

Environmental Improvements at Albras through Joint Venture Project

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Abstract

Although the environmental collaboration between Albras and Hydro trace back to 2003 as an environmental audit, the effort was re-enforced in 2013 after obtaining Vale's shares in Albras when Hydro acquired Alunorte. The task then was to assess the Gas Treatment Centres (GTC) capabilities and capacities, which after 2003 were expanded with new technology chambers and ducting resulting in a complex duct layout. The GTCs themselves demonstrated to have more than sufficient capacity to handle and scrub the prescribed amount of gas containing gaseous and particulate fluorides. Lack of balancing, i.e., the distribution of gas suction from each pot, was however identified, resulting in cells with leakages to the environment. A simplified method for obtaining balance was developed so that the operators could maintain this themselves as part of operation. Moreover, the superstructure did not distribute the suction evenly internally, and the ducting from the cells towards the GTC had issues such as abrupt cross-sectional changes and lack of cross sectional area giving high pressure drop and reduced suction capacity. In addition, the alumina feeding system was incapacitated due to malfunctioning fluidisation. By simple actions these issues have been corrected and to some extent implemented at Albras.

Keywords: Gas Treatment Centre, capacity, balancing, gas ducts.

1. Introduction and Background

The Albras Smelter was started up 1985 to 1990 with the existing technology of AP13 and AP14, which at that time were free from technology fee. The suction rate in the former gas suction system was 3 960 Nm³/h per pot. Albras was then expanded in 2000 - 2001, with 96 new cells and current creep combined with a suction rate up to 4 600 Nm³/h, also implemented for all cells. The latest big change came in 2008 when the entire gas suction system and new dry scrubber GTCs were introduced. In Figure 1 the historical beginning and development are shown.



Figure 1. Historical Collage Albras.

In August 2000, Hydro Aluminium carried out a technical audit at Albras. The audit report put emphasis on benchmarking and process operation. The technical audit report further concluded that the emissions from the pot rooms were too high. Based on the recommendations from the technical audit report, an environmental audit was done in March 2003. The environmental audit report determined the status of the plant with respect to efficiency of pot room ventilation, cell hooding, gas collection and ducting, raw material handling and gas scrubbers. A detailed list of suggestions and recommendations were presented in the “Environmental Audit Report for Albras”. This report has later been used as a roadmap for the Environmental efforts carried out in the collaboration between Hydro and Albras.

In 2013 the collaboration work was re-vitalised, due to Hydro’s increased shareholder position. High and increasing fluoride emissions was one of the first focus points for Hydro.

The work group then started a root cause analysis of the emissions, and found the following focal points:

- GTC capacity and status
- Super structure (cell) hooding
 - Suction
 - Distribution of suction
- Main Ducting for gas collection.

It was quickly assessed that the GTC filter capacity on paper should be sufficient for the operation, the cause had to be found elsewhere. By following the process scheme from production source back towards the GTC, the internal flow-distribution was measured for a superstructure that was ready for start-up, and a skewed suction profile towards the suction end was discovered. After this discovery, the task became to remove bottlenecks going from the cell to the GTCs.

2. Gas Treatment Centres (GTCs) Assessment

The Albras smelter consists of 4 potlines. The smelter has a total of 960 cells, and 19 separately operated GTCs. The layout of dry scrubbers in Albras is as shown in Figure 2 below. It is divided into Plantas 1 through 5. Where:

- Planta 1 & 2 is type Fläkt (now GE) of the 1990’s
- Planta 3 is Type ProceDAir (now Solios) of 2001
- Planta 5 is Type Alstom (now GE) ABART 600 of 2007

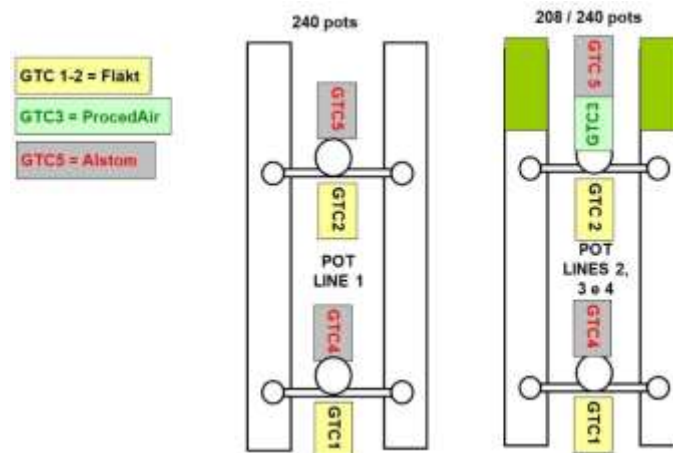


Figure 2. Potline and GTC layout at Albras.

When summarising documentation from the different GTC suppliers, the suction rate from each pot comes to 5 630 Nm³/h for Line 1 and to 5 900 Nm³/h for Line 2, 3 and 4, all at 150 °C. This shall be sufficient to seal the AP13/14 when suction is distributed evenly between the cells and within each cell. Thus, the reactors and filters, have some spare capacity as of today when maintained properly.

2.1. Ducting

When measuring on the different cells at positions typically known to have less suction rate, end of branch ducts, etc. one finds that the suction available for distribution does not meet the expected level mentioned before. In conclusion the main ducts must have some influence. As a result, from this the pressure drop along the main ducts (Figure 3), starting from the expansion (points Main 06A/B) towards the collection duct (Main 01) were measured.

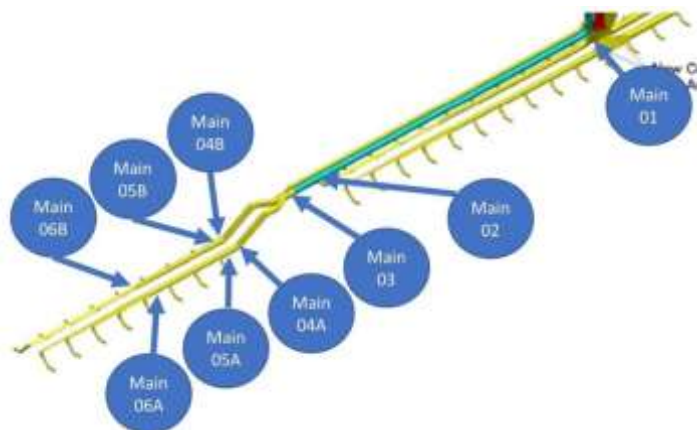


Figure 3. Measuring points on main ducts from expansion to the collection duct.

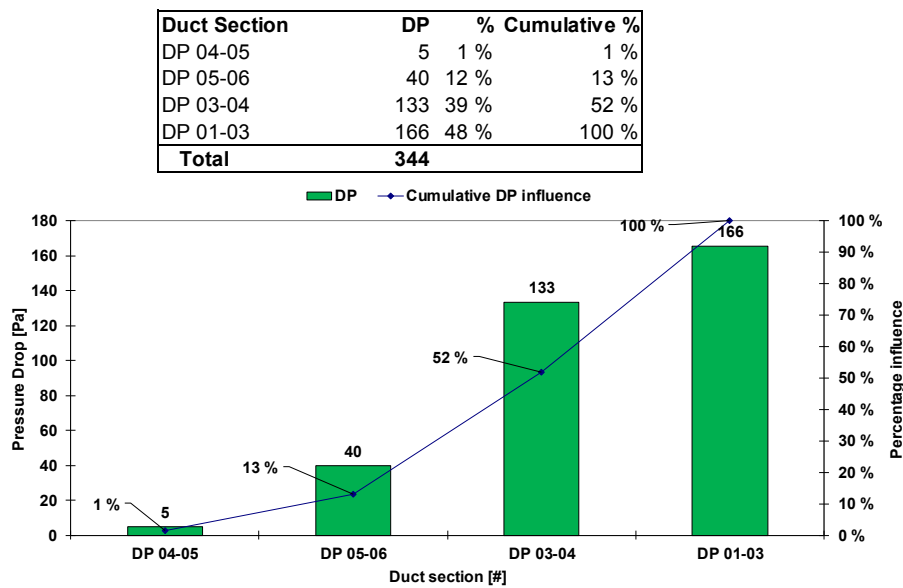


Figure 4. Pareto analysis of pressure drop on main ducts from expansion to the collection duct.

The analysis of the measured results was then put into a Pareto analysis given below in Figure 4. One can see that the pressure drop along the collection ducts from the cells, stretches 06-05-04, sums up to 45 Pa out of 344 Pa, i.e. 13 %. Further, the collection of the two branches into one duct (point 04-03) contributes with 133 Pa (39 %), and the straight section from 3-1 gives 166 Pa (48 %). This means that the straight duct, which preferably should not have too much pressure drop, might be too small for handling the gas amount, and the pressure drop due to friction becomes too large.

