

Upgrade of Existing Cell Feeding Systems

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Abstract

The Material Distribution Systems are fully automated systems. Once installed and well commissioned they are sometimes forgotten and their influence on the process is overlooked. But there are definitely influences on the reduction process from the feeding system. As all plants worldwide have to watch out for optimization potentials, a deeper look into the Material Distribution System is worthwhile. Not only could there be a potential to optimize maintenance cost, the distribution system may as well have an influence on the material itself. This is the topic of this paper. At first the preconditions for this task are reviewed. Based on this, several laboratory investigations on alumina and other powders has been undertaken to evaluate options for the ideal Material Distribution System and as well for upgrades of existing Material Distribution Systems.

Keywords: Cell feeding system, material handling, energy efficiency, conversion of cell feeding system.

1. Introduction

Smelters are in operation for several decades. Capacities of the potlines are increased during this time. The auxiliary equipment like the material distribution equipment is sometimes a limitation for the process or has to be upgraded as capacity is increased. But there might be other issues, which effect the decision for an upgrade or a modification of an existing distribution system. The conveying process could as well have an effect on the material properties and there will be a feedback to the conveying and the smelting process. Attrition or segregation are examples, to name only some of them. In this article, the different effects that varying parameter will have on the behavior of the material are highlighted. To verify these effects extensive tests with several materials have been performed, references [1, 2, and 6]. For the particle sizes present in the alumina industry, the very fine fraction is often the fraction responsible for flow problems. So if looking at a mixture of materials, the question is, how much poorly-flowing fine material, e.g. from particle attrition and fracture, can a free-flowing coarse material tolerate without any significant change in its flow characteristics?

The first part of the investigation has already been presented in [1] and will only be summarized briefly. The second part of the investigation was the wear behaviour of the material and fluidization tests. In a next step the different criteria for a decision for upgrade or modification of a conveying and distribution system are highlighted. In the third step, some option for modifications are introduced.

2. Theoretical Considerations

The flow behavior of bulk materials is essentially determined by the adhesive forces acting between the individual particles in relation to the external forces acting on the mass of bulk material. This means that the respective packing structure of each mixture, i.e., compacted, loosely packed, fluidized, etc., influences the behavior of the mixture. Mixtures of two dry,

spherical monoparticulate fractions with a particle diameter ratio of $R_d = (d_{s,f} / d_{s,g}) \rightarrow 0$, $d_{s,f}$ = diameter of fine particles, $d_{s,g}$ = diameter of coarse (gross) particles, are in theory easy to describe and are used as a model for the bulk material mixtures consisting of a very fine and a coarse fraction which are examined here. A more comprehensive approach is given in [2].

The mixtures are characterized by their mass share of fine material, x_f :

$$x_f = \frac{M_{s,f}}{M_{s,f} + M_{s,g}} \quad (1)$$

If an increasing quantity of fine material with a relative void volume of ε_f is mixed into a coarse material with a relative void volume of ε_g then the free space between the coarse particles is initially filled by the fine material without causing any increase in the total volume $V = V_s + V_g$ of the mixture, where V_s is the volume of solids and V_g is the volume of the gas in the voids. As the voids are filled, the packing density of the solid material increases and the relative void volume of the mixture ε_M decreases. When the available volume between the particles of coarse material is completely filled up, any further addition of fine material will lead to an enlargement of the particle structure, i.e., the relative void volume of the mixture ε_M increases again. These interrelationships are depicted in Figure 1 for loosely packed coarse ash/fly ash mixtures with $\varepsilon_g = 0.5054$, coarse ash, and $\varepsilon_f = 0.6708$, fly ash (compare [1 - 3, 5 - 7]).

