Light Metals 2010 *Edited by: John A. Johnson*
TMS (The Minerals, Metals & Materials Society), 2010

REDUNDANCY OF SECURITY FILTRATION

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Keywords: Security Filtration, Clarification Technology, Cost Savings

1. ABSTRACT

Security Filtration in the Bayer alumina refinery aims at controlling the contamination of alumina product by lowering the solids concentration in the decanter / settler overflow to the desired level in the Liquor to Precipitation (LTP).

Significant strides have been made in the design of high rate thickeners and their feedwells, and similarly in the preparation of modern synthetic flocculants. Recent technological developments enable to achieve solids levels in the bauxite residue settler overflow which are low enough to meet the targeted solids in LTP. This applies to existing refineries as well as to brownfield and greenfield expansion projects.

These developments provide an opportunity to lower alumina refinery operating and capital costs by (partly) by-passing or excluding the Security Filtration area. Savings include opex savings up to .8-1.4 $/tA and, in case of brownfield and greenfield projects, capex savings of 15-25 $/Annual tA.

2. SECURITY FILTRATION IN ALUMINA REFINING

2.1 Purpose

The purpose of the Security Filtration area in the Bayer alumina refining process is to lower through filtration the solids concentration in the decanter / settler (or sometimes first washer) overflow to the desired level in the Liquor to Precipitation (LTP) to meet alumina product quality requirements.

A horizontal Security Filter – "Kelly Press"

The criteria for solids in LTP can be derived from the targeted product alumina quality specifications. For instance the AP 18/30 specification for Fe_2O_3 in product alumina is <0.0165%. Assuming for example 62% Fe_2O_3 in the overflow solids and a precipitation yield of 75 g/l, the solids in LTP should not exceed 20 mg/l.

The solids levels in the filtrate from Security Filtration typically range from 5-15 mg/l [1, 2, 3].

2.2 Digestion Blowoff Ratio Limitation

In some alumina refineries the Security Filtration area puts a limitation on the digestion blowoff (DBO) ratio due to excessive formation of hydrate scale on the filter cloth from too high supersaturation levels for the variability of the operating temperature. Partial or full elimination of Security Filtration in such a situation would make it feasible to increase the DBO ratio because the liquor remains at a higher and less variable temperature.

The gain in DBO ratio depends on the specific situation of an existing alumina refinery, and could be of the order of 0.02-0.03 A/C ratio points. Depending on the liquor conditions of the plant and the operation of the precipitation area, this could improve precipitation yield by 2-4 g/l. This improvement could either be used to increase plant production capacity and/or be used to improve energy efficiency, etc.

2.3 Capital and Operating Costs, Economics

The installed capital cost (capex) of the Security Filtration area for brownfield and greenfield alumina capacity expansion projects depends on a number of factors such as location, technology employed, refinery capacity, etc, and ranges indicatively from 15-25 $/Annual tA capacity. In other words for an alumina capacity expansion project of 1 Mt/year, the capex of the Security Filtration area may be of the order of 15-25 M$.

The operating cost (opex) of the Security Filtration area includes fixed costs (e.g. labour, maintenance) and variable costs (e.g. filter aid, filter cloth). The total opex for Security Filtration differs from plant to plant, and indicatively ranges from 1.2-1.8 $/tA (incl. sustaining capital). Lime for TCA (tri-calcium aluminate – filter aid) often comprises a large element of the opex of Security Filtration. To achieve the targeted settler overflow solids in a line-up excluding Security Filtration, alternative (perhaps more expensive) or additional flocculants may be required (refer sections 3 and 4 below). This means that net opex savings would be less than the range indicated above. Assuming that the costs of alternative or additional flocculants are of the order of 0.4 $/tA, the net opex savings would amount to 0.8-1.4 $/tA (incl. sustaining capital).

Indicative NPV's are as follows:

- Existing refinery at 1 Mt/y capacity fully by-passing Security Filtration, and 1.1 $/tA net opex savings: NPV(8%) = 8 M$.
- Brownfield / greenfield expansion project of 1 Mt/y capacity, 1.1 $/tA net opex savings and 25 M$ net capex savings: NPV(8%) = 28 M$.

3. RECENT CLARIFICATION TECHNOLOGY DEVELOPMENTS

Settler overflow solids in current alumina refinery operations differ from plant to plant and may typically range from 100-250 mg/l [4, 5].

