Increased Flow Rate and Reduced Filtration Cost by Using Scale Retardant Filter Technology for Bayer Liquor Clarification

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Abstract

Alumina pregnant liquor clarification is carried out in horizontal and vertical pressure leaf filters. In dependence of Bauxite composition and conditions of digestion, scale containing different elements can crystallize on the filtration equipment. The scale reduces volume of tanks, flow in pipes and throughput of filter media. In order to maintain the flow rate through the filter media, a regular caustic cleaning is performed. However, despite cleaning cycles, an unavoidable reduction of liquor flow is observed from cycle to cycle. Eventually, scale growth reduces the flow rate to a minimum value that triggers the need for filter refurbishing. For plants, which experience bad control of flocculation, it can instantly clog the filter media and decrease the flow. This requires a rapid replacement of filter bags, since the combination of flocculent and scale makes the flow recovery almost impossible. Sefar x-Scale filter media technology was developed with the aim to delay scaling on the filter bag surface during clarification operation. The solution comes from combining optimized spinning parameters with an improved yarn formulation and from using EPDM components for filter bag manufacturing. The results presented in this paper show the liquor flow rate achieved with x-Scale filter media is more constant and decreases slower when compared to conventional filter bags. The improvement of flow, along with the service life increase, provide a reduction in filtration cost. This paper describes the approach and field results achieved, using Scale retardant filter technology.

Keywords: Bayer liquor clarification, pressure leaf filter for alumina, Sefar x-scale technology, scale retardant filter media.

1. Introduction

1.1. Scale Composition

Bauxite is an ore of variable composition containing often-undesired elements. Silica and Titania are, for instance, among these undesirable elements. Once solubilized in the conditions of digestion of the Bayer process, these elements react very quickly to form crystalline solids. The products of crystallization, combined with aluminum hydrate ($Al(OH)_3$), can form a hard layer on equipment and filter media surface, commonly known as scale. Scaling during pregnant liquor clarification is a major issue for filter equipment and filter media used in the Bayer process. It limits the service life of filter bags and consequently increases the cost of ownership and maintenance efforts. The scale forms particularly in the filtration area during the liquor clarification process, when the alumina- saturated solution starts to crystallize on any available surface (Figure 1).

Figure 1. Scale on top of the pressure leaf filter before filter bag refurbishing.

Depending on the bauxite origin and composition, the scale normally contains alumina trihydrate ($Al(OH)_3$) but can also contain other solids like iron oxide (Fe_2O_3), tricalcium aluminate ($3CaO \cdot Al_2O_3 \cdot xH_2O$) or sodalite $Na_6[Al_6Si_6O_{24}].2NaX \cdot 6H_2O$, where X can be OH^-, Cl^-, NO_3^-, ½ CO_3^{2-}, or ½ SO_4^{2-}. Figure 2 shows the scaling on the filter bag surface at the end of filter bag lifetime.

Figure 2. Scale on the filter bag during filter refurbishing.

1.2. Impact of Scaling on Clarification Process

Even though periodical sodium hydroxide cleaning sequences in between filtration cycles are performed, the few soaking hours in 200 - 450 grams per litre of Na_2CO_3 solution at 80 – 100 °C can't completely regenerate the filter media. The hydrate crystals strongly attach to the filter media yarn surface, seeding scale growth (Figure 3) and slowly but consequently block the filter media pores.