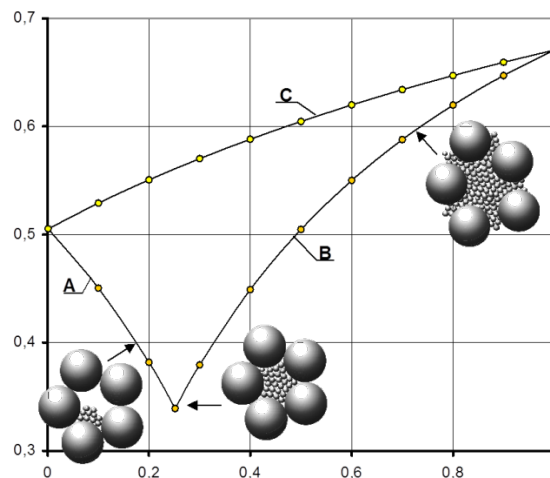


Figure 1. Relationship between relative voidage volume (vertical axis) and relative fines content (horizontal axis) [2, 5]. Relative volume is defined with respect to total volume.

For the case analyzed here, $R_d \rightarrow 0$, the two lower curves A and B apply. All the ε_M values of dual-particle mixtures, consisting of spherical or approximately spherical particles, are located between the three limiting curves A-B-C.

An analysis of the structure of the coarse particle fraction shows that its void volume consists of larger voids between the coarse particles and narrower connecting channels between these voids (compare [2], [8]). Without causing any expansion of the structure, only fine material particles with a maximum diameter of $d_{s,FK}$ (filler particles) can fit into the interparticle voids. In the case of practical, i.e. unstructured, dual-particle mixtures above grain size ratios of

$(d_{s,f} / d_{s,g}) > 0,50$ the addition of fine particles almost always leads to an immediate enlargement of the coarse particle structure. Consecutively there will be a continuous alteration of bulk material properties with changing ratio of fine fraction x_f . From a certain point, the fines content is dominant and a further increase does not result in an increase in strength [2]. The expected course is shown in Figure 2.

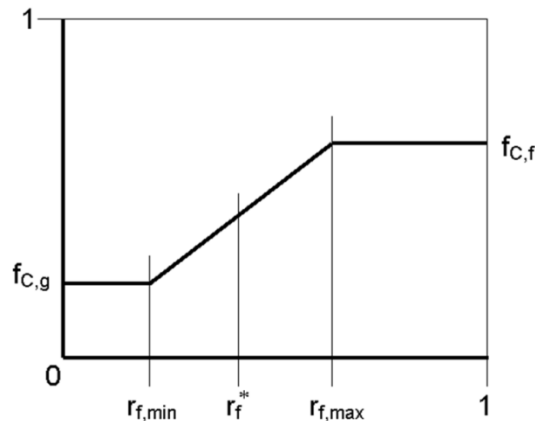


Figure 2. Expected course of compressive strength versus share of fines in the material [2].

For the main investigation, a larger sample of secondary alumina was split into several fractions. Additionally other material samples were used for further tests. The different materials are listed in Table 1.

Table 1. Material used for the investigation.

Material		Batch Number
Alumina Hydrate	Median diameter 90 μm	A
Primary alumina very fine	Very fine fraction $d < 5 \mu\text{m}$	B
Primary floury type of alumina	Complete material sample	C
Secondary Alumina	Complete Material Sample	D
Secondary Alumina Very Fine	Screened $d < 20 \mu\text{m}$	D1
Secondary Alumina Fine	Screened $d < 45 \mu\text{m}$	D2
Secondary Alumina Coarse	Screened $d > 100 \mu\text{m}$	D3

3. Measurements on Particle Size and Material Behaviour

Depending on the material different tests were initiated. The following tests, listed in Table 2 are presented.

Table 2. Tests covered in this paper.

Tests initiated	Material	Batch
Shear Tests	Several Mixtures of fine and coarse secondary alumina	D, D1, D2, D3
Aeration behavior	Different grain sizes of secondary alumina	D, D1, D2, D3
Deaeration behavior	Various grain sizes of secondary alumina	D, D1, D2, D3
Wear tests	Various tests with varying impact velocities	D, C
Long time aeration	Secondary Alumina	D
Horizontal conveying	Secondary Alumina	D

3.1. Shear Tests

Shear Tests allow for a reliable judgement of the storage and handling behaviour of a powder. In the shear test the material is compacted with a certain load in vertical direction and sheared in horizontal direction. Shear tests allow for a detailed insight into the storage and handling behaviour of a powderous material [9 - 13].