Table 1. Pressure drop Calculations for main duct from point 3-1.

	Units	With Original Tube	Tube size giving acceptable velocity	Adding Extra Tube	
				Tube 1	Tube 2
Duct Diametre	[m]	1.4	1.7	1.4	1.4
Duct Radius	[m]	0.7	0.85	0.7	0.7
Duct Length	[m]	78	78	78	78
Duct Cross Section	[m ²]	1.5394	2.2698	1.5394	1.5394
Gas Temperature	[°C]	150	150	150	150
Gas Density	[kg/m ³]	0.83	0.83	0.83	0.83
Gas Flow Cell	[Nm ³ /h]	5 900	5 900	5 900	5 900
Gas Flow Normalised	[Nm ³ /h]	94 400	94 400	47 200	47 200
Actual Gas Flow	[m ³ /h]	146 268	146 268	73 134	73 134
Gas Velocity	[m/s]	26.4	17.9	13.2	13.2
Reynolds number	[#]	1 713 080	1 410 772	856 540	856 529
Tube roughness	[m]	0.001	0.001	0.001	0.001
Friction (Haaland)	[#]	0.0184	0.0176	0.0186	0.0186
dP (Darcy)	[Pa]	297	108	75	
Velocity <20,->					
Velocity <10,16>					
Velocity <16,20>					

In Table 1, calculations of the pressure drop for different tube configurations are shown. As can be seen, with the gas amounts given the Original Tube (Table 1) gives large theoretical pressure

drop and high velocity, whereas the ideal tube diameter would be Ø1.7 m, resulting in 17.9 m/s. To reduce pressure-drop by adding an extra tube, one would need a quite large tube to compensate for the extra wall friction, hence ending up with a Ø 1.4 m tube. The risk then is to get a very low velocity, which might cause particulates settling in the duct. However, pneumatic transport of alumina defines the pick-up-velocity to 10 m/s, so the 13.2 m/s should be sufficient.

2.2. Balancing Cell Suction

As explained earlier, the GTCs' filter capacity at Albras is sufficient. That said, the suction flow rate from each cell, must be above the cells leakage points to keep them sealed. From this it is imperative that the available suction rate is kept evenly distributed to the entire cell population, so that all cells are kept above their leakage point. It only takes one or two cells punctured to give noticeable increase in emissions.

2.3. Theory

It is too time consuming to balance each individual cell with complete dynamic pressure measurements. To optimise the time vs. accuracy the following routine has been developed:

1. Find a pot in the middle of the branch to use for calibration
2. Measure the total flow with at least five valve settings, stretching the area of the calibration.
3. Plot the measured static pressure versus the measured flow, and correlate to the power function on the generic form of

$$Q^* = kP_{Stat}^{\alpha} \quad (1)$$

where: Q^* Suction flow [Nm³/h]
 P_{Stat} Static Pressure [Pa]
 k constant determined in correlation
 α constant determined in correlation.

When the equation has been determined, the static pressure corresponding with desired flow will be calculated, and the cell suction can be adjusted to the desired static pressure by throttling the valve.

2.4. Practical

In May 2017, the Hydro group measured dynamic and static pressures, giving the flow for several cells at different positions with different static pressures in Pot Line 3. This time around, based on previous experience, the setting of the static pressure for balancing was also performed with a temperature dependent correction. In practice, static pressures were adjusted with the same percentage increase/decrease as percentage temperature deviation compared to calibration average. This resulted in less iterations for the valve adjustments. Factors found during calibration must be applied during the same period of time since the constants will vary depending on outside temperature, measuring personnel and equipment. These measurements gave the basis for the calibration curve used for balancing the Albras cells given in Figure 5 below.

