UPGRADING OF A CONVENTIONAL PRECIPITATION LAYOUT IN EURALLUMINA REFINERY

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1. Introduction

The Eurallumina refinery was constructed in Sardinia, Italy, in early seventies, with Kaiser Aluminum technology, and a plant design similar to others already installed in Louisiana and Australia (QAL).The original rated plant capacity was 600,000 tonnes of smelter-grade alumina per annum, with a stated extra-capacity of +20% coming from experience.

The feed ore to the refinery has been Weipa bauxite since the beginning, including an intermediate period of 15 years during which, due to the interest of the Italian shareholder existing at that time, a portion of the African Boke bauxite was treated in blend with Weipa.

Since 1998, when the refinery was ownership changed to Comalco (56.16%) and Glencore (43.84%), the bauxite feed has returned to 100% Weipa.

The original plant operation produced floury and sandy alumina and only at a later stage moved totally to sandy, which was more sensitive to the organics, in particular the oxalate build-up in the liquor.

The precipitation design consists of 3 chains of 12 conical bottom tanks in series, of which 10 are with 90° cone, draft tube and impeller, and the last two with 60° cone, and airlift.

Seed classification is achieved by three stages of hydrate separation and thickening of three different granulometry — primary or coarse hydrate (the product), secondary or intermediate hydrate and tertiary or fine hydrate. These last two are recycled as precipitation seed. The fine seed is washed in hot water to remove most of the oxalate accompanying with it, according to Kaiser Aluminum technology.

The production level from the original values has increased progressively year by year, until in recent times when the threshold of 1 million tonnes has been achieved. This production increase stems from a number of improvements put in place around the whole plant, and in particular from those changes necessary to enable production at higher liquor flows and higher seed charge in precipitation without running into major operational problems or product quality concerns.

Attempts to force the process conditions and increase the production level in the past often turned into troubles in precipitation, with seed imbalance, excessive hydrate in Tertiaries, ending up into rake blockages and subsequent loss of production. There were also problems associated with a worsening of the oxalate removal operation, increase of oxalate in the liquor and consequent deterioration in product quality.

A number of improvements were made in the white area, which are described in this paper. The modifications resulted in an upgrade of the precipitation unit, increasing alumina yield and the ability to tolerate higher circulation of liquor and solids. At the same time a better performance of oxalate removal facilities was also obtained.

2. Limits and problems of the original design

2.1 *In Precipitation*

a) Solids level increase in the precipitators and the usage of a chemical like the oxalate precipitation retardant seemed to contribute to the formation of hydrate pea gravel, rich in oxalate, as hydrate slurry progressed through precipitation lines. Tanks with conical bottom agitated by impeller and draft tube did not appear properly designed to face this type of problem.

   The conical bottom in fact acted as a trap where relatively coarse hydrate stagnated and grew more and more, from which the pea gravel, a few millimetres size, formed. This material could never be resuspended by the tank agitation, therefore it had to be drained out by periodical "milking" of the tank cone, by tank recycling (via *pump-off* pump) and scale-trap cleaning.

   The rate of gravel formation was so high that very frequent purging operation became necessary, stressing the resources (operators' availability) to the limit. Attempts to automate the milking operation by adoption of motorised bayonet valves did not prove successful. The problem of pea gravel accumulation was so serious in a few tanks that it completely prevented agitation and tanks were lost, becoming full of settled hydrate in short operational periods. A particularly bad experience was the loss of two consecutive precipitators, which resulted in a serious upset of the precipitation chain and took a long time to recover the lost tanks.

b) As recycled seed was suspended in spent liquor, progressive increase of seed charge turned into higher re-circulation of spent liquor through precipitation. The loss of retention time was so high as to discourage the seed charge increase over certain values.

c) The seed charge increase, with its burden of accompanying spent liquor, over-stressed the cooling capacity of the Flash Interstages in Precipitation. This was particularly evident in the summer, when the cooling system runs at its limit due to the local weather being hot and at times wet.

2.2 *In Classification*

a) Higher flows and higher solids through classification units turn unavoidably into more hydrate transferred to the Tertiary Thickeners. A gravity classifier run at higher flows suffers reduced solids recovery, coarser underflow product and increased overflow solids content. More Tertiary seed means more seed to be washed for oxalate removal whilst the seed is diluted in its oxalate content.

b) The performance of the oxalate removal facilities gets poorer, due either to more hydrate to treat and to the related diluted oxalate liquor. The consequence of this is an increase of oxalate in the plant liquor, with detrimental effect in precipitation (higher production of fines and poor settling).

c) For years, tertiary thickeners represented the most critical equipment of the process, as any period of fines production and/or any troubles suffered upstream in the classification lines could turn into higher accumulation of hydrate in the Tertiaries, often ending up into rake blockage and related flow cut/ production cut. On a few occasions, in the past, following high production of tertiary seed, in order to avoid the rakes blockage, fine hydrate was drained out of the tertiaries, blended with the bauxite and treated again in digestion. This, of course meant a reduced production capacity.

   The solids content at the Secondary Thickeners' overflow proved to be a key parameter to be kept within an acceptable range, in order to ensure the correct operation of the units located downstream.

3. Precipitator modification

The troubles suffered at the precipitators were studied and it was concluded that EA precipitators were suffering from defective agitation, especially in the deep cone where the hydrate falling inside the apex, in particular the coarser particles had no chance to get suspended again.

3.1 *The false flat bottom*

The agitation with draft-tube and impeller design can be better adapted in flat bottomed tanks than in tanks with conical bottom, as demonstrated in more modern units elsewhere. The change to transform a conical bottom precipitator into a flat bottom tank would involve significant expenditure of capital and long time of tank unavailability for the process.