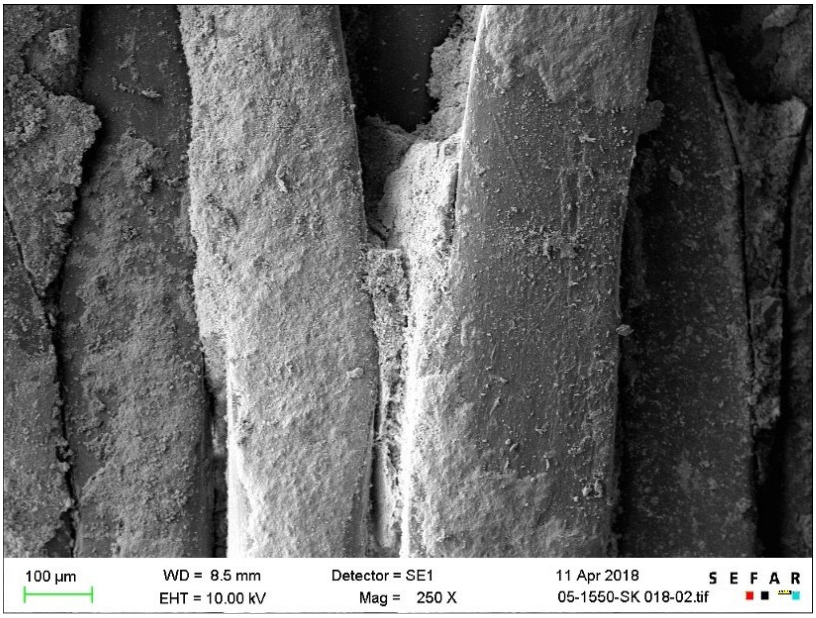

Figure 3. Magnified filter media with scaling on yarn surface.

A reduction of liquor flow through the filter media occurs over time (Figure 4) and a filter bag refurbishing gets necessary.

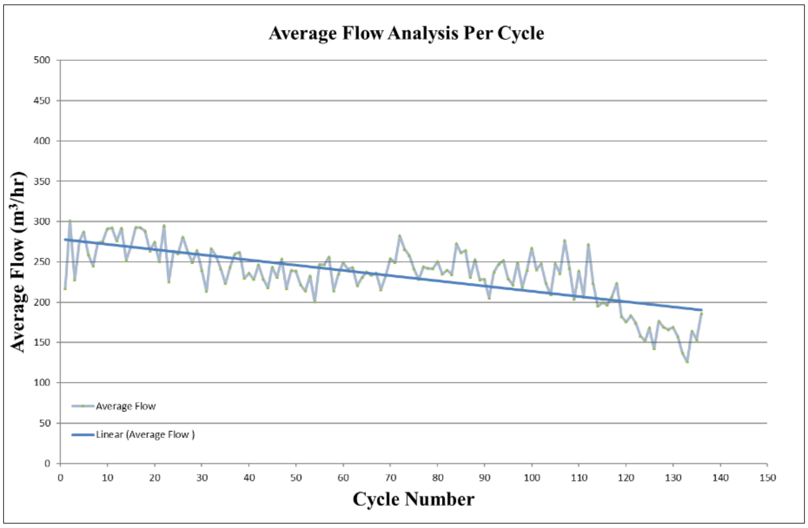

Figure 4. Average liquor flow over time.

By optimising the material, components and manufacturing processes of filter bags, it is possible to delay scaling. Together with major alumina refineries, Sefar has developed an answer for better handling of scaling, called the x-Scale technology. This paper presents the results from the field, using scale retardant filter technology.

2. Experimental

2.1. Effect of Yarn Formulation on Scaling

The filter media utilized for Bayer liquor clarification is mainly made of Polypropylene (PP) monofilament yarns. PP is often identified as if it is a single material, but in fact, it is a family of materials. Each member has a different mechanical, thermal and chemical behavior.

Polypropylene is made of many monomers attached together. The number of monomers in a polymer chain varies. Figure 5 shows the results of a size exclusion chromatography analysis obtained for three different yarns all made of 100 % PP. The size exclusion chromatography gives the weight fraction in function of molar mass. The molar mass is directly related to the number of monomers composing the molecular chains of the spun yarn.

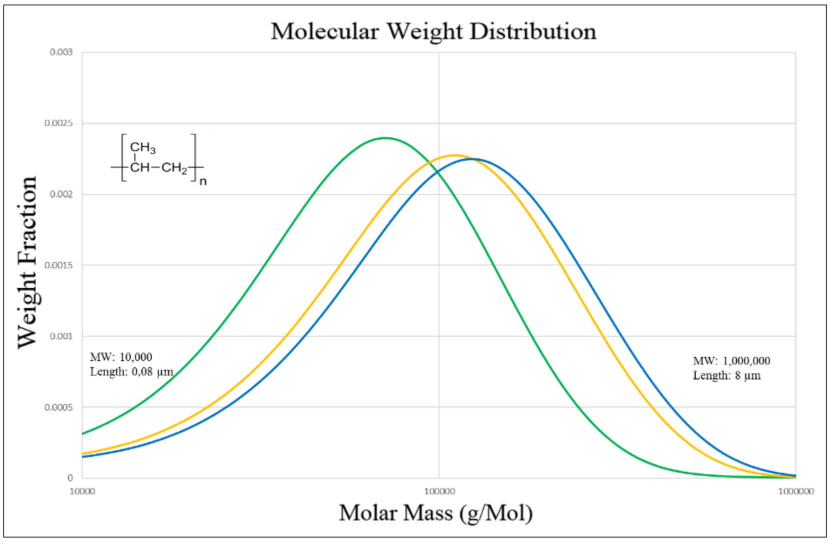

Figure 5. Molar mass distributions of PP.