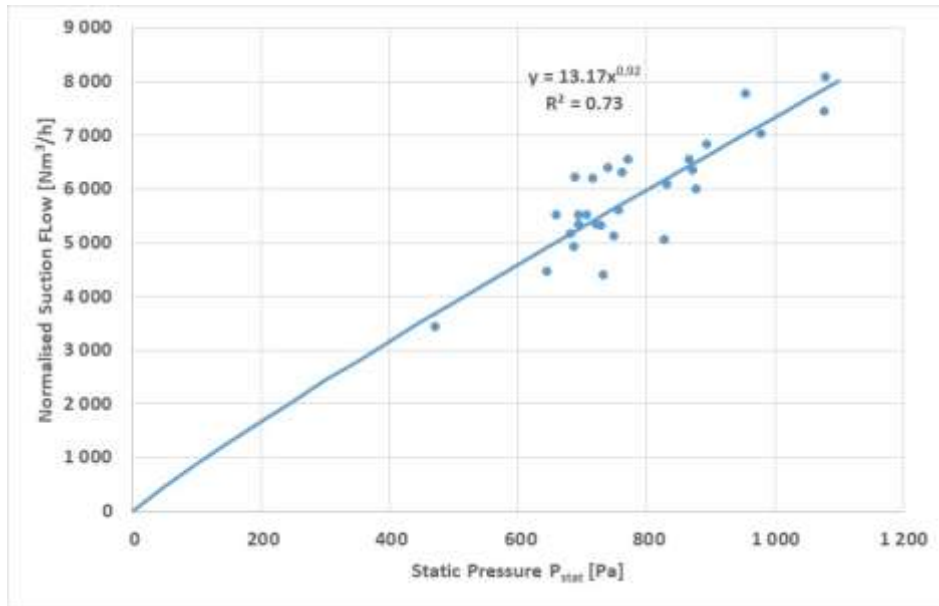


Figure 5. Calibration curve for static pressure versus flow

The correlation curve created by using the power function gives a correlation between flow and static pressure. By using the equation in Figure 5, it is possible to estimate or calculate the static pressure that correlate to the wanted flow of 5 900 Nm³/h using a solver or a goal seek function in Excel. The whole idea is to calculate the static pressure that corresponds to the wanted flow of 5 900 Nm³/h or the temperature that will give the flow of 5 900 Nm³/h at a defined pressure.

Unfortunately, in hot and humid climates with more or less constant temperature, the last correlation or calculation is very hard to obtain due to the poor stretch of the correlation curve of temperature versus static pressure. One workaround is to use the average of the temperature in the measuring group if the number of measurements is sufficient. Then one uses the solver or goal seek function to calculate the temperature at the static pressure in question.

Table 2. Balancing Setpoint Table.

Temp	P _{stat}	Temp	P _{stat}	Temp	P _{stat}	Temp	P _{stat}
119	705	127	752	135	800	143	847
120	711	128	758	136	806	144	853
121	717	129	764	137	812	145	859
122	723	130	770	138	818	146	865
123	729	131	776	139	824	147	871
124	735	132	782	140	829	148	877
125	741	133	788	141	835	149	883
126	747	134	794	142	841	150	889

The balancing recipe for Albras is simplified because pot room temperature, outside temperature and humidity are almost constant, which means that the calibration curve and the balancing recipe are independent of the yearly changes. After measuring the cells and defining the correlation curve for the flow versus static pressure one calculates the temperature that fits to the flow and pressure. The setpoint temperature for the Albras case is equal to the average temperature for all the measurements done in the same time span, for instance May 2017, here marked yellow. Having defined the setpoint temperature and the corresponding pressure one needs to establish the setpoint table for temperature and pressure, as shown in Figure 6, were T_{bal} = T_{average} = 133 and P_{bal} = 788 Pa, corresponding to 5 900 Nm³/h at 133 °C.