Significant strides have been made in the design of high rate thickeners and their feedwells, and similarly in the preparation of modern synthetic flocculants. This may be illustrated by a paper presented by Tim Laros (FLSmidth Minerals, USA) at the Light Metals 2009 conference [6], which mentions that today's sizing parameters for settlers include an overflow clarity of 50 ppm. Another illustration may be AMIRA's project P266F "Improving Thickener Technology" (see http://www.p266project.com), which includes a novel feedwell design as outlined on the website (http://www.p266project.com/Pages/About/ProjectAchievements.asp).

Reportedly plant tests have been executed aimed at settler overflow solids <10 mg/l, including stepwise application of a combination of flocculants achieving about 5 mg/l solids, allowing part of the clarified liquor to by-pass Security Filtration. In another case a second clarification step was performed. However no refinery seems to have implemented by-passing Security Filtration as a routine practice. Perhaps this is understandable from an operator's perspective (perhaps caused by an aversion to change operating practices), but less so from an operating cost perspective (refer section 2.3).

In other words recent technological developments enable achieving solids levels (clarity) in the settler overflow which are low enough to meet the targeted solids in Liquor to Precipitation. This applies to existing refineries as well as to brownfield and greenfield projects.

Important aspects are of course the specific nature of a bauxite residue and the scaling issues of its related liquor, and the protection of the precipitation area from upsets in the settler operation that could result in too high solids levels in Liquor to Precipitation. These are addressed in section 4 below.

4. REDUNDANCY OF SECURITY FILTRATION

The above mentioned technological developments provide an opportunity to lower alumina refinery operating and capital costs by (partly) by-passing (in an existing refinery) or excluding (in a brownfield or greenfield project) the Security Filtration area. Refer to section 2.3 for cost savings. For a brownfield or greenfield project this would mean that the following significant facilities and operations would no longer be required (see also Figure 1):

- Infrastructure requirements of a security filtration area (building, structural steel, pipe racks, air supply, piping, etc).
- Security filters including controls, other peripherals (valves, motors, piping) and related activities such as re-clothing and caustic cleaning.
- Clear filtrate tanks and peripherals.
- Cloudy filtrate tanks and peripherals.
- Filter waste (sometimes called press mud dump) tanks and peripherals.
- Filter aid tank and peripherals. The alumina losses related to the use of filter aid will disappear, ranging from typically 0.4-0.7% Al_2O_3 (abs). In other words the refinery's alumina recovery from bauxite will improve by the same absolute percentage, improving bauxite consumption and lowering residue generation.
- In general terms, the exclusion of Security Filtration as unit operation from a brownfield or greenfield project represents a simplification of the layout, operation and maintenance of the Bayer loop of an alumina refinery.

This opportunity may be considered from three perspectives: existing refineries, brownfield expansion projects and greenfield expansion projects.

4.1 Existing Refineries

The current economic climate provides an extra incentive to alumina producers (Alcoa, BHPBilliton, Dadco, Nalco, Rio Tinto Alcan, UC Rusal, Vale, etc) to find ways of lowering operating cost and sustaining capital.

The above outlined technological development provides an opportunity fitting this objective very well.

Note that the solids in liquor to precipitation often include fine TCA (filter aid). By-passing Security Filtration therefore has the added advantage in many cases of reducing calcium in the product alumina.

Existing alumina refineries could consider by-passing (part of) the settler overflow around the Security Filtration area. This requires sufficiently low solids concentrations in the settler overflow and in the filtrate from Security Filtration, and could be implemented in phases as follows.

4.1.1 Phase 1 – No Additional Requirements

Example: a plant's current settler overflow solids are at 100 mg/l, the solids in the filtrate from Security Filtration are at 10 mg/l, and the Liquor to Precipitation (LTP) should not have more than 20 mg/l solids for alumina quality reasons. Assuming that there are no other relevant constraints, about 10% of the settler overflow could be by-passed around Security Filtration while still meeting the criterion for solids in LTP, i.e. without additional requirements. Operating cost savings depend on the specific plant situation and could indicatively be of the order of 0.1-0.2 $/tA.

4.1.2 Phase 2 – Improve Settler Overflow Solids

If in the above example the settler overflow solids are decreased e.g. to 50mg/l through a combination of using a different mix of flocculants and/or modifications to the settler feedwell, about 25% of the settler overflow could be by-passed around Security Filtration while still meeting the criterion for solids in LTP. Depending on the mix of flocculants required, opex savings could be of the order of 0.2-0.4 $/tA.

