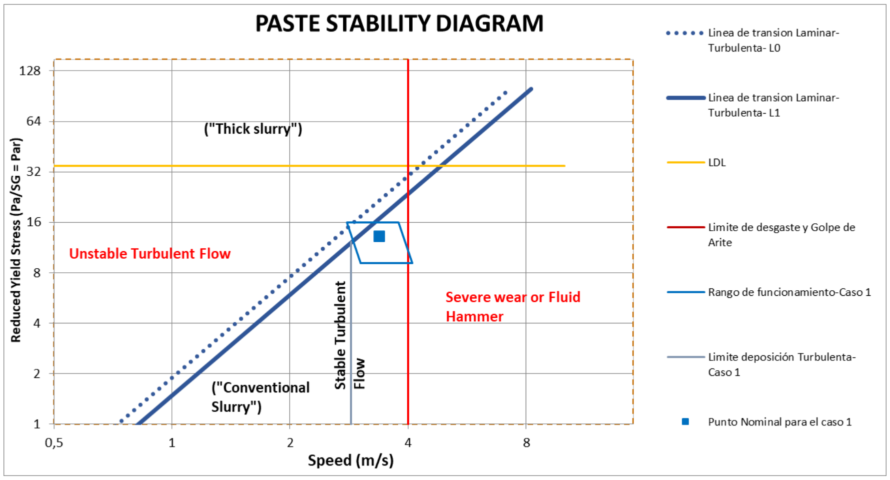

Figure 1 – Paste stability graph

RESULTS AND DISCUSSION

The pressure requirements for the pumping station and the pipeline were assessed using hydraulic gradient lines (Figure 2). This analysis provided the following key findings:

- The hydraulic gradient lines are steeper than the pipeline profile slope, indicating no intersection with the pipeline during normal operation. This suggests that fully pressurized flow conditions are expected throughout the system.
- The required pumping head shows significant variation depending on the target flowrate, highlighting the sensitivity of the system to operational changes.

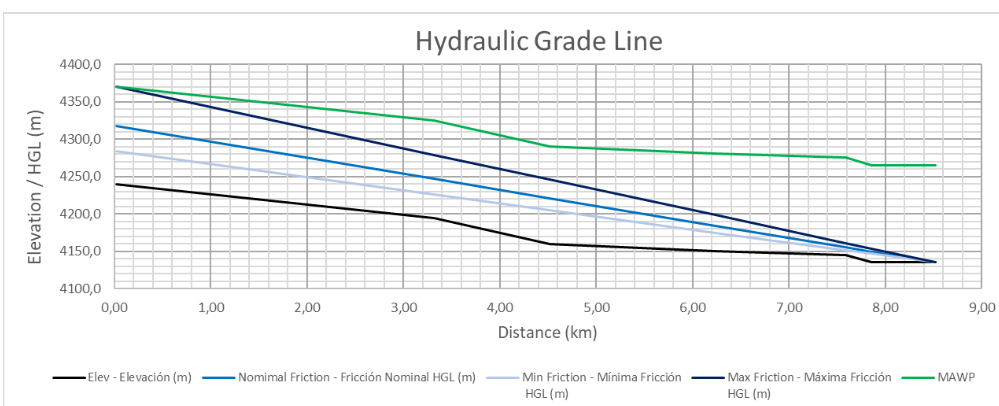

Figure 2 – Hydraulic gradient lines – Distant discharge

Figure 3 presents the resulting theoretical duty points for a two-pump series centrifugal configuration. The results indicate that:

- The required pump head is highly sensitive to variations in operating flowrate.
- The proposed pump operating window does not fully cover the entire range of pumping requirements.
- Any deviation between the actual and estimated hydraulic gradient—due to changes in slurry rheology, pipeline conditions, or model accuracy—can significantly impact the required pump operating range, thereby affecting the overall reliability of the system.