Shear tests were carried out with the reference sample for secondary alumina and several mixtures of fine and coarse material. The monoaxial compressive strengths f_c are considered at the compaction stress $\sigma_l = 4600$ Pa. Different ratios of mixtures of fine and coarse material are shown in Figure 3.

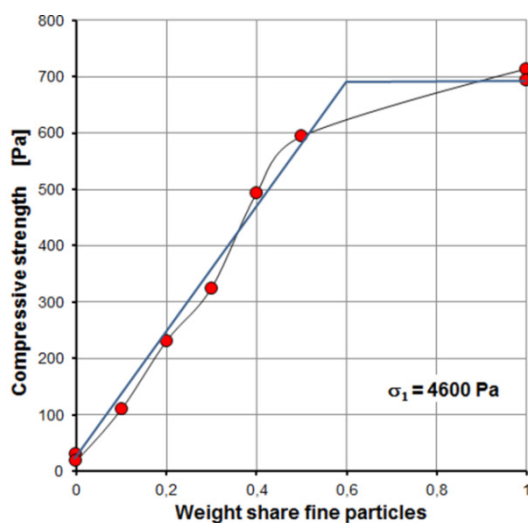


Figure 3. Compressive strength of different weight share of fine material [1].

It can easily be seen, that increase of the fines results in a higher compressive strength of the material. In other words addition of the fines results in an in general more cohesive material. But with a small amount of fines added the effect is nearly negligible. It needs to be noted that the results from the tests correspond with the theoretical considerations, that from a certain amount of added fines, the cohesion of the fines fraction is dominant and the strength of the mixture is on the same level as the complete fine fraction (compare [2]).

From these tests, the flow factor (ff) is generated:

$$ff = \frac{\sigma_1}{f_c} \quad (2)$$

where: f_c Compressive strength and
 σ_1 Principal consolidation stress.

A high number of the flow factor indicates a good flowability, while a small number means a material with a poor flowability (see Figure 4)

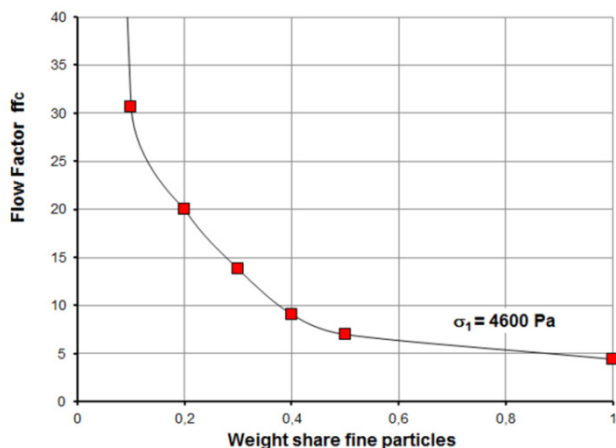


Figure 4. Flow factor versus weight share of fine particles [1].

As the consolidation stress is kept constant, a lower compressive strength leads to high numbers for the flow factor. But even though there is a decrease in flowability with an addition of fines, compared with other known materials, the fraction passing 45 μm is still material with a reasonable flowability (see [13]).

3.2. Aeration and Deaeration

The particle size does massively affect the fluidization behavior [14]. The interdependence is well known in all industries using fluidization technologies. Smelter grade alumina is usually easy to fluidize, and has a very high air permeability. When aeration air is stopped the material will settle very fast. If only separate particle fractions are fluidized the resulting effect is different. For a comparison of this behavior the powder is fluidized with a defined velocity, while there is pressure transmitter installed in the air supply. The pressure will indicate the load above the air column. When the air supply is stopped suddenly, the pressure will drop to zero. The timing for this pressure drop will be stopped.