This step would require some laboratory test work encompassing residue settling tests to investigate which (mix of) flocculants results in the required settler overflow clarity improvement while still meeting other process conditions. The scope of test work depends on a plant's existing line-up, potential line-up modifications, etc. Modifications to the settler feedwell may or may not be required depending on the results of the test work.

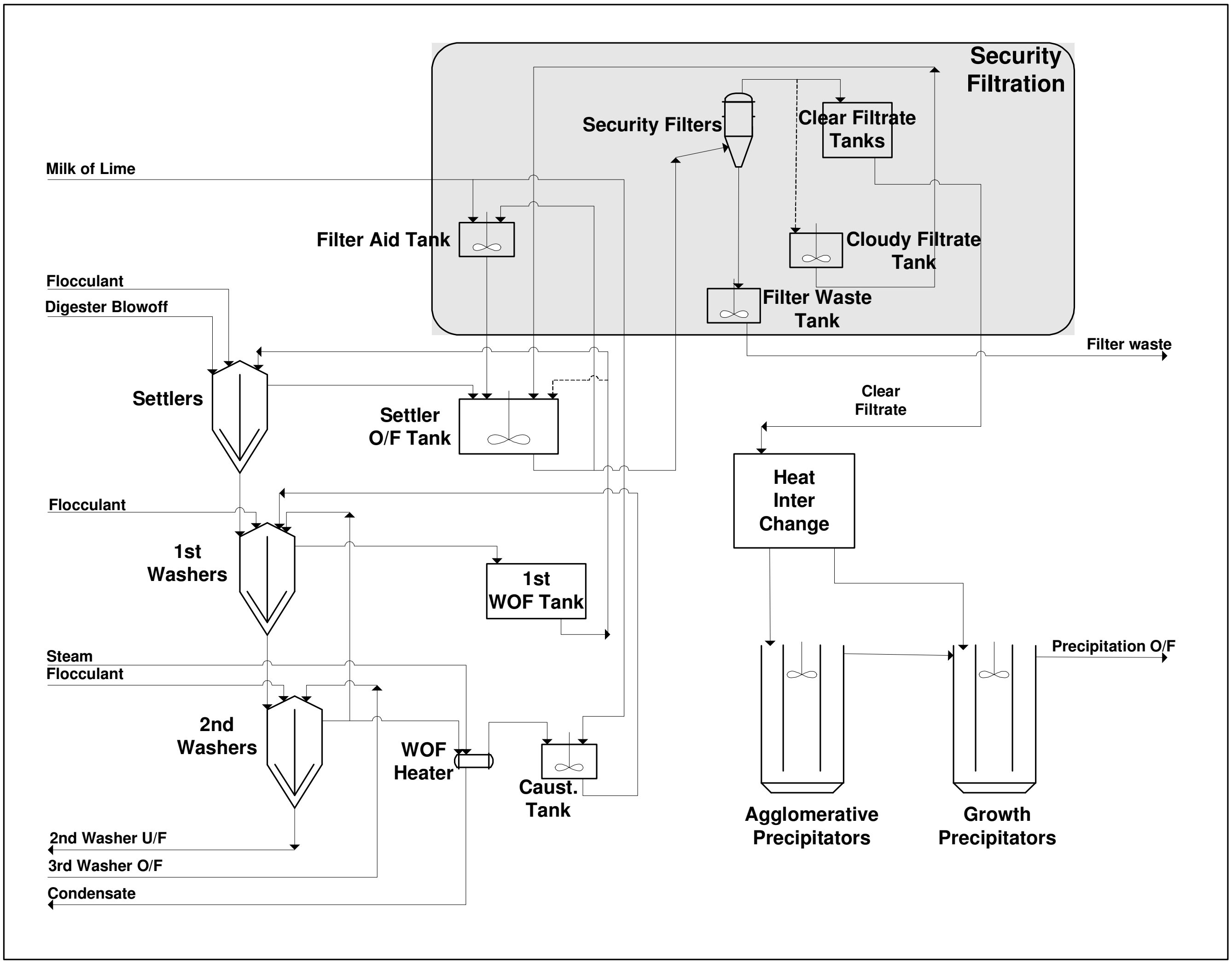

Figure 1 – Security Filtration, Settling & Precipitation

4.1.3 Phase 3 – Complete by-pass of Security Filtration

The results from Phase 2 could provide the basis to further improve the settler overflow solids to the point that no settler overflow passes through the Security Filtration area. Depending on the requirement of the mix of flocculants and the current usage, opex savings could be of the order of 0.8-1.4 $/tA (refer section 2.3).