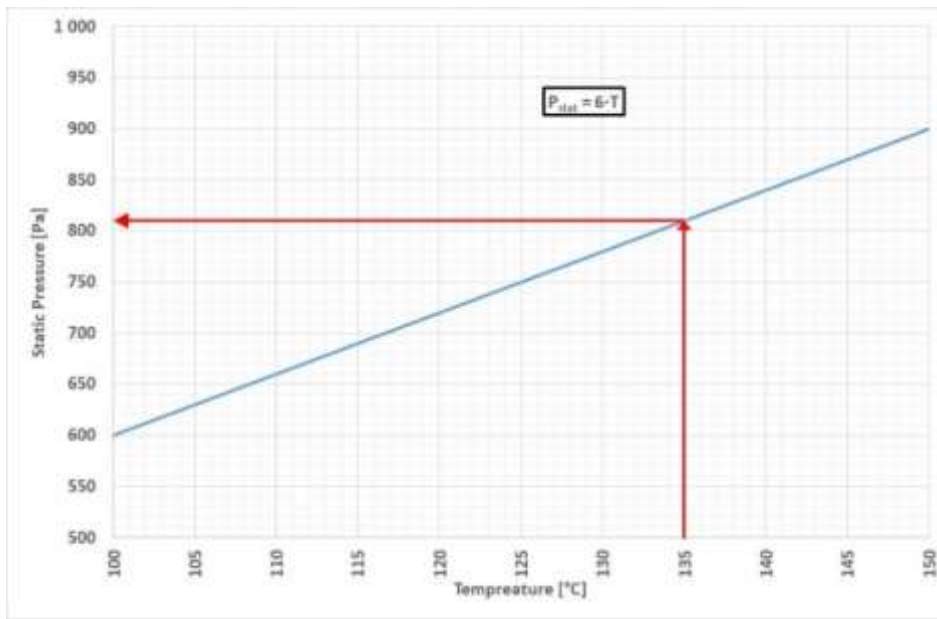


Figure 6. Simplified temperature corrected pressure set point for static pressure.

By using the simplified equation, multiplying the temperature with 6, it is easy to balance and setting the pressure and hence the flow. Example Temperature 135 °C, resulting in needed static pressure of 810 Pa to fulfil the target of 5 900 Nm³/h, i.e. measure temperature and multiply by 6. From this a simple but effective way of keeping the suction in balance is established.

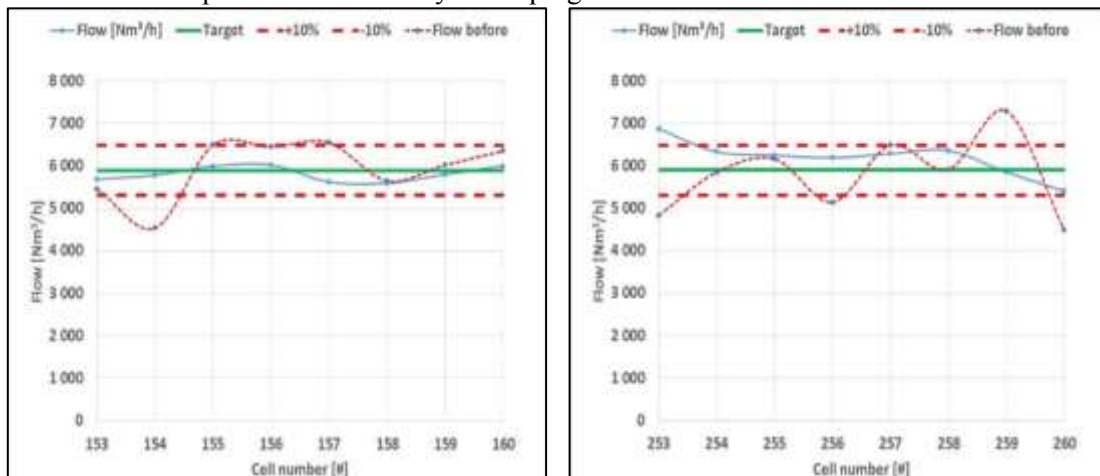


Figure 7. Balancing Sala A, Expansion cells

The Hydro team tested the simplified procedure in Pot Line 3, Sala A, on the expansion cells, to do a sort of verification of how it worked in practice. The status of the cells was measured, i.e. the dynamic pressure, static pressure, and temperature to get the flow. The temperature was then measured, and the static pressure was set to the calculated value by adjusting the regulating valve to reach the wanted flow. Then one must wait until the heat balance of the cells have stabilized before the next measurement and fine adjustment of the regulating valve can be conducted. The result of the balancing performed by use the recipe in Pot Line 3, Sala A, is shown in Figure 7.

2.5. Cell Suction Internal Distribution

The collection ducts on the cell are symmetric along the length of the superstructure, one side is sketched in Figure 8. When inspecting the superstructure, the workgroup discovered that the regulation valves for the 6-suction points, called Mini-hoods, 3 on each side was missing. Hence each of the inlets were fully open, favouring suction from the inlets closest to the connection towards the main ducts. It is important to have the suction evenly distributed, since all cells have leakage areas along the complete length of the superstructure, and hence the suction should suck evenly across the entire superstructure.