The mean molar mass values for the three yarns are 84 000 grams, 130 000 grams and 146 000 grams. The differences of molar mass is quite important and affects the thermal properties of yarn. The most suitable molar mass distribution in terms of thermal oxidation resistance was chosen because any oxidation of the yarn surface results in increased scaling. To further increase oxidation resistance, chemical additives are added to the polymer formulation. The improved formulation (IF) utilizes best possible combination of polymer molar mass distribution with a mixture of three different additives to obtain best possible resistance- without compromising the mechanical properties.

2.2. Effect of Spinning Parameters on Scaling

Another factor affecting scaling is the crystallinity of the yarn. The crystallinity is influenced by the spinning parameters during yarn extrusion. It has an influence on surface morphology and oxidation resistance. Figure 6 presents a schematic drawing of yarn microstructure with the lines representing the PP chains of monomers. When these chains are organized, they form crystalline regions - if not, they form amorphous structures. The thermal profile during yarn spinning determines the proportion of each form on the surface. The ratio of amorphous and crystalline regions influences the yarn surface and in thus, the susceptibility to scaling.

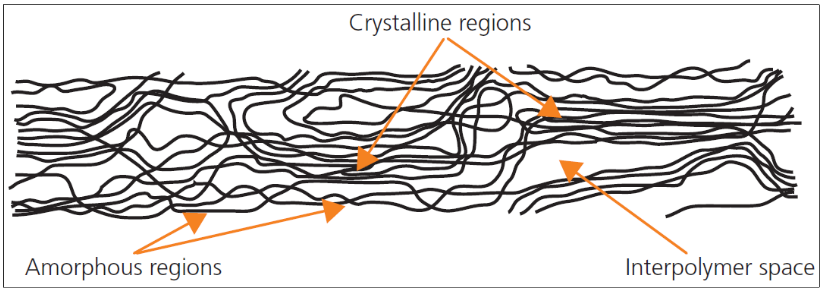

Figure 6. Schematic drawing of PP yarn.

2.3. Conditions of Plant Test

To avoid oxidation and obtain a smooth yarn surface, the formulation and spinning conditions were optimized without compromising on mechanical properties. The improved yarn formulation (IF) is called "Sefar x-Scale" technology and was used to weave a filter media, similar to the one, produced with the standard yarn formulation (SF). The two filter media were compared in various plant tests. In order to get a reliable comparison, one pressure leaf filter was equipped with IF filter media next to another filter with SF filter media. Both filters were brought online at the same time and were fed from the same tank. Figure 7 shows the schematic set up of the test configuration.

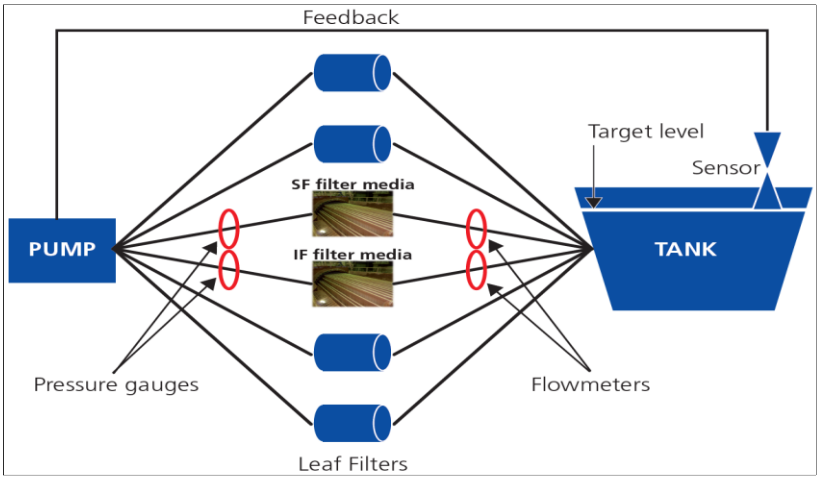

Figure 7. Test configuration of pressure leaf filters.

