Concepts for Alumina Handling in Smelters - Efficiency from Port to Pot

Jan Paepcke[1], Arne Hilck[2], Michael Altmann-Rinck[3] and Andrej Meinhardt[4]
1. Territory Sales Manager,
2. Group Manager Technical Center,
3. Senior Sales Manager,
4. Sales Manager,
Claudius Peters Projects, Buxtehude, Germany
Corresponding author: arne.hilck@claudiuspeters.com

Abstract

The aluminium production depends on a stable and constant flow of alumina. Variations in particle size of the material effect the smelter operation. Investment cost for transport and storage need to be as low as possible. The handling system should only need low maintenance and the system should be as energy efficient as possible. In this paper different concepts of storage, handling and conveying of alumina are described. Based on laboratory tests with different materials and field experience the methods of conveying are compared. With modifications to existing plants there are different requirements compared to new installations, which would allow for completely new concepts for the layout of the system. There is no One-size-fits-all-solution.

Keywords: Alumina conveying, alumina attrition, efficiency of conveying, storage.

1. General Criteria for Decisions

The criteria of a transport system are mainly easy to describe, low cost, no disturbance.
In detail the question is more complex. With Greenfield Installation the decisive factor is only the cost, Capex-cost. Technical requirements, like conveying capacity, or storage capacity are defined in advance and suppliers respond to these requirements. In most cases the cheapest system is chosen, technical advantages that come up during the negotiation process are in most cases not considered, as this would start a new cycle of negotiations.

The same applies for technical advantages that a system from one supplier might have towards other systems, for example: maintenance cost or other life cycle aspects, as these are often not considered. With changing general preconditions for the installation other aspects like environmental aspects or aspects for a fair trade could come into focus (see Figure 1).

Therefore, it is crucial to define the right parameters in advance under the given preconditions. In this paper is defined a set of general parameters for conveying and storage solutions in smelters and compares different options for these tasks.

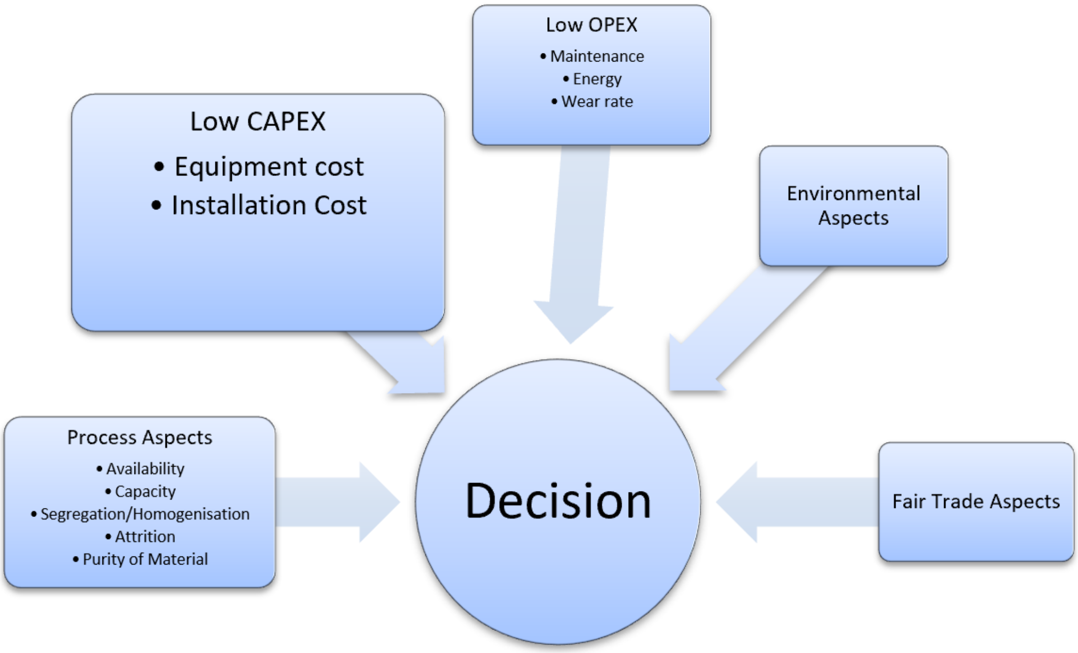

Figure 23. Factors influencing the decision to upgrade conveying systems.