Once all of the settler overflow by-passes Security Filtration, the digestion blowoff (DBO) A/C ratio may be increased at those refineries where the Security Filtration area puts a limitation on the DBO ratio due to the excessive formation of hydrate scale on filter cloth. As mentioned in section 2.2 above, precipitation yield improvement may be of the order of 2-4 g/l. The test work mentioned in section 4.1.2 could include tests to quantify the potential for an increase of the DBO A/C. Alternatively, historical plant operating data may provide the information required to assess this potential.

4.1.4 Strategy for High Solids in Settler Overflow

Obviously, it will be necessary to have a strategy in place how to handle an upset in the operation of the settler(s) that results in too high solids concentrations in LTP and thus deterioration of product quality. Causes could be unplanned and relatively fast changes in bauxite composition, control and instrumentation problems, significant flow fluctuations of the DBO, etc.

Essentially the operating measures required to remedy this situation for this case (existing refinery) are similar to the operating steps currently in place if such an event was to happen today.

In addition to the steps currently being applied in such a situation, or perhaps as an alternative to those steps, the settler overflow at an undesirably high solids level may be directed to an offline settler overflow tank until the required number of security filters have been put online and other necessary steps have been taken. Due to a specific refinery design and / or its operating requirements, details of the necessary steps may require tailoring.

Or in other words for existing refineries the fallback position is to re-direct the settler overflow to the existing Security Filtration area, i.e. reverting to the situation before the settler overflow by-passed the Security Filtration area. When the filter building is being by passed it will of course take at least half an hour to an hour to make up a fresh batch of TCA before the filters can be brought back into service. An alternative may be to use a filter aid from a flocculant supplier which can be turned on immediately when the problem occurs.

4.1.5 Implementation – Existing Refinery

An advantage for existing refineries is that phased implementation of this opportunity is possible as described above. Implementation includes the following steps:

Phase 1

- Review if current product specifications or other process requirements would allow partly by-passing settler overflow (SOF) past Security Filtration, e.g. into the clear filtrate (CF) tanks.
- Review and execute laboratory test work required to confirm that changes in process conditions will not adversely affect product quality and / or other process conditions. The expectation is that minimal if any test work will be required at this stage.
- Review existing SOF and CF line-ups and piping with respect to the potential to by-pass the Security Filtration area, and execute necessary piping modifications if required. Depending on the number of on-line settlers and the available piping, a consideration could for instance be to line up the SOF of one settler to by-pass the Security Filtration area.
- If the refinery has a process simulator in place as described in a paper presented at the 2008 Alumina Quality Workshop in Darwin [7], simulate the effect of by-passing the Security Filtration area. Change the control and safety systems as required in order to align with the new process configuration.

Phase 2

In addition to Phase 1:

- Review and execute the laboratory residue settling tests required to improve current SOF solids to the point that a significant part (e.g. 25-30%) can be by-passed. Tests would encompass establishing settling rates, overflow and underflow solids for different types of flocculant and at varying flocculant dosages, and residual flocculant in overflow liquor.
- Review if modifications to one or more settler feed wells are required with the same objective.
- Execute the necessary piping and other modifications required.
- Execute additional changes to the control and safety systems as required.

Phase 3

In addition to Phase 2:

- Review if the results of Phase 2 provide a basis to fully by-pass SOF past Security Filtration.
- Perhaps additional lab and plant tests are required and / or additional settler feed wells may require modifying.
- Execute additional changes to the control and safety systems as required.

The expected implementation time for Phases 1-3 is 4-7 months. Implementation for an individual refinery requires tailoring to its specific situation.

For both Phases 2 and 3 discussed above, co-operation with a flocculant supplier (Ciba, Cytec, Nalco, SNF Floerger, etc) would not be an absolute requirement, however should assist in speeding up its implementation. If modifications to the feedwell of the settler(s) are contemplated, co-operation with AMIRA / CSIRO or a technology supplier such as FLSmidth Dorr-Oliver Eimco, Hatch, Outotec etc, may be appropriate.