For these reasons a trial was conducted installing in one precipitator cone a false flat bottom. This consisted of a circular steel plate with holes to permit the hydrate to pass underneath and act as a support to the plate; avoiding in this way the more costly modifications to the tank. It was estimated that the small volume loss would correspond to the volume occupied previously by the stagnating hydrate that was already a loss to the process.

3.2 *The dip tube*

The original 3m deep duct to discharge the slurry flow from one precipitator tank to the next was replaced by a dip tube that went to the bottom of the precipitator. The tube, starting from the area immediately below the draft tube, was sized to carry full flow in order to provide in the tank bottom the maximum of sweeping action and to minimise possible stagnation of coarse hydrate particles. The formation of hydrate gravel has been significantly reduced and the requirement for tank purging or 'milking' operation has also significantly reduced. It is fair to suggest that tank scaling has also significantly reduced with minimisation of pea gravel formation.

3.3 *The air injection*

The passage from each precipitator to the next via the dip tube involving an additional pressure drop would turn into a higher level in the tank. To avoid this the dip tube has been provided with a small air injection enough to decrease the average density inside the dip tube and promote the slurry circulation at the required flow.

3.4 *The impeller*

During the period of poor precipitation operations and modifications for improvements, opportunity was taken to study and improve the agitator impeller design. A fluid dynamic modelling study was conducted in collaboration with CSIRO and a new impeller design was obtained. The existing impeller provided unstable conditions at low flows that would be exacerbated should if there is an accumulation of hydrate in the cone at the same time. The new design and the associated straightening vanes were also energy efficient allowing good mixing at reduced speeds, resulting in significant power savings and related advantages for the gear reducer connecting the agitator shaft with the electrical motor. After successful plant trials, tanks are receiving impellers as they come off line within operational and budget constraints.

The above modifications implemented in the precipitation area had the effect of significantly improving the life of the precipitators, reducing gravel generation/scale formation.

4. The Hydrate seed cycloning

Higher production in a Bayer plant is normally accompanied by an increase in flow in Precipitation and seed charge. The quantity of hydrate to be recycled in precipitation as seed charge can not increase above a certain threshold represented by the thickeners capacity. Exceeding this would alter the granulometry of different hydrate seeds, and more hydrate would be transferred to the tertiary thickeners with associated operational troubles.

Hydrocyclones, operating in parallel with the thickeners were chosen to handle the additional classification load.

4.1 *First trials*

In the initial project the cyclone clusters were located on top of the existing classification units (i.e. thickeners), to work in parallel with these. The hydrate delivered by the cyclone underflow had to be pumped back to precipitation involving a tank with the related pumps, piping, scale traps and the associated work. The installation of cyclones before the problems of precipitators were solved, in particular the pea gravel problem, combined with a poor design of the cluster troughs, caused this project to fail. The main reason for this was the presence of gravel transferred from the precipitators up to the cyclones, which were easy to plug and result in unsafe overflow of caustic slurry from an elevated location.

4.2 *Definitive installation*

A new type of cluster was then designed, more rational and safeguarded against possible cyclone blockages, in order to avoid liquor spilling from height. A better location for the clusters was chosen — above the precipitators — in such a way as to discharge the cyclone underflow directly into the precipitator designated to receive the seed charge, thus eliminating the need for handling facilities for the slurry including pumps. In the meantime, the problem of the gravel generation in the precipitators had significantly improved, following the modifications made in the tanks. Finally, a more efficient cyclone design was adopted for the new installation, contributing to make seed charge preparation more reliable and quality effective. The clusters were designed to potentially accept additional cyclones to accommodate future flow increases that happened in the following years without any interference to operations.

4.3 *Cyclone performance*

The cyclones are fed with a part of the hydrate slurry exiting from precipitation that, in absence of cyclones, should be passed entirely through the thickeners. In order to support a progressive increase of seed charge in precipitation, the flow addressed to the cyclone batteries has been increased over time up to nearly 60% of the total flow destined to classification.

The cyclone performance is reported in the following table.

	Solid (g/l)	+45micron (%)	oxalate (%)
Feed	420	93	—
Underflow	950	96	0.1
Overflow	100	85	0.2–0.3

In this way the classification units could remain operating at almost unchanged load, at least of solids' load, which represented a safe choice in respect of the granulometry of the product. The cyclone underflow is directed to the precipitation tanks whilst the overflow returns to classification. Although the classification load is shared by the cyclones, plant flows have gone up in recent times. The thickeners are affected by a higher flows, however the relief of its solid content given by the cyclones makes the flow acceptable by the units without compromising the thickeners' efficiency.

On the other hand, the cyclone operation contributed to significantly reduce the solid carryover from the Secondary Thickeners, from the original $^{-}$20 g/l to †15 g/l and the fine hydrate passed on to Tertiaries has become enriched in its oxalate content. This in itself has resulted in improved oxalate removal from the plant.

5. The Hydrate seed filtration

The increase of seed charge, necessary to increase the liquor productivity and production rate, causes a reduced holding time in precipitation. The operation of seed charge increase involves a significant recycle of spent liquor to accompany the hydrate seed, with its negative effect on the retention time in precipitation, which is generally already reduced by the plant flow stressed to the maximum capacity of the units.

Some of Bayer plants have their precipitation followed by filtration units which deliquor the hydrate slurry coming out of precipitation without any distinction between the coarse and the fine seed. Others, like Eurallumina, have the classification process, to separate the coarse hydrate from the finer seed and recycle this last as a seed charge to better perