

Management of HDPS Siphon System in AP40 Kitimat Smelter - Roadmap of Challenges and Process Optimization

Pradeep Varma Kalidindi¹, Thomas Walterhouse², Sonny Walterhouse³,
Jean-Nicolas Maltais⁴, Raymond Emond⁵, Jean-Philippe Laine⁶,
Guillaume Girault⁷ and Thomas Gandia⁸

1. Reduction Process Superintendent

2, 3. Reduction Process Technicians

Rio Tinto BC Works, Kitimat, Canada

4. Principal Advisor, Scrubbing

5. Consultant, Scrubbing

6. Technical Services Atlantic & Reduction & Scrubbing

Rio Tinto, Saguenay, Canada

7. Head of Technology

Reel Norway, Oslo, Norway

8. Process & Technology Manager

Reel Alesa, Aix-en-Provence, France

Corresponding author: pradeep.varma@riotinto.com

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Abstract

Kitimat Aluminium Smelter uses AP40 Technology with eight sections of 48 pots in a single pot line configuration with a unique asymmetric gas treatment centre (GTC) configuration requiring a unique “siphon” alumina conveying system. The Siphon bridges the North and South Hyper Dense Phase System (HDPS) branches by transferring alumina underneath the centre passage. Siphon design posed many challenges during commissioning, start up and is still undergoing optimization. There were occasions in relation to siphon functionality leading to disruption of alumina supply to south branch of the pot room. The original design used air injection points in the south column to assist the material flow, however the nozzles experienced severe scaling phenomenon which induced operational challenges. Technical trials have made it possible to overcome this problem by installing an air injection under the fluidization fabric at the outlet of the horizontal part of the siphon. Air injection is equipped with a static flow control (SFC) which favours optimization of air flow and pressure within the siphon. Balancing the HDPS through multiple measurements and finetuning the operational set points in conjunction with rigorous checks and balances has greatly improved the reliability and operation efficiency of the siphon system.

Keywords: Hyper dense phase system (HDPS), Siphon, Alumina supply disruption, Static flow control (SFC).

1. Introduction

The Hyper Dense Phase System (HDPS) is a specialized alumina distribution system used in aluminum smelting operations to efficiently move alumina powder across long distances horizontally, without relying heavily on mechanical conveyors [1]. The system is particularly advantageous for facilities where space constraints, building layouts, or energy efficiency drive the need for non-mechanical material transport solutions.

1.1 Kitimat Design

In the Kitimat smelter layout, the decision to place only one Gas Treatment Centre (GTC) per four sections introduced a new set of logistical constraints. Specifically, alumina needed to be transported from silos located in the north courtyard to pots in the south courtyard, with a central passage and other infrastructure bisecting the site. To address this, a siphon-based HDPS was developed to vertically route the alumina from one side of the central passage to the other.

Kitimat has 384 pots operating at 405 to 415 kA, requiring between 95–97 t/h of alumina, meaning 48 tonnes of alumina is transported through the four siphons every hour. When supplying half of the potline through the siphons there is an increased risk. For example, if one siphon system fails, there is a total of 18 hours of alumina autonomy available to fix the issue before putting 48 pots in “sleeping mode” or stopping their operation. While innovative, this siphon design presented unique engineering, operational, and safety challenges, which Kitimat was able to manage through innovative problem solving and future planning.

Figure 1 shows the cross section of the Siphon System, Figures 2–6 Show the material flow from the North HDPS branch to the 6.5-meter descent to the siphon, the 6.5-meter ascent to the South HDPS branch and a 300-meter stretch of HDPS on the South branch. Arrows in these Figures indicate the alumina flow.