In Figure 5, this was done for different material fractions. One line shows the deaeration with stirred materials (material in movement), while the second line shows the values without agitating. The two large material sizes show a very quick pressure drop. The fraction of particles < 45 μm has a very long duration to come to rest.

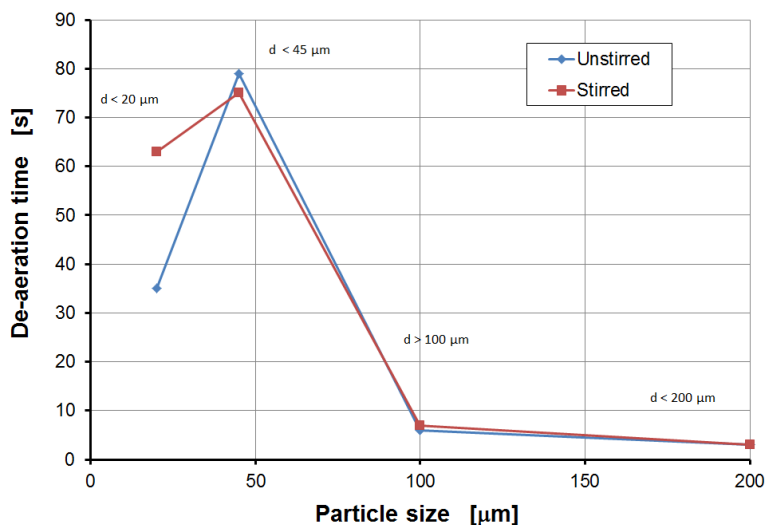


Figure 5. Deaeration time versus particle size [1].

With a very fine fraction it is easily possible that stable channels are formed, therefore there is a huge difference visible between stirred and unstirred aeration time on the left side of the graph.

3.3. Permanent Aeration

A test with a vertical standpipe was carried out, which has been aerated with a constant air velocity. In the standpipe test the aeration was running for 1 h with a material column of 300 mm in height. After the aeration was stopped the material was screened out in three different elevations (Figure 6).

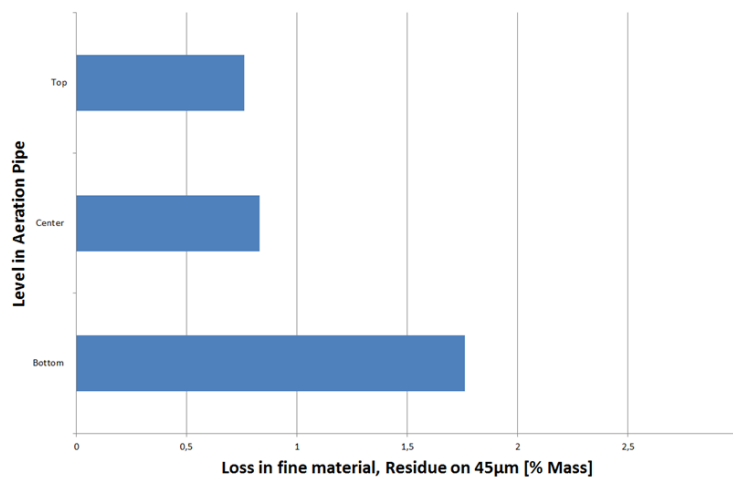


Figure 6. Loss in fine material at 3 different elevations of aeration pipe [1].

With a long aeration time the fine material fraction ($> 45 \mu\text{m}$) obviously did not even travel upward in the material, but easily it escaped into the deaeration. This would be especially the very fine material less than $20 \mu\text{m}$ in size.

3.4. Test for Horizontal aeration

For the second test a horizontal aeroslide (Figure 7) was aerated for a certain time and afterwards the aeroslide was emptied with a very low discharge rate to simulate condition in the horizontal system. This test would identify the take-off behaviour of the fine particles and the movement of the coarser particles. Following the discharge of the particles, the rest of material in the aeroslide (approx. 10 mm in height) and the material at the receiving point were screened and the values were compared with the material properties of the feed material.

In the Figure 8, left, the result of the screening $45 \mu\text{m}$ can be seen, a significant part of the fine particles escaped to the deaeration and only the coarser particles remained in the system.



Figure 7. Test aeroslide rig.

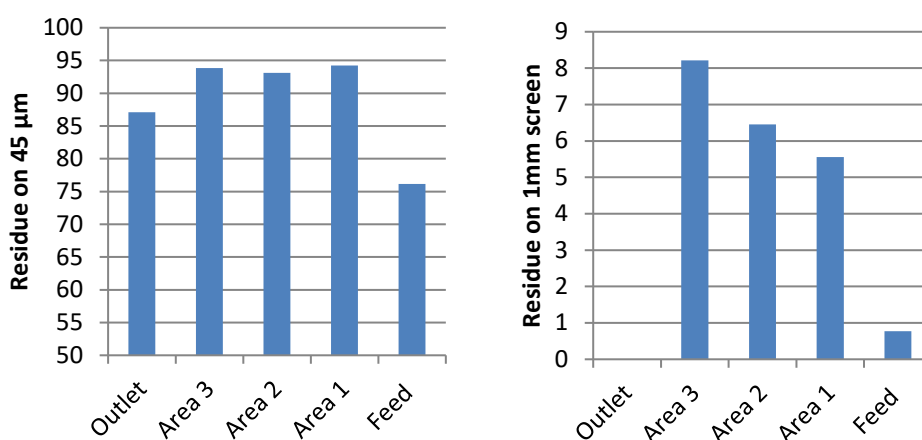


Figure 8. Residue on 45 μm (left) and on 1 mm (right) after long term aeration and discharge.

A second screening of the particles showed, that the coarse particles were kept at the bottom of the aeroslide and did not travel to the outlet, which was only 10 mm above the fabric. So, every small step in an aeroslide will create disturbances, even with very low conveying velocities.

3.5. Wear/Fracture Tests

With Yancy-Geer-Price test device (see [24]), commonly named YGP-tester, different impact velocities to a material can be simulated. It mainly consists of a rotor with an adjustable speed with attached wear plates and usually its purpose is to help predicting wear rate. In this case it was used in the opposite sense to detect the impact velocity, at which material starts to crack. This would help to identify a velocity, which a pneumatic conveying should not exceed to prevent massive attrition.

Tests with a material with an extremely high tendency for attrition showed the following results (see Figure 9). With increasing velocities significant increase in fine material can be seen.

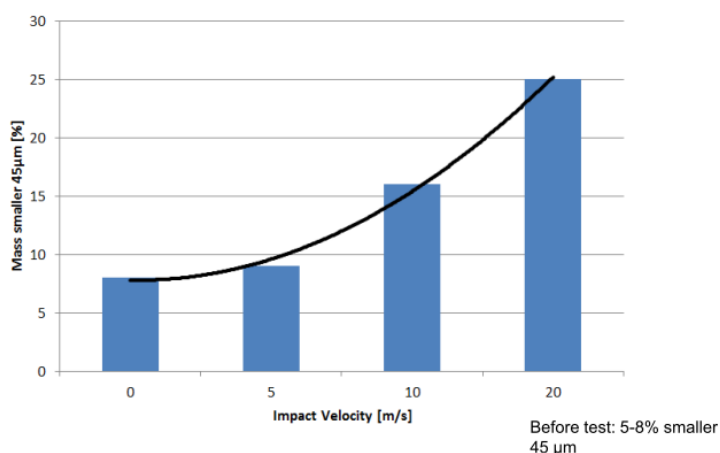


Figure 9. Different impact velocities and increase of fines.