In the configuration of the plant and as the pressure of the feeding pump is variable and controlled by the level in the filtrate tank, it is necessary to record flow and pressure to compare the filter media. During the filtration cycle, the flow decreases due to the cake resistance. Figure 8 shows a typical flow pattern for subsequent cycles. When the scaling is getting more severe, the liquor flow decreases. In order to get a comparison, only the flow at the start of the cycle was taken into account, when the cake is thin and the filter media itself mainly causes the flow restriction.

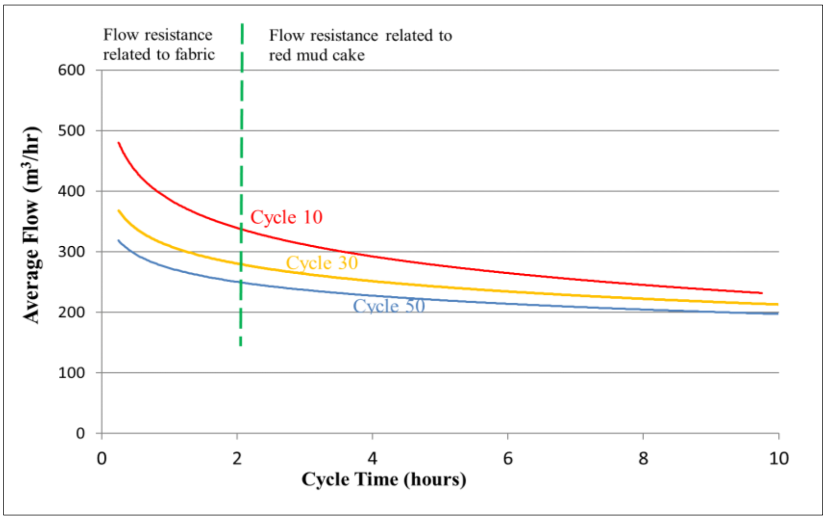

Figure 8. Typical flow pattern.

2.4. Filter Media Results in Regular Process Conditions

The starting flow and pressure/ flow ratio can vary from filter to filter due to the conditions of the filter leafs, scale in the pipes and distance between filter and liquor tank. Therefore, it is more important to compare the slope than the initial flow. Figure 9 and Figure 10 are the plots of the flow and development of pressure/ flow ratio achieved for each cycle for IF and SF filter media. Filtration time of each cycle is 10 hours. The results show clearly, that the slope of the filter operated with IF filter media is more constant and decreases slower, providing a higher number of cycles above the lower limit of flow accepted by the plant.

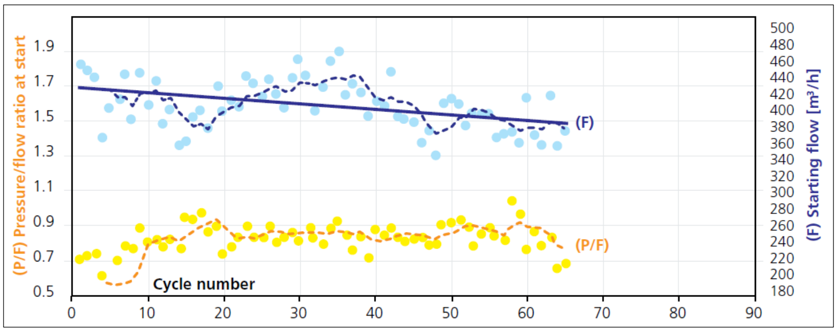

Figure 9. Flow and pressure/ flow ratio using SF filter media.

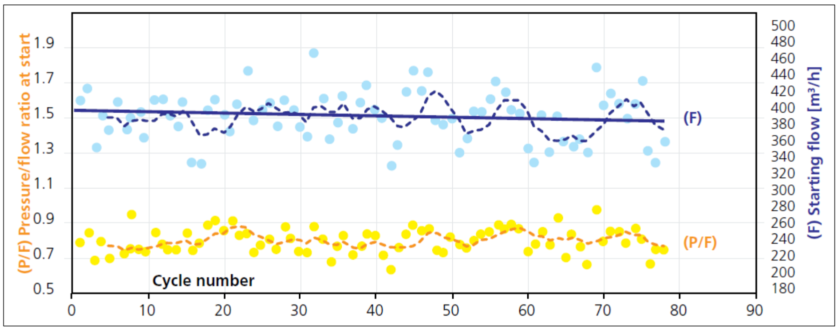

Figure 10. Flow and pressure/ flow ratio using IF filter media.