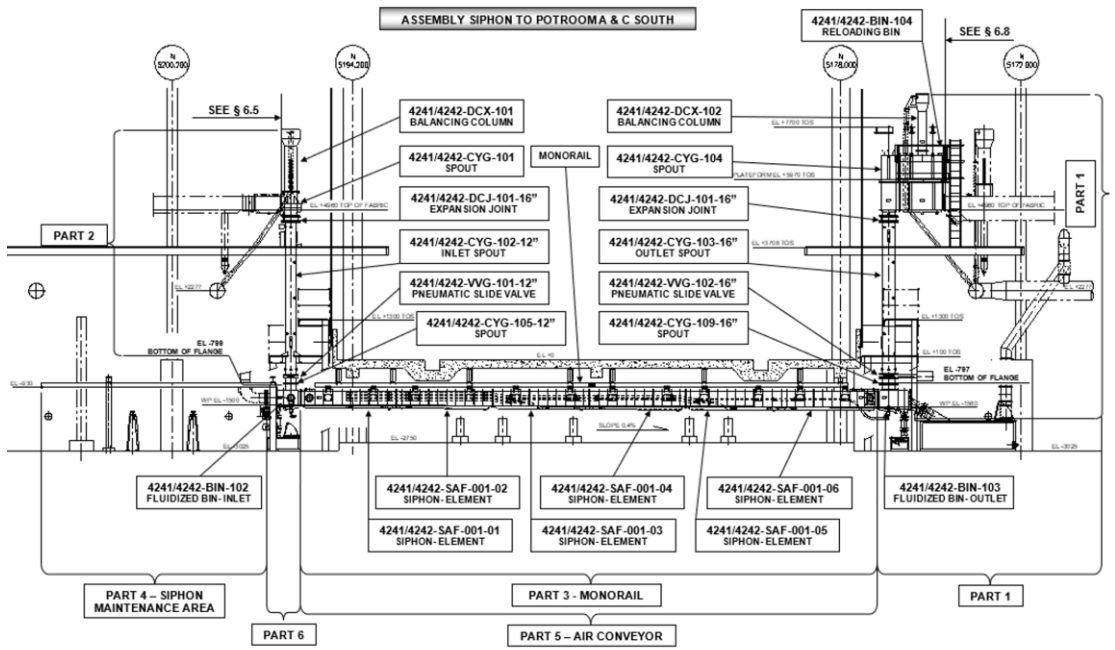


Figure 1. Cross section of the siphon system.



Figure 2. HDPS feeding the inlet side of the siphon.



Figure 3. Siphon under center passage.

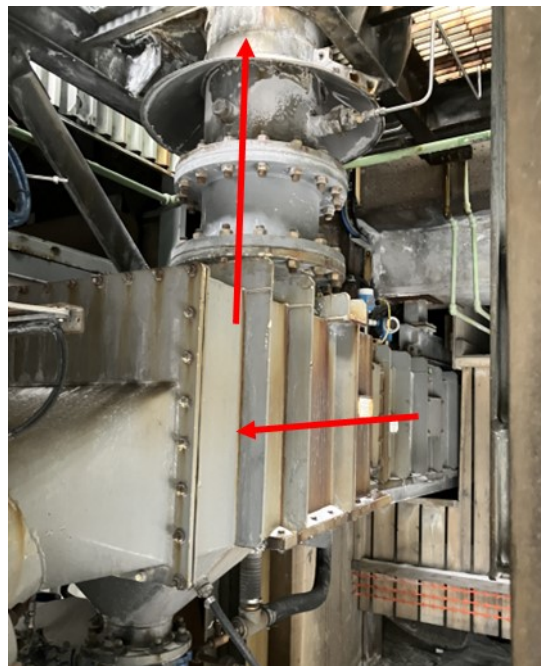


Figure 4. Siphon outlet column.



Figure 5. Outlet column feeding south HDPS.



Figure 6. South HDPS branch

1.2 Siphon Design and Flow Path

The initial concept was to construct the GTCs in only two courtyards instead of four. This required the alumina to traverse under the central passage of the plant using a siphon that descends into the basement and ascends to the South HDPS branch. Though practical in layout, the resulting system requires finely balanced airflow and material transport conditions to function reliably.

To have a reliable supply of alumina to the South HDPS branch, the siphon needs to maintain a consistent flow of alumina from the input on the North side to the output on the South. The natural gravity-driven portion of the siphon worked well, but lifting the alumina 6.5 m back up the South column requires additional air pressure and system support. Without the additional support the siphon over pressurizes causing a stoppage of alumina flow and loss of material to the south HDPS.