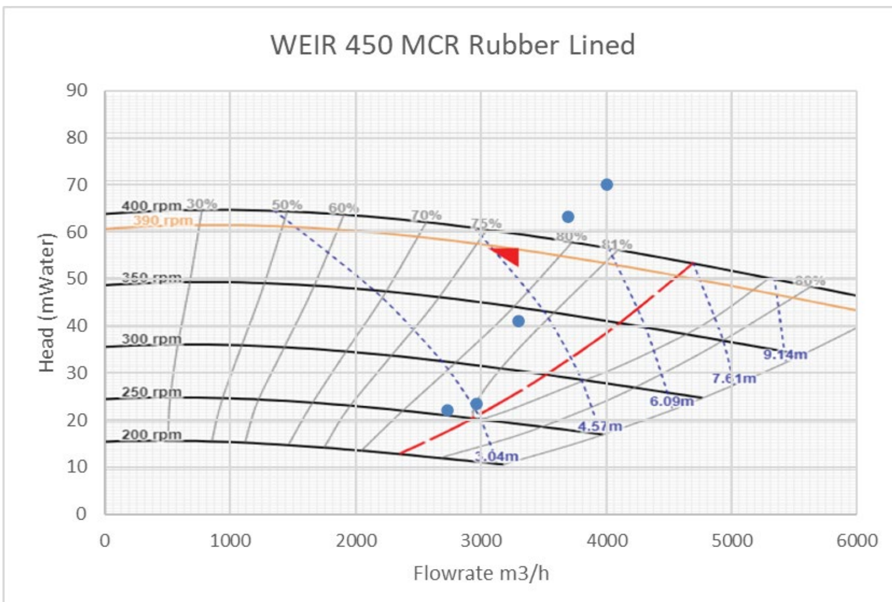

Figure 3 – Operating duty points with a 2 series pump arrangement,

PROPOSED SOLUTION

The proposed alternative solution consists of relocating the tailings box to a higher elevation, allowing slurry to be discharged through a pipeline operating under open-channel flow conditions. Calculations confirm that a Ø42 DR11 pipeline with a 2% slope is appropriate for this setup. To reach the new elevation, the thickener underflow pumping system would be upgraded to a two-pump series arrangement, requiring only one additional pump—thus saving one unit compared to the original option. Figure 4 presents the resulting hydraulic grade line (HGL), while Figure 5 displays the corresponding pump duty points.