In order to verify the effect of the IF filter media, another test was performed in a different plant. This time, the total amount of filtrate was measured during each cycle. The Figure 11 presents the average flow for each cycle, comparing IF and SF filter media.

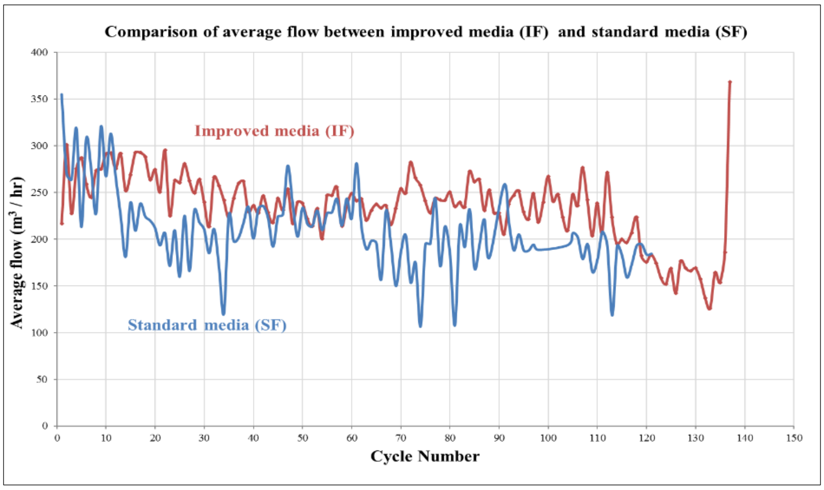

Figure 11. Average flow comparison IF and SF filter media.

Figure 12 presents the average flow during lifetime. The IF filter medias' average flow was approx. 25 % higher than the SF filter media compared during 120 filtration cycles. Suspended solids in clarified liquor also met the plant's requirements.

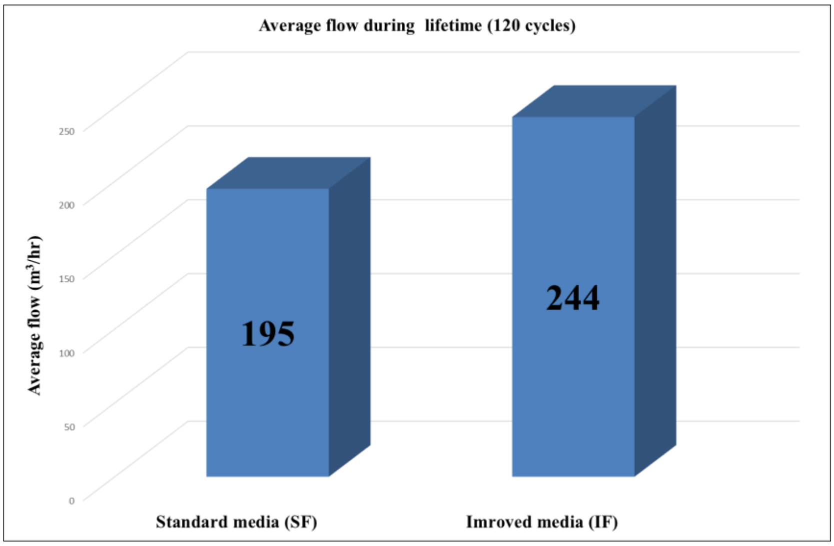

Figure 12. Average flow comparison between IF and SF filter media.

2.5. Filter Media Results in over-flocculation Conditions

An unexpected situation of over-flocculation occurred during one of the tests. The effect is presented in Figure 13, around cycle number 30. Despite the increase of the pump pressure, the flow continues to drop from cycle to cycle for SF filter media. The filter operated with IF filter media received the same liquor, but shows no drop in flow rate (Figure 14). A complete refurbishing of all filters was done, after the over-flocculation event occurred.