1.3 Pressure Limitations

In 2015 during the startup of the HDPS, the original design featured rupturing discs rated at 95 kPa to relieve excessive pressure and protect the system. However, these discs ruptured prematurely under normal operating conditions and were unable to support the pressure levels required to move alumina efficiently through the siphon.

Resolution: The rupturing discs were removed and replaced with process safety relief valves set to 150 kPa approximately (22 psi) as depicted in Figures 7–8 below. Process safety relief valves regulate pressure effectively by venting excess air only when required and reseal automatically once the pressure normalizes.



Figure 7. Decommissioned rupture discs.



Figure 8. Process safety relief valve.

1.4 Variable Frequency Drive (VFD) Optimization

The blowers that supply air underneath the HDPS canvas run on a VFD this allows the modulation of amperage increasing or decreasing the maximum air pressures. Original VFD design targeted blower operation at 90–95 %. Operational demands required increasing blower output to 105–110 %. Thanks to the capacity headroom of Flakt woods centrifugal fan, the adjustment took place in 2016, this was a great improvement and increased velocity through the canvas to move material more quickly to the end of the branch after the siphon. However, with the increased pressure underneath the canvas the alumina was pushed higher up the degassing columns.

1.5 Improvement of Degassing Columns

The original degassing columns were designed to accommodate a lower HDPS pressures running between 18–21 kPa underneath the canvas. As operational pressures rose to 24–26 kPa and sometimes as high as 30 kPa. Higher pressures push the alumina further up the degassing columns increasing the risk of alumina flowing into the GTC ducting, the increase in siphon pressure further pushed alumina up the degassing columns at the inlet and outlet of the siphon. The columns close to the siphon were unable to handle the increased backpressure resulting in alumina being purged directly into the gas ducting of the GTC.

Resolution: In 2015 the degassing columns affected by the higher pressures were increased in height by two meters. This modification allowed the system to operate under higher pressures without risking overflowing and contamination of the gas ducts.

1.6 South Column Air Support and Scaling

The south column after the siphon requires additional air support. To achieve this, two air nozzles were installed originally mid-way up the south column to inject compressed air and aid the upward movement of alumina. However, these nozzles quickly experienced severe scaling, rendering them ineffective after only a few weeks. In 2015 the nozzles were removed from service. Shown below in Figure 9 and Figure 10 are the nozzles and their location in the column.



Figure 9. Siphon column nozzle.



Figure 10. Nozzles location in the column.

Resolution: The failure of south column nozzles led to the implementation of the Static Flow Control (SFC) system. The SFC injects air beneath the south column outlet at a slightly higher pressure than the rest of the system. This design creates a more efficient flow and reduces the risk of back pressure inside the siphon. The siphon was in critical condition and struggling to operate since November 2022, and the SFC was implemented in 2024 (Figure 11).

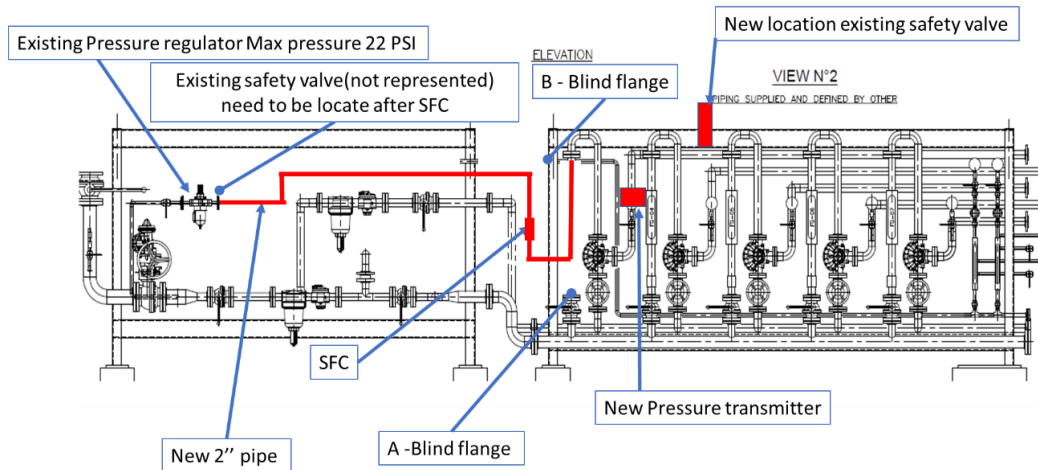


Figure 11. Static flow control improvement drawing.