In the following section we will focus on the parameters of the process and the general requirements on the different tasks that arise from these parameters.

2. Requirements from the Smelter

At the bottom line, the pot needs a stable supply of material that holds homogenous properties within a certain window of operation. The main requirements have already been comprehensively discussed in many other papers [1 - 6].

The smelter grade alumina (SGA) arriving at the pot must have very stable properties. Attrition of the material particles during the process steps upfront must be minimized. Wear on the system itself may lead to impurities in the material.

Besides these details there are some general requirements that have to be fulfilled by the transport line from port to pot. All foreign particles need to be screened from the material at the best possible position, whereby these foreign particles are likely to be parts from rail or ship transport, or from loading and unloading operations. Agglomerations could grow during road or rail transport and need to be deagglomerated or screened from the system. If the root cause of agglomerations is clear, e.g. take up of humidity in a transport step, they should be avoided as much as possible, as the effects like blockages are massive and the moisture content reduces the performance considerably.

In Table 1, the general requirements are summarized:

Table 1. Requirements on storage and handling from the process side.

Item	Target	Effect
Availability	100% at the pots, at other process steps a reduced availability maybe acceptable.	All storage and transport capacities need to sufficiently sized for this requirement from the backend. All intermediate capacities need to follow.
Homogeneous material	No segregation of fines (<45 microns) or coarse particles	Precondition is a stable material supply in a narrow property window in the beginning. Several handling steps will follow. All electrolysis cells should have the same material available at all positions, otherwise the cell with the worst material could define the operation for all cells.
Wear resistance	No impurities from transport and handling and high availability	Impurities will have an effect on material quality, high wear would have an effect on availability and maintenance cost
Screening of foreign particles	Keep foreign particles out of the system and avoid process contamination	Foreign particles could result from former process steps and should be screened out to avoid blockages or shortcuts in the process.

The logistics of the material are shown below. The operations in the logistic chain are distributed into storage and conveying operations.

In the next parts the different options and their influence on the overall process will be discussed separately for conveying and storage. The GTC process itself will not be investigated here.

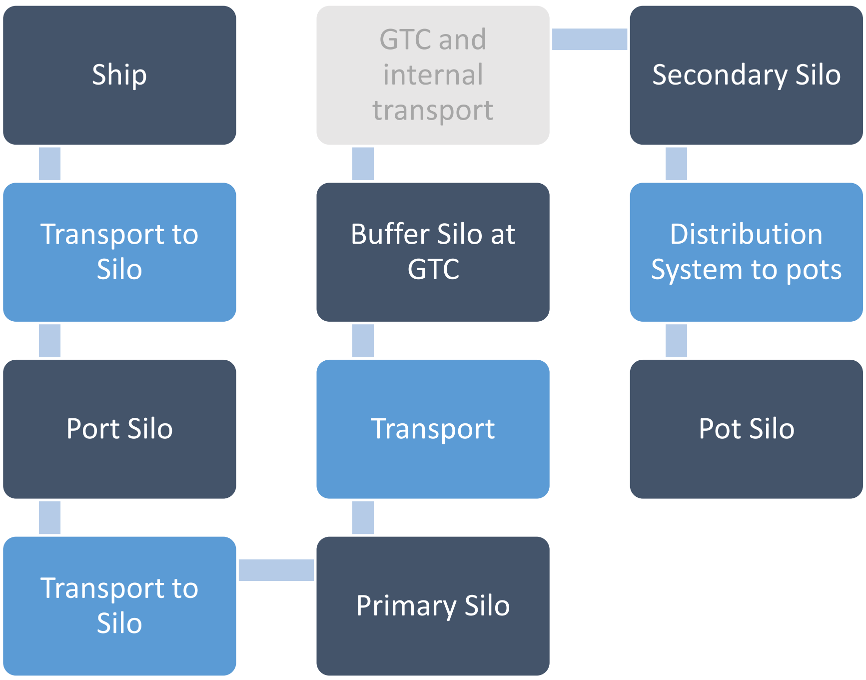

Figure 24. Logistic flow of the material with the different steps, a storage operation is shown in dark blue, a conveying (or GTC) in a light blue.