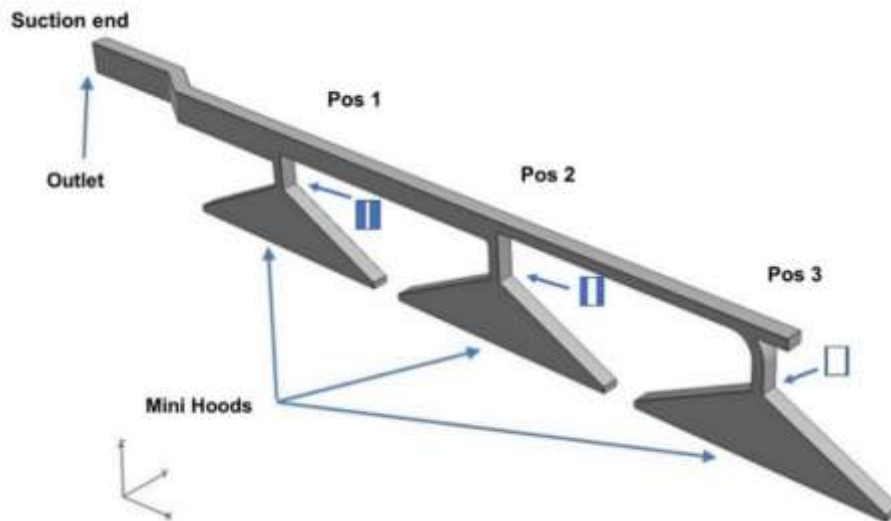


Figure 8. Half gas collection duct system on cell.

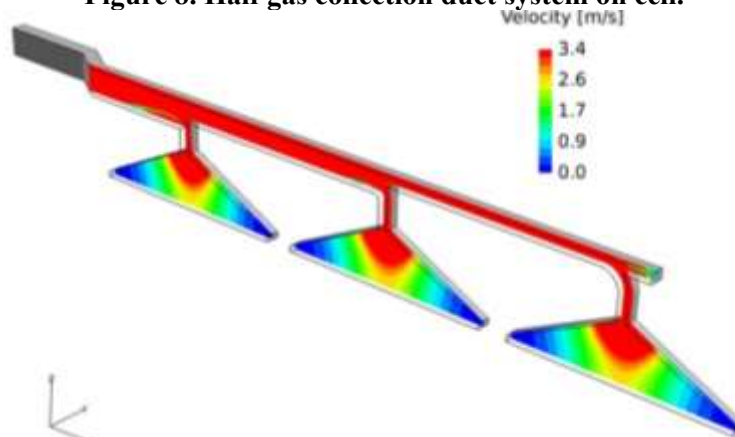


Figure 9. Velocity contours, balanced system.

Measurement carried out before and after actions were done are shown in Figure 10. As can be seen, the hood closest to outlet takes away almost 50 % of the suction, whilst the hood on the far end is left with only 20 %. This will result in leakage areas on the far end will very quickly cause punctuation of the cell hooding. Then after the re-design (Figure 10), the suction is evenly distributed. By applying Computational Fluid Dynamics (CFD) simulations (Figure 9), a fixed restriction plate was calculated for each position, and inserted as indicated in Figure 8.

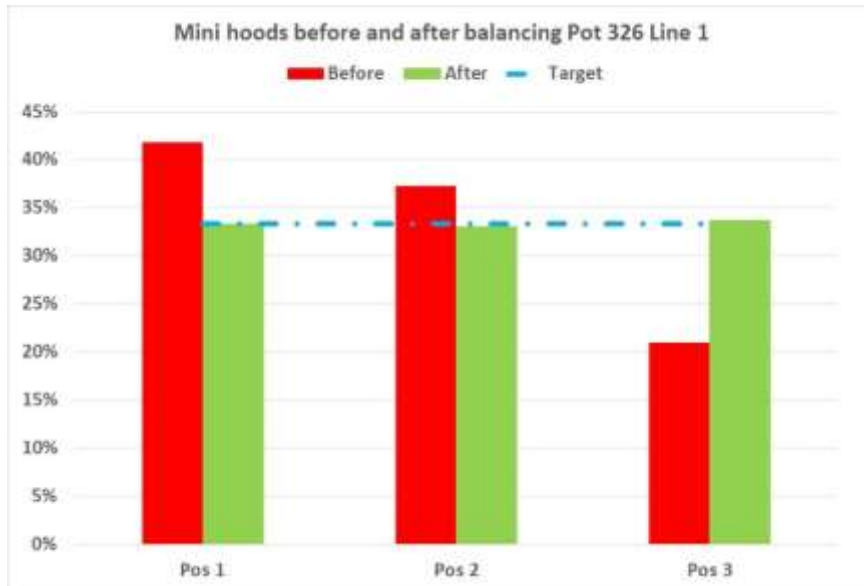


Figure 10. Results of mini hoods balancing.