1.7 Balancing Material Flow

The siphon required careful balancing between the volume of alumina entering the system and the volume being discharged. An imbalance, particularly if more material entered than could exit, resulted in siphon plugging and total system stoppage.

Resolution: In 2016 a set of automated control parameters were set up to trim the fluidization airflow control valves, based on real-time pressure readings at three key points: before the siphon, after the siphon and at the end of the HDPS lines. These control valves now modulate airflow to maintain smooth and balanced alumina transport.

1.8 Inadequate Hose Clamps

The air chambers on each section of the siphon are connected by rubber hoses that clamp onto a metal pipe for each section. The hose clamps used were not strong enough to endure the higher pressures implemented during commissioning, resulting in higher operational stress. Over time the clamps loosened, and hoses detached, resulting in air leaks, loss of flow, and system failure.

Resolution: The maintenance team sourced and installed heavy-duty industrial clamps capable of maintaining secure connections under continuous vibration and high pressure.

1.9 Rain Ingress and Weatherproofing

Being an outdoor system in a region known for high rainfall (Kitimat is in a temperate rainforest), the HDPS is vulnerable to water ingress through inspection ports, flanges, degassing columns, and connection points.

Resolution: All HDPS inspection hatches and connections on the south branches were fitted with custom aluminum covers to prevent direct rain entry. Additional sealing methods are being trialed to prevent water ingress through the degassing columns, which have a negative pressure that could draw in air (and potentially water) during operation if there is a poor seal. Extensive study and process optimization trials were conducted on this subject in 2023. Few follow up initiatives are currently still in progress on in this regard. Operation challenges still persist during heavy rainfall in B building specifically 2000 south HDPS branch.

1.10 Pressure Transmitter Adjustment

Original pressure transmitters had a calibrating range of 0–15 kPa, these pressure transmitters were being used to modulate the control valves that increased or decreased the pressure underneath the canvas regulating the flow of alumina to the siphon. With no negative offset visual, there was no way to know when there was a true negative offset in the pressure transmitters.

Resolution: A modification of the calibrating ranges from -5 to 15 kPa took place in 2024. This allows for better detection of faults, particularly during routine weekly flushes where the pressures should go to 0 kPa. If there is a transmitter that starts to have a large negative offset, the transmitter needs to be calibrated back to zero ensuring proper reading and flow to the siphon. Affected pressure transmitters are highlighted in Figure 12.

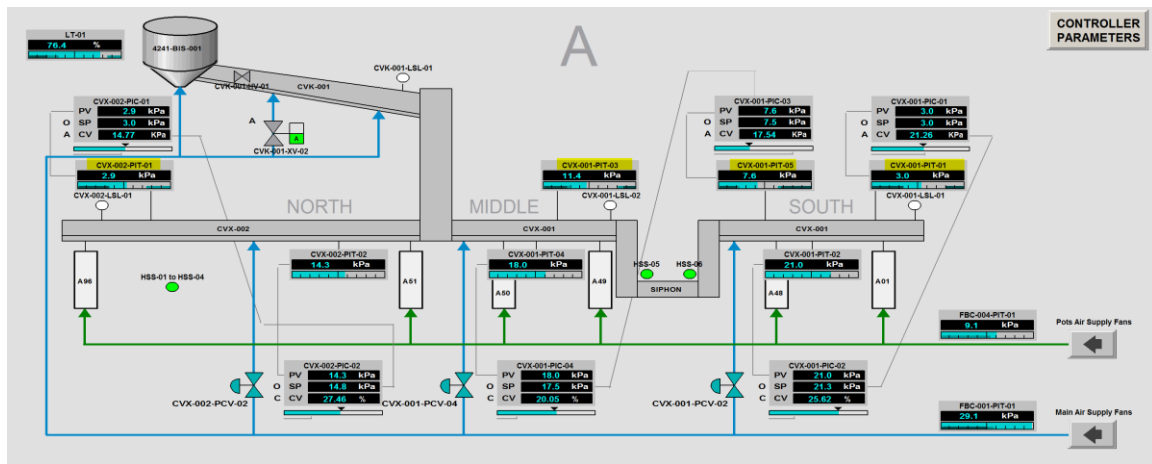


Figure 12. HDPS affected bubble pressures.