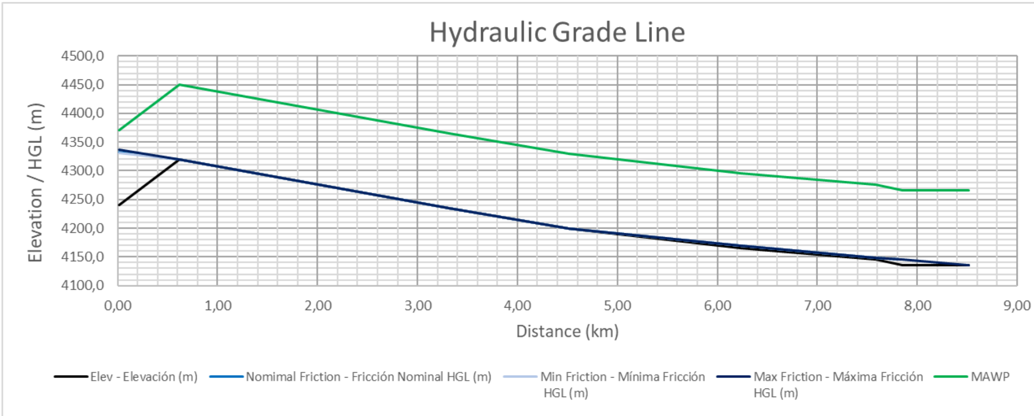

Figure 4 – Hydraulic gradient lines – Distant discharge

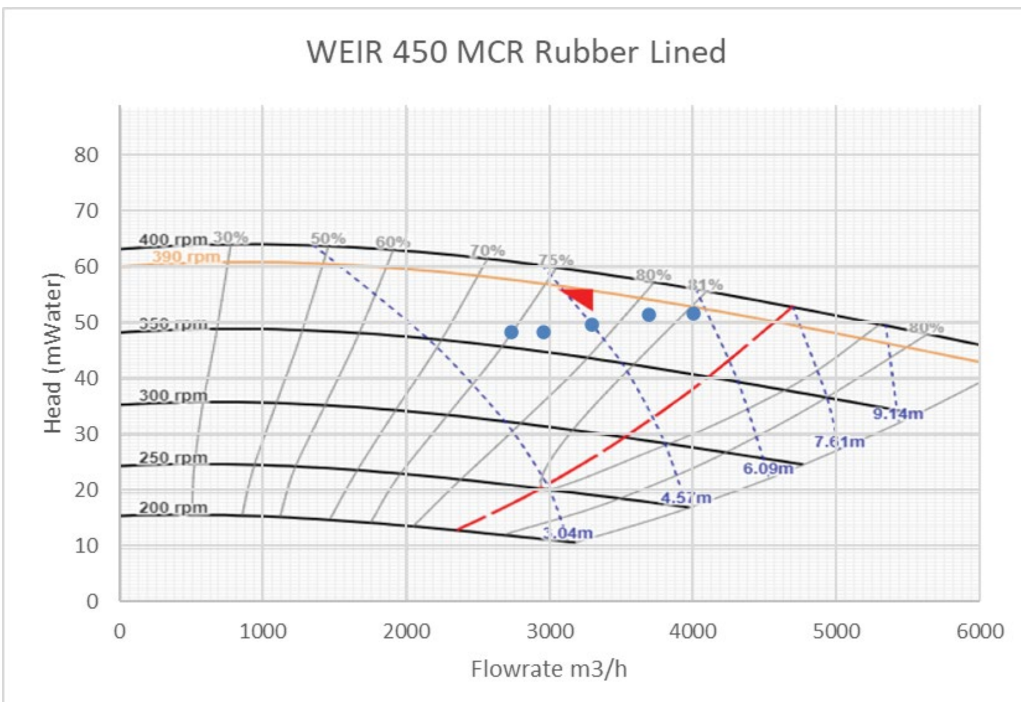

Figure 5 – Operating duty points with a 2 series pump arrangement,

ALTERNATIVE SOLUTIONS

Other solutions considered in the analysis, as an alternative to relocating the pumping system, were the following:

- **Choke station:** Due to the high variability in the required pressure and flow conditions, a control system was proposed that would allow the discharge pressure to be regulated, thus adjusting the pump operating points within their normal operating window. This option was complex for the production levels handled by the system, as it involved orifice plates, control valves, and large-diameter accessories.
- **Pumps in series. One running on.** Although the pumping system consists of two pumps operating in series, due to pressure variations, one of the alternatives considered was to turn on only one pump or both to accommodate the system's operating window. After a study, it was determined that, due to the high variability of the system, this was not feasible.

While these alternatives were also evaluated, it was decided to move forward by relocating the pumping station due to the practicality of this option.

CONCLUSION

The selection of locations for the Tailings Storage Facility (TSF) and the process plant is subject to several significant constraints. These often lead to elevation differences along the tailings pipeline, so any adjustment to the position of either the TSF or the plant can have a major impact on some of the most cost-intensive components of mine operations. Nevertheless, opportunities exist to optimize the slurry pipeline corridor, resulting in a more reliable and efficient tailings transport system.

These findings underscore the challenges of designing robust pumping systems when the natural downhill grade is insufficient to allow for fully gravity-driven transport. In such circumstances, design decisions may be ill-informed, resulting in expensive and unnecessarily complex pumping solutions. However, by improving the pipeline corridor layout, it is possible to create more favorable conditions for tailings transport, ultimately achieving more reliable and environmentally sound operations.

Key considerations include:

- **Gravity systems:** Ideal slopes depend primarily on slurry characteristics such as type, concentration, and flowrate. While specific designs must be tailored to each case, slopes in the range of 3% to 1.5% generally cover a wide range of applications. Higher concentrations and lower flowrates typically require steeper slopes.

- **Pumping systems:** Avoid configurations where the required pump head is only a small fraction of the pipeline's total friction head, as is often the case in downhill pumping scenarios. These systems are highly sensitive to changes in slurry properties and flowrate, and pumps may lack the flexibility needed to operate effectively under such conditions.

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NOMENCLATURE

TSF	Tailings Storage Facility
HGL	Hydraulic grade line
SG	Solids Density
D50	Average particle size
Cw	Concentration Range by Weight
T	Tailings Production Range
Ys	Rheology – Yield Stress
μb	Rheology – Coefficient of Stiffness

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