3. Storage of Material

Storage operation can have an effect on the homogeneity of the material. Dyroy investigated this effect comprehensively [2, 6]. The main influence on segregation of material is in most cases the air current segregation in conjunction with the funnel flow in silos [7, 8]. Material segregates by particle size at transfer points and inlet points into silos [6, 9]. By this mechanism fine particles travel to the perimeter of the silo and are collected there. A side effect is that the fine fraction usually carries a high degree of impurities and if the alumina is not homogeneous then an increase of the number of anode effects in pots is to be expected. When the silo is kept at the same filling level, then the fines accumulate at the perimeter while the material is discharged in the center discharge funnel only. The finer material will only be extracted if the silo is emptied without frequent filling of the silo.

One option to minimize this effect is to change standard operation procedures to allow for a variation in the silo levels at regular intervals and drain the sides of a silo as follows: When the silos are emptied to a certain degree without filling, the discharge funnel expands to the outer perimeter, thereby extracting the whole area and extracting the fines as well [5]. In this way the segregation effect can be minimized periodically.

To counteract the segregation at silos or even allow for a homogenization of the material, further measures such as anti-segregation systems are needed [6, 10]. The effect of a segregation of the particles in the air current exists for various types of storage facilities, but especially for large diameter silos with large volumes and long retention times. Here this phenomenon plays a key role. This means that for larger silos with diameters in excess of 10 m, anti-segregation measures are recommended.

In most cases for smaller silos it will be possible to modify the outlet design to prevent segregation. This is achieved as follows:

- Create a mass flow silo design to avoid funnel flow;
- Increase the number of outlets and improve the active area in a silo; and
- Work on the SOP as mentioned above.

If a segregation has occurred then it is nearly impossible to homogenize the material inside the silo again. One of the issues is that this is because it is hardly recognized as a root cause. The segregation is a result of a classification process of large amounts of material inside the silo. It would then be necessary to measure online while discharging, and screen the fine material out, store it and dose it again to the main material stream. This should be avoided and counteracted at the point of occurrence with Anti-Segregation-Systems at the feed point of silos.
In other industries, where the fluctuations of material quality with short periods are occurring on a regular basis, silos are designed as mixing or homogenizing silos. Similar installations can help in the alumina industry as well when fluctuations with a short period are occurring such as in the refinery.

4. Pneumatic Conveying of Material

Regarding the conveying of material, here the impact of segregation is much less as the retention time in the conveying equipment (not focusing on long range travelling railcars) is minimal and there is mostly a back mixing at the transfer points, which can as well be optimized by design features. So process wise the key factors will be attrition, wear and availability for the conveying. Cost wise it will be mainly the cost of installation and mush less the cost of operation as aeroslide installations need nearly no maintenance compared to other conveyors. A brief commentary on the different options is presented in Table 2 and 3.

Table 2. Different options for pneumatic conveying.

System	Impact on process items	Comment
Airlift	High velocities for lifting the material, but low impact effects at the receiving point, and only one impact point.	High air volumes at moderate pressures, resulting in a very reliable solution that is easy to maintain, but not very energy efficient. Formation of scale is notorious in these systems. Note: high wear if running at partial load.
Horizontal Aeroslide	Low velocities, but long retention time, deaeration points need to be properly sized to avoid take off of small particle fraction.	Highly reliable system, but regular cleaning and screening of coarse particles is necessary
Inclined aeroslide	Low velocities, stable operation	Higher installation cost compared to horizontal systems. Low on operational costs.
Conventional pneumatic pipe conveying	High air volumes	High flexibility of routing, but high attrition due to high impact at bends, scaling due to high pressures

The pneumatic systems do have a high flexibility for the routing, but if the conveying is done with high pressures some disadvantages arise, at least when handling secondary alumina. Mechanical systems do have less flexibility in routing and need in most cases more maintenance. Some mechanical solutions are presented in the next table.

Table 3. Mechanical conveying options compared with standard pneumatic systems.

System	Impact on process items	Comment
Bucket elevator	Low velocities, stable operation, erosive material needs to be considered by the design	Requires more maintenance and storage capacities need to be designed accordingly, vent points need to be slightly oversized to reduce fines-take off
Belt conveyor	Low velocities, stable operation, impact of dust on bearings needs to be considered by design	Requires more maintenance and storage capacities need to be designed accordingly
Closed belt conveyor/pipe conveyor	Low velocities, stable operation, impact of dust needs to be considered	Requires more maintenance and storage capacities need to be designed accordingly

A comparison on basis of installed power is done in figure 3, if a closed belt conveyor is added to the table, the installed power is in most cases slightly above the power requirements for a flat belt conveyor, due to the closing of the belt. On the other hand the closed belt has more flexibility in routing [11].