So far (23/08-2018) 62 % of the 960 cells has been modified, which will improve the internal gas distribution in the superstructure and hence the gas collection efficiency giving good hooding quality accordingly

2.6. Cell Duct Optimising

Since the Albras smelter has been modernised in several stages, some left over from former times seems to occur, in this case the electrical insulation part, which is only 300 mm in diameter from cell to main ducts. This probably has to do with access to moulding of such pieces locally, or just overlooked.

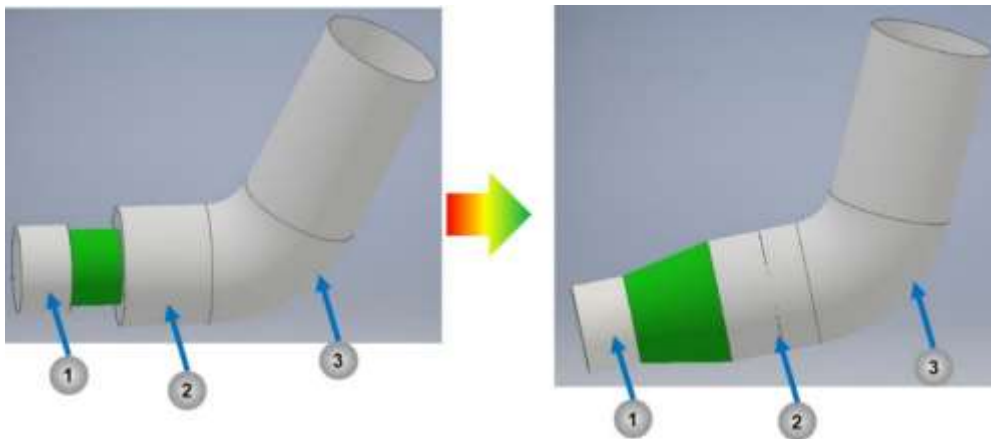


Figure 11. Changed electrical insulation part on cell connection duct.

However, this leftover has a significant impact on flow capacity and energy consumption for the cell suction. In Figure 11, the original and improved insulation part are shown with measuring points 1-3.

The effect of the described change was sketched up and simulated in CFD, and the results from the CFD clearly demonstrated a potential pressure drop saving.

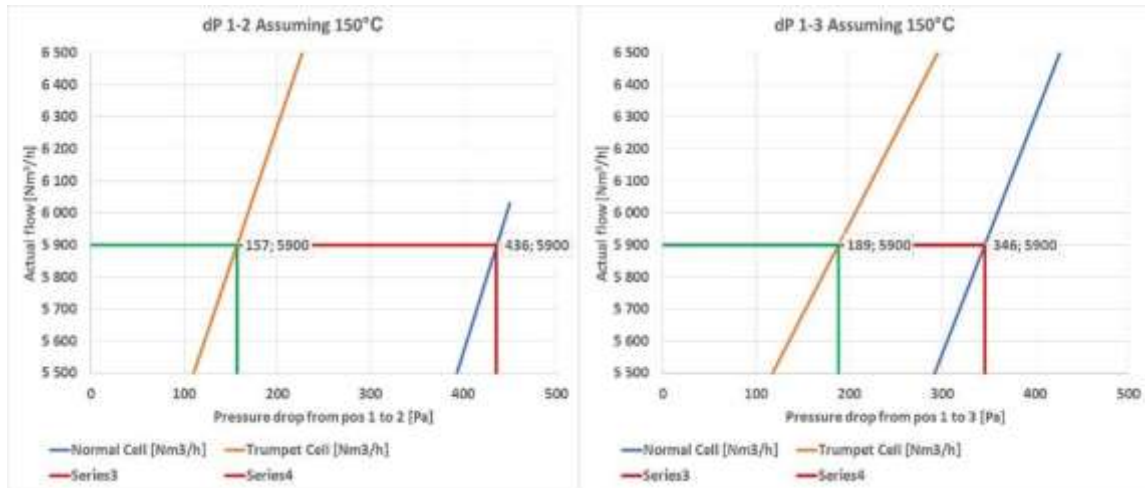


Figure 12. Pressure drop and flow from cells before and after gas duct change, from point 1-2 (left) and 1-3 (right).