The material in a later case was a floury alumina with a very high attrition tendency. As a conclusion at least this material would really need extremely low velocities.

Table 3. Results of powder investigation.

Tests initiated	Results
Shear Tests	Changing grain sizes changes flowability, but only superfines rapidly reduces flowability
Deaeration/Aeration behaviour	Alumina shows “friendly” behaviour, but control behaviour is affected by changing grain sizes
Deaeration behavior	Various grain sizes of secondary alumina
Attrition tests	From a certain impact velocity, particle breaks, so low differential velocities are preferred
Long time aeration	With a long time aeration the fine material fraction escapes (into the gas duct)
Horizontal Aeroslide and Longtime fluidization	Laminar separation of material,

4. Criteria for Upgrade of Existing Cell Feeding Systems

Several factors can be influential, when a system is squeezed to the limits. It is very important to know the limit of a conveying system, before the limit is reached, because otherwise it will affect the cell operation. If frequent maintenance is already needed to a system before a capacity increase, the window for maintenance work will be minimized after a capacity increase. The margin for unforeseen maintenance is then reduced. If a capacity increase needs an upgrade of velocities or pressures of a system there might be an effect on the operation of the system and, e.g., the scaling rate might increase. The size of intermediate storage capacities might be critical as well and might need an upgrade.

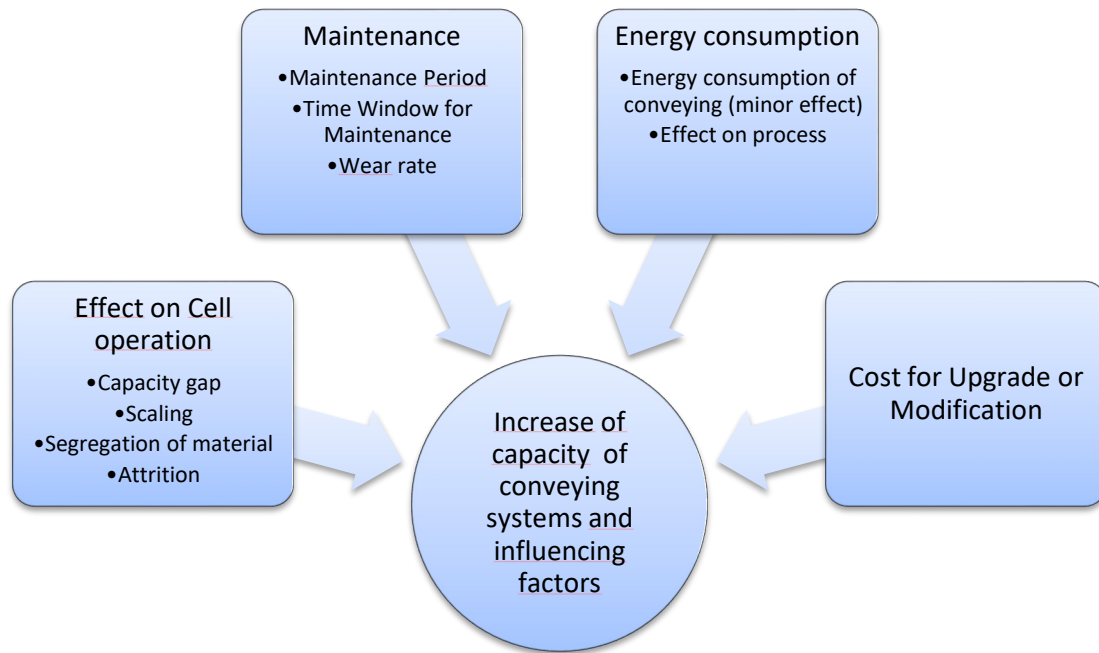


Figure 10. Factors influencing the decision to upgrade conveying systems.

Besides the capacity of the conveying there are several other factors leading to decision criteria for the question upgrade or modification. The main items are the operational safety and the timeframe for maintenance or modification.