The different options are compared in the table below. There is not really a single solution that covers every aspect and every task finds her best fit solution. The long-distance conveyors will need some maintenance at regular intervals. As these are usually in use (e.g. between ship and plant) maintenance times can be planned. For vertical transports like bucket elevators there is often a standby solution available if it is in a more critical position in the logistic chain.

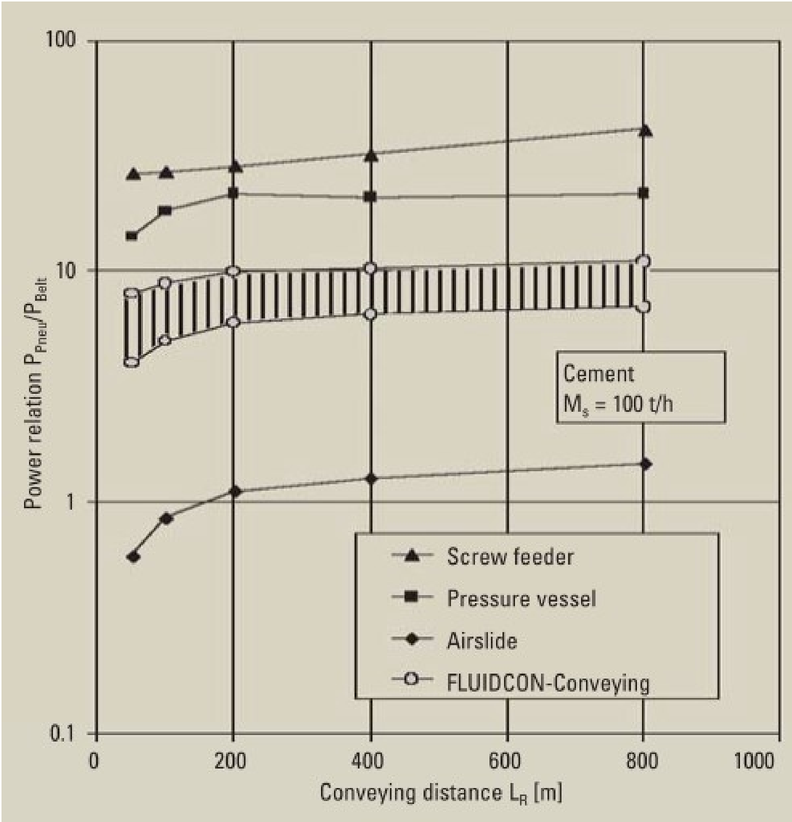

Figure 3. Installed power of different conveying systems (reference basis belt conveyor) [12].

Table 4. Qualitative comparison of conveying options (+ positive, - negative).

	Attrition	Scaling	Wear	Availability
Airlift	+	+	+	+
Horizontal Aeroslide	++	+	++	+
Inclined aeroslide	++	++	++	++
Conventional pneumatic pipe conveying	-	-	+	
Hybrid pneumatic conveying (Fluidcon)	+	+	+	+
Bucket elevator	++	++	+	**0**
Belt conveyor	++	++	+	**0**
Closed belt conveyor/pipe conveyor	++	++	+	**0**

5. Screening of Material

The screening of material plays an important role for some conveying and process steps. While screening of foreign matter, like metal pieces from loading operations is crucial for the further conveying, the screening of oversized particles can help to reduce downtime of horizontal aeroslide systems due to blockages in the system. Scale should be screened out before it can enter an aeroslide system because they will lead to blockages over time. Screens without moving parts have a slight advantage for small capacities, as the wear is minimal.

6. Material Distribution

The last process step for the powder handling upfront the electrolysis cell is the material distribution system. The main requirement is to supply consistent and homogeneous material to all connected pots. For this task often a horizontal aeroslide system is used. The problem is, however, that as conveying distances increase the retention time in the aeroslide increases as well and in that case two problems can occur. First is the segregation of coarse particles at the bottom part of aeroslides and they will be extracted primarily at the beginning of the line. If there is no screening of the coarser particles, then these may lead to blockages. The second point are the fine particles that need to be closely looked at in large installations and investigate if they can be taken out, otherwise an even particle size distribution is not possible.