From the plots above, the achieved pressure drop reduction ends up at 157 Pa which would directly save fan energy in the GTC. At the same time the pot has the flow equivalent to 122 Pa in extra suction capacity. This solution is being implemented first at suction challenged cells, so far 6 %, and then a full implementation will be done as soon as possible due to the high energy saving potential.

3. Alumina Dose Silos

Although, the feeding of alumina does not directly affect the GTCs, the Bulk Solids Handling of the alumina often falls to GTC personnel. Moreover, the functionality of the feeding equipment influences all the operations and performance of a cell - if not working, open cell time and thus environment impact increases. The cell silo for alumina at Albras is filled by the Pot Tending Machine (PTM) and has a fluidised bottom to be able to discharge the alumina out of the silo through the feeder. During inspections, many of these fluidisation cloths were found to be severely damaged, Figure 13, resulting in not being able to discharge the silo completely.



Figure 13. Fluidising (left) ruined old polyester fabric, (right) new aramid quality.

So far (23/08-2018) the conversion to the new type fabric has reached 26 % of all cells. When not being aware of this, the dose signal from the control system side is given, but there is no material feed and likelihood of anode effects increases. When becoming aware of this one would need to top up these silos more often to get material out of them, and hence use valuable PTM time. As a solution, the type of fabric to be used was changed, and there has been an intensified effort to replace damaged pads. The new fabric withstands better the conditions in the bottom of the silo on the cell, both chemically and heat, hence having a longer life time expectancy. With all silos in working order, opportunity to keep control of the alumina concentration in the electrolytic bath has improved. The other important effect of this change of

fabric is that the availability of the PTM increases. This because the filling and discharge intervals now fits with the consumption of the cell and the silo volume. However, increasing the Line current will interfere with this balance and some correction must be done in the future.

4. Conclusions

The collaboration between Hydro and Albras, seen from a GTC/ Environmental point of view, has been materialising itself in various implementations. The improvements have been low cost with high impact, preparing Albras for future production increase and better process stability.

The GTCs have been assessed and found sufficient - given that the surrounding facilities are working adequately, i.e. systems such as ducting and raw material feed.

A method to ensure good utilisation of the GTCs, an effective simple method of keeping the suction balanced between the cells, has been invoked, and are giving results.

Internal suction balance of the cells has been defined, and are currently implemented on 62 % of the cells, and the results are demonstrating better hooding.

Potential to increase suction from cells and at the same time save fan energy has been found through optimisation of the electrical insulation part and are currently being implemented on the cells, 6 % up to now.

Experience concerning type of fluidising fabric has been shared. 26 % of the cells are now up-graded, and the alumina silos on these cells are now functioning as intended and should last longer, increase the filling intervals and the availability for the Pot Tending Machines.

5. Further Work

During the collaboration, an external supplier for side covers has been involved, and currently a test batch of covers for 32 cells, 500 covers, has arrived at Albras. These will soon be used in a comparative test, to determine the exact effect.

As Albras aims to have more efficient production. However, the alumina filling of the cells using the pot tending machine now claims to much time, hence a closed automated alumina distribution system is being surveyed.

Moreover, as the production increase, the buffering silos in the GTCs are becoming too small. Work on how to increase the buffer capacity integrated with existing GTCs have commenced.

6. Acknowledgements

Such efforts carried out over time in collaboration between Hydro and Albras results in many people to acknowledge from both present and historically. Without support and contribution from the following, these and future actions would not be possible. Tammy Monteiro Da Costa Antunes, Marcella Fernanda Ferreira, Fernando Rocha De Menezes, Fabio Jardim da Costa, Kurt Jan Nilsson, Pål Vigeleand, Kjell Edgar Sagen, Norunn Hegna, Jose Carlos Saki Jr., Sergio Antonio Costa de Matos, Knut O. Austreid, Thorvald Mellerud, Sven Sundgot, Joao Batista Fialho de Menezes. Thank You All.