2. Maintenance and Operational Practices

Alongside all the improvements to the operating systems, there is still the operational and maintenance procedures that need to be followed to ensure an efficient operation of the HDPS system. Some of the maintenance procedures help remove additional operational stress and reduce the systems requirements when already running above 100 % capacity.

2.1 Weekly Flushing Protocol

A regular flushing schedule was introduced to keep the south-side branches of the HDPS free from non-fluidizable material to ensure a continuous flow of alumina with minimal blower air required. These flushes also serve to identify malfunctioning transmitters.

2.2 Annual Vacuuming

To maintain optimal operational efficiency, the south branches of the HDPS undergo a vacuum cleaning once annually. This procedure is essential for the removal of accumulated alumina and other debris that may hinder effective material flow through the system. By eliminating these obstructions, the system ensures unobstructed alumina transport at reduced blower pressures beneath the canvas, thereby decreasing the mechanical load on the blowers.

Operating the blowers at a lower initial pressure not only conserves energy but also provides a critical pressure margin that can be utilized if flow resistance increases due to the gradual buildup of scale or non-fluidizable particulates. This proactive maintenance strategy enhances system resilience and prolongs equipment lifespan by allowing for adaptive pressure adjustments as operational conditions evolve.

3. Improved Performance after SFC Implementation

Following the initiation of the SFC project, a significant reduction in siphon bubble pressure was observed. This decrease suggests improved efficiency in alumina flow through the siphon. Additionally, the HDPS was able to achieve its bubble pressure set point downstream of the siphon with reduced material input or a lower inlet bubble pressure. This improvement contributes to decreased operational stress on the system as shown in Figure 13. Figure 14 shows the location of the siphon bubble pressure transmitter.

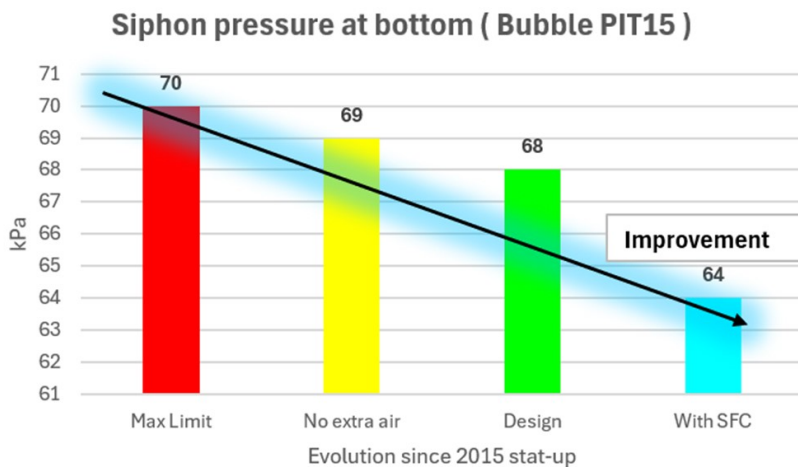


Figure 13. PIT-15 bubble pressure improvement after SFC.