5. Hybrid-FLUIDCON-Cell-Feeding (FCF) - An Option for Upgrades?

The FLUIDCON-System has been introduced to the market of conveying systems by Claudius Peters only 15 years ago [17, 18]. The frequently growing number of copies of the system proves the beauty of the idea. The system is a combination of an aeroslide conveying a conventional pipe conveying. The difference to existing systems would be the aerated lower part of the conveying pipe. By this means, it would be possible to reduce the necessary conveying velocity and necessary pressure difference for conveying of material significantly. Reduced velocity and reduced pressure would allow for a higher capacity of a system at a given air supply and reduced negative side effects.

The Fluidcon allows for significantly lower conveying velocities compared to conventional pipe conveying systems. The modular arrangement allows for new installations of conveying systems but as well for replacement of old systems. A cell feeding system based on the FLUIDCON-idea was proposed already by Wolf and others [16]. The next step would be to use a mixed system of FLUIDCON as a solution for upgrade of existing conveying systems. The difference to existing systems would be the aerated lower part of the conveying pipe. By this means it would be possible to reduce the necessary conveying velocity and necessary pressure difference for conveying of material significantly. Reduced velocity and reduced pressure would allow for a higher capacity of a system at a given air supply and reduced negative side effects. The routing of the FLUIDCON-system would go either horizontal or with inclination, so several different arrangements are possible. In most cases the FLUIDCON-system can follow the already existing routing.

An example of the system is given below. In this particular case, from an existing system the feeding on the cells is done with a FLUIDCON-system to overcome blockages by coarse particles.

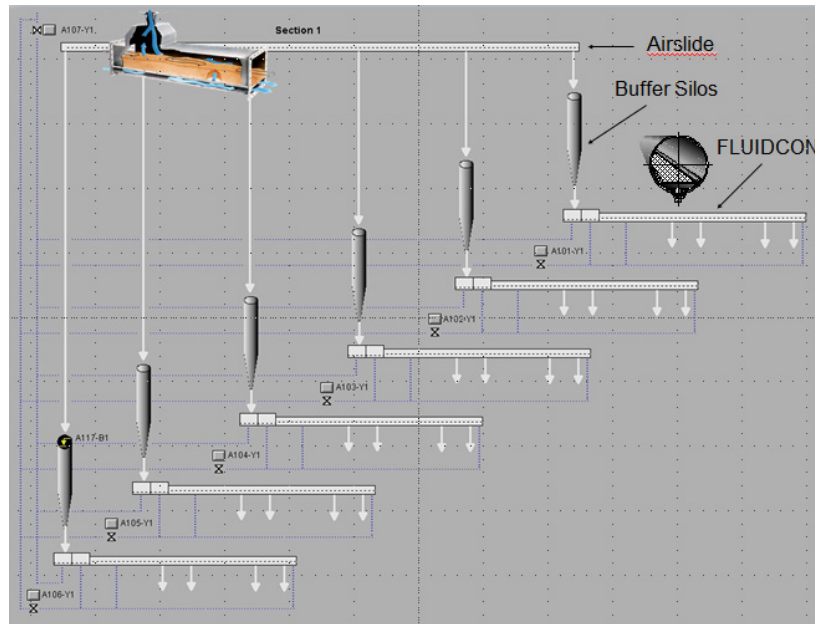


Figure 11. Example of a hybrid FCF-System.

Several factors might influence the decision how to proceed forward. Restrictions regarding dimension or regarding air consumption will influence the actual condition. So every case must be evaluated in detail.

6. Outlook

Several laboratory investigations have been made to evaluate influencing factors of particle size distribution and material behaviour of alumina. Target was to assess the effects, that changes in the conveying parameter will have on a system already installed and to determine the magnitude of these effects. The fine fraction will always create the most headache and the generation of fines has to be avoided or reduced. Looking at upgrades of existing installation, a Hybrid FCF-system will be advantageous. But only a detailed calculation from case to case will give clear answers.

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