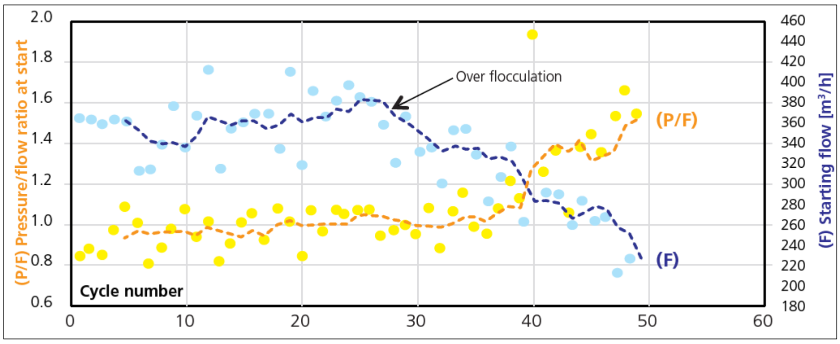

Figure 13. Flow and pressure/ flow ratio using SF filter media.

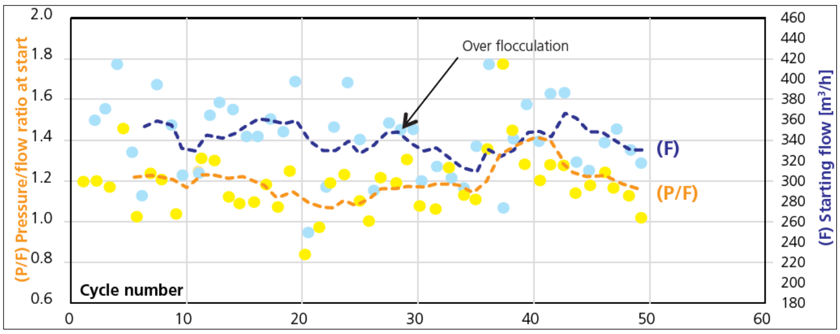

Figure 14. Flow and pressure/ flow ratio using IF filter media.

2.6. Scale Retardant Components for Filter Bags

The filter media is not the only part of filtration bags, which can benefit from scale retardant materials. The use of Sefar x-Scale components, made of ethylene propylene diene monomer (EPDM), can delay scale growth and ease the bags replacement [1]. An example of horizontal leaf filter bag with regular closure, using staples (Figure 15) and with Sefar x-Scale EPDM closure (Figure 16) are shown at the beginning and end of service life. The conditions of operation are presented in Table 1. Used in the same conditions of operation, the EPDM closure was less scaled. It was much easier to refurbish and exposed the workers to less safety risks, such as removing the scale by hammer.

Figure 15. Regular leaf filter closing by stapling, before and after use.

Figure 16. Sefar x-Scale EPDM leaf filter closing before and after use.

Table 1. Test conditions & results of different leaf filter closures

	Operation (Days)	Average flow (l/min)	Cycles	Solids in filtrate (mg/l)	Caustic (g/l)	A/C ratio	Temp. (°C)
Regular closure	94	2800	293	4.0	358	0.12	96
EPDM closure	116	2600	394	3.9	370	0.14	101

A similar based EPDM material was used for multichannel pressure leaf filters (i.e Diastar). The Figure 17 shows two bags on the same collector at end of lifetime. One bag has a regular neck made of woven fabric and the others are made from Sefar x-Scale EPDM. Again, there is a clear effect of EPDM, reducing the scaling and the time needed to refurbish the filters.

Figure 17. Effect of Sefar x-Scale EPDM closure on scaling.

3. Summary and Conclusions

Scaling is a major issue, which increases overall cost of filtration during clarification process. Together with major alumina refineries, Sefar has developed an answer for better handling of scaling, called the Sefar x-Scale technology - a dedicated range of filter media and filter bag closures. Sefar x-Scale technology has proven to delay scale growth and to meet the desired flow rate and liquor clarity- taking into account the particle size of the pre-coat filter aid (TCA or hydrate) used. The following advantages were proven in the field experiments:

- Reduced, delayed overall scaling
- Increase of liquor flow rate (up to 25 %)
- Improvement in service life of filter bags (up to 20 %)
- Better capability to handle over flocculated liquor
- Reduction in filtration cost per ton of alumina produced

4. References

1. François Faure and Luc Parent, “New Closure for Leaf Filters”, *Alumina Quality Workshop 2015*, Perth, Australia, 19 – 23 April 2015, Interactive Proceedings, Page 69