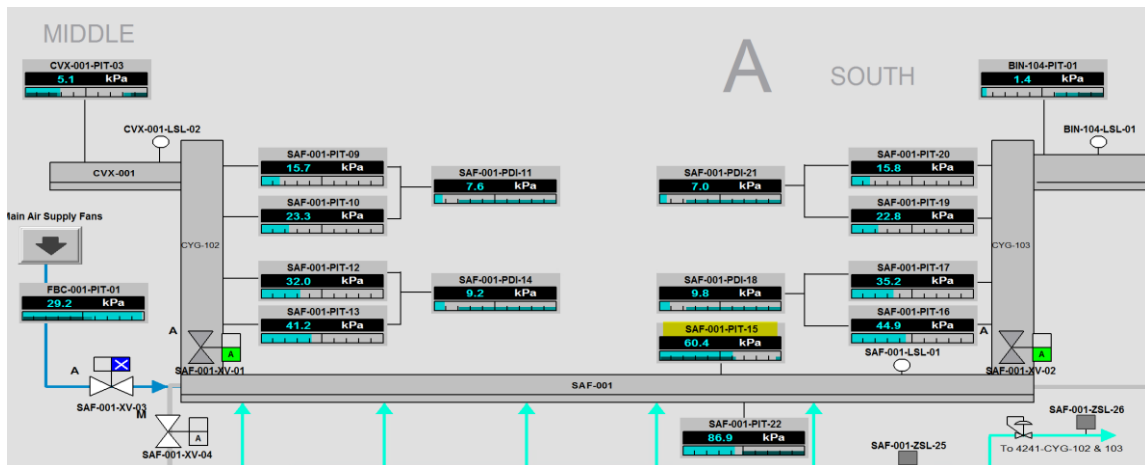


Figure 14. Location of PIT-15.

4. Siphon Failure Event

In February 2025 there was a siphon failure on a weekend at 6:30am, taking 14 hours to fix the issue and an additional hour and a half to fill the HDPS, shown in Figure 15. This is an example of a siphon failure that brought the plant close to putting pots in “Sleeping mode” or euthanizing pots.

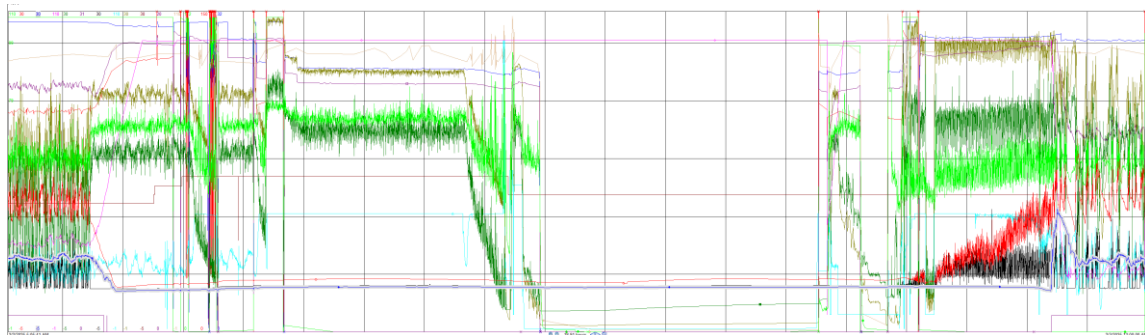


Figure 15. Siphon bubble pressure loss.

5. Future Improvements

Once the SFC is implemented across all 4 of the siphons it will greatly reduce the operational challenges experienced with the Siphon system creating a more efficient and reliable conveying system.

There are still ongoing improvements with some of the HDPS branches. B building specifically 2000 south HDPS branch is the only section currently impacted during heavy rainfall and is expected to improve after the SFC implementation. Waterproofing optimization remains a high priority. As the system operates outdoors year-round in a wet climate, advanced covers and improved sealing solutions are being considered.

Data monitoring, and operational setpoints will continue to be studied to further improve the pressure targets as well as more accurately correlating pressure data, valve positions, and flow rates across all HDPS branches in real time.

6. Conclusions

Operating a unique HDPS with an integrated vertical siphon poses significant technical and operational challenges. However, through continuous optimization of the system's pressure regulation, air delivery, structural integrity, and material flow paths, the siphon system has evolved into a highly functional and efficient solution. With further refinement, it stands as a pioneering example for how future smelters might adopt similar systems in constrained or non-traditional layouts. The lessons learned here may set the groundwork for innovation in alumina transport and plant design in the years to come.

References

1. G. Girault, P. Godde, JP. Laine and H. Hemati, Recent developments in hyper-dense phase alumina handling systems, *Light Metals* 2016, 493–498. https://doi.org/10.1007/978-3-319-48251-4_81