As new pot lines get bigger this is becoming more and more a challenge [3, 13, 14]. In the table below different options for a material distribution are compared.
a) Pipe conveying with valves to all receiving points;
b) Horizontal aeroslides; and
c) Inclined aeroslides.

While with a horizontal aeroslide the coarse material fractions will be found more likely in the first part of the system the inclined aeroslide will have a more even particle size distribution over the entire conveying length. The overall air consumption is less, as the inclined system runs intermittently to refill pre-bins when needed.
Compared to this a pipe conveying will have high velocities and higher pressure drops in conveying distance, resulting in scaling or material attrition. If there is no inclination in the system, the coarse particles might need to be drained out at the front end of a distribution system, as the accumulation of coarse particles in the front end might affect the overall transport capacity.

Table 5. Different Options for Material Distribution [13]

		Version A	**Version B**	**Version C**
Description		Pipe conveying with separate valves	Horizontal aeroslide	Inclined aeroslide
Installation Cost				
	Supporting Structure	Only piping small size	Horizontal easy to install, but high demand deaeration	Inclined aeroslide not easy to install
	Mechanical Equipment	Minor but a lot of valves	Same as inclined	
	Installation	Very easy	Easy	Easy
	Electrical Equipment	Lot of valves	Fewer to no valves	Few valves
Operational Cost				
	Air Consumption	High	High	Low
	Air Pressure	High	Low	Low
	Wear Parts	Very high demand	Low demand	Low demand
Operational aspects				
	Scaling	Very high	Possible	Very Low
	Segregation	Low	Possible	Low
	Attrition	High	Low	Low
	Control of operation	Reasonable	Low	Very good
	Monitoring of operation	Reasonable	Low	Good

7. Conclusions

The requirements and decision parameter for different conveying equipment is highlighted. Different storage and handling procedures are compared. There is no solution that fits every requirement, but for every requirement there is a solution that fits best.

8. References

6. Peter Hilgraf, Jan Paepcke and Arne Hilck, Influence of handling parameter on powder properties, *Light Metals* 2017, 501-506.
7. Are Dyroy, Quantification and mitigation of segregation in the handling of alumina in aluminium production, PhD thesis, University of Greenwich 2006
8. Shane Pollé et al., The Challenge to Supply Consistent Alumina Quality to all Pots on increasingly longer and Higher Capacity Potlines, *Light Metals* 2016, 499- 503.
9. Stephen J. Lindsay, Attrition of Alumina in Smelter Handling and Scrubbing Systems, Light Metals 2011, 163-168
10. Ose, S. Soerhuus, S. Dyroy, A. Karlsen, M. Alumina Handling in the Smelter, Light Metals 2018, 487-492
11. Arne Hilck, Are Dyroy, Morten Karlsen, Segregation Effects during Transport and Storage; *19th International Symposium of ICSOBA*, 29 October – 2 November 2012, Belem, Brazil, Paper AL16.
12. Andrew Jenike, Storage and Flow of Solids. *Bull. No. 123, Utah Engng. Exp. Station*, Univ. of Utah, Salt Lake City, 1964.
13. Jürgen Tomas, Modellierung des Fließverhaltens von Schüttgütern auf der Grundlage der Wechselwirkungskräfte zwischen den Partikeln und Anwendung bei der Auslegung von Bunkeranlagen. *PhD-Thesis, TU Bergakademie Freiberg* (1991).
14. Peter Hilgraf, Pneumatische Förderung, Springer 2019
15. Morten Karlsen, Are Dyroy, Berndt Nagell, Gisle Enstad, Peter Hilgraf, New Aerated Distribution (ADS) and Anti Segregation (ASS) Systems for Alumina. Light Metals 2002
16. Scajin Ramjee, Phil Staples, Pipe Conveyors for Infrastructure Projects, *Bulk Solids Handling*, Vol. 35, 4/2015, 20-27
17. Jens Garbe, Andreas Wolf, Arne Hilck, Pneumatic conveying of alumina - comparison of technologies, *33rd International Conference of ICSOBA*, *Travaux 44*, 29 November – 1 December 2015, Dubai, UAE, Paper AL 08, 567-572.
18. Jan Paepcke, Arne Hilck, Sergey V. Marshalko, Operational Experience of Advanced Alumina Handling Technology in a Russian Smelter, *Light Metals* 2013, 753-759
19. Jan Paepcke et al.,Startup and Tuning of Material Distribution System at Aluminium Smelter in Qatar; *Light Metals* 2014, 743-746.