4.2 Brownfield Expansion Projects

The medium term perspective is to consider the outlined development as element of a brownfield expansion project for an existing refinery. Refinery capacity expansion projects of typically 500,000 ton/year alumina and above are generally considered brownfield expansions as they often require additional trains / units to be added to some of the major plant areas such as digestion, precipitation etc.

In this case the opportunity is to exclude new (additional) Security Filtration capacity from the scope of the brownfield project (refer to the beginning of section 4 with respect to relevant facilities and operations involved). This technological development provides an opportunity which is attractive to alumina producers that are considering a brownfield capacity expansion as well as to technology suppliers offering technology for brownfield expansion projects of the alumina industry.

As mentioned earlier, the design of modern mud settling facilities offered by several technology suppliers enables achieving settler overflow solids which are acceptable for direct feed to the precipitation building. Designs by these suppliers may include proprietary feedwell designs and/or feedwell modifications developed in co-operation with others.

Again, a key issue is the specific nature of the bauxite residue and therefore laboratory test work is required to investigate which (combination of) flocculants will result in the required settler overflow clarity.

4.2.1 Capital Cost (Capex) Savings

As outlined in section 2.3, the actual brownfield capex for Security Filtration depends on the scope and context of the project and consequently may vary widely. However when a new or significantly expanded existing Security Filtration building is required, the capex may range from 15-25 $/Annual tA capacity. For a brownfield expansion project of 500,000 ton/year this would mean a capex of about 8-13 Million $.

As discussed earlier, (slightly) modified clarification equipment may be required (e.g. modified feedwells), and/or some alternative equipment may be considered for inclusion in the scope of the brownfield project (e.g. an extra – redundant – settler, an additional settler overflow tank or precipitation tank). The related additional capex is expected to be significantly less than the capex saved, i.e. the overall capex savings remain largely as mentioned above.

Security Filtration Facility

4.2.2 Operating Cost (Opex) Savings

Refer to section 2.3: the net opex drop would be of the order of 0.8-1.4 $/tA.

Note that the improvement in alumina recovery as mentioned at the beginning of section 4 above is not included in these opex numbers.

4.2.3 Strategy for High Solids in Settler Overflow

Similar to existing refineries, a strategy needs to be developed how to handle an upset in the operation of the bauxite residue settler(s) in the case of a brownfield expansion project which does not include a Security Filtration area.

Several strategies are possible, and it depends on the combination of the existing facilities and the brownfield project which one would be most appropriate to a specific refinery. One of these strategies may be described as "upstream" because it encompasses design aspects related to facilities upstream of Security Filtration:

- Include state-of-the-art digestion and settler controls in the design (such as DBO controls, mud level indication and controls, clarity measurement – on-line turbidity meters).
- Include additional settler overflow (SOF) tank capacity in the design. Conventionally the SOF tanks act as buffer between the settlers and the Security Filtration area, while the Clear Filtrate tanks do the same between Security Filtration and the precipitation area. However in this case the SOF tanks act as buffer between the settlers and precipitation. In practical terms this would normally mean that larger SOF tanks are required. Optionally an additional SOF tank is included in the design. The rationale being that sufficient SOF tank capacity is included to enable solving potential operational problems which would otherwise result in too high solids in the settler overflow, ensuring in the mean time that the main plant flow is not (significantly) affected.
- In other words, while the operational problem is being solved, the SOF at too high solids is collected in a separate SOF tank.
- This liquor needs to be stabilised for instance by the addition of a small amount of lime because as it cools auto-precipitation could occur.
- When the problem is solved, bleed the liquor of the "contaminated" (too high solids concentration) SOF tank over a period of time into the settler feed flow. Additional flocculant may be required (requires testing).

An alternative "upstream" strategy could encompass the inclusion of an extra settler in the brownfield design. This extra settler would be brought on line in case of an operational problem which has resulted in too high solids in the settler overflow (SOF). The extra settler would act as "second stage settler", receiving the normal settler's overflow as feed, with the overflow becoming the "new" SOF to precipitation and the underflow being bled over a period of time into the normal settler's feed.

In addition to the above mentioned "upstream" strategies the brownfield project design could include "downstream" elements (encompassing design aspects related to facilities downstream of Security Filtration), such as:

- The contaminated SOF tank (refer first upstream strategy covered above) may be bled over a period of time into the liquor to precipitation flow. The first agglomerative precipitator could then be operated in a "scavenging" (or "scalping") mode. Depending on the specific plant situation, the off-spec product from this tank may either be added to the regular material from the agglomeration step, recycled for instance to the digestion feed flow, or directed to a liquor burner if present.
- Alternatively, an extra agglomerative precipitation tank may be added to the design. As above this extra tank can be lined up as "scavenging" precipitator.

Other strategies may be more appropriate to the brownfield expansion of a particular plant.

For some brownfield expansion projects the existing Security Filtration area may provide (some) excess capacity that may be put to use in case of upsets of the settler operation.

In the quantification of the overall annual plant operating factor for a brownfield expansion project, this aspect (a strategy for high solids in settler overflow) should be taken into account. It is expected that for a state-of-the-art design brownfield alumina project which excludes a Security Filtration area the annual plant operating factor should not be significantly different from a similar design which includes one.

Key is that the potential of high solids in settler overflow is taken into account in the design of the brownfield project. As mentioned earlier, high solids in settler overflow may be caused by unplanned and relatively fast changes in bauxite composition, control and instrumentation problems, significant flow fluctuations of the DBO, etc. These aspects need therefore extra attention during process design (and mine design – specifically with respect to bauxite quality control).

4.2.4 Implementation – Brownfield Project

Implementing a brownfield expansion project which excludes Security Filtration is in outline not significantly different from a design including one:

- Design and execute appropriate laboratory residue settling test work for the (range of) bauxite feed compositions that will be used. This test work includes both the "standard" type of tests normally performed for the design of a clarification area (refer first bullet under Phase 2 in section 4.1.5), and additional tests covering the emergency line-up required in case of high solids in the settler overflow (as described in section 4.2.3).
- Co-operation with a flocculant supplier (to investigate which – combination of – flocculants will result in the required settler overflow clarity) and a technology supplier

for the design of the mud settling equipment is recommended.

- If the brownfield expansion is designed with the use of a process simulator as mentioned in section 4.1.5, model the effect of excluding the Security Filtration area and the necessary changes in the control and safety systems.
- If possible, some key design aspects for the settling area (settler feed well, combination of flocculants, dosages, settling rates, overflow clarities, etc) could be tested in the existing plant to confirm laboratory test work data. In this case most of the steps apply mentioned above for implementation Phases 2 and 3 in an existing refinery (refer section 4.1.5).

If the activities of the last bullet point above are included, implementation of the opportunity in a brownfield project is expected to require 4-9 months in addition to the time normally required when the brownfield project design includes Security Filtration.

If no large scale tests in an existing plant are included, the implementation of the opportunity in a brownfield project is expected to require 1-3 months in addition to the time normally required when the brownfield project design includes Security Filtration.

The above mentioned does not necessarily mean an extension of the normal brownfield project duration with these periods: if the indicated activities are performed as part of an R&D effort before or in parallel to the brownfield project, project development duration should not be affected at all.

4.3 Greenfield Expansion Projects

The long term perspective is to consider the outlined development as element of a greenfield alumina project.

In this case the opportunity is similar to that of the brownfield expansion case, i.e. excluding Security Filtration from the scope of the greenfield project, and is attractive both to companies considering a greenfield project as well and to technology suppliers offering technology to the alumina industry

4.3.1 Capital Cost Savings: 20-25 $/Annual tA capacity

The low end of this range is higher than that of the brownfield expansion case, because the option of expanding an existing Security Filtration building does not apply to a greenfield project.

4.3.2 Operating Cost Savings: refer section 4.2.2

4.3.3 Strategy for High Solids in Settler Overflow. Refer section 4.2.3

4.3.4 Implementation – Greenfield Project

The implementation of a greenfield alumina refining project design which does not include a Security Filtration area encompasses the first three bullet points described in section 4.2.4 for a brownfield project.

A difference with a brownfield project, is that the owner of a greenfield project may not have an operating plant in which design aspects for the settling area can be tested in the field. However this is not a major issue because properly executed laboratory residue settling test work results these days do not require confirmation by large scale tests.

The implementation of the opportunity in a greenfield project is expected to require 1-3 months in addition to the time normally required when the greenfield project design includes Security Filtration. The same comment applies with respect to this period as to the implementation period of the brownfield project (refer section 4.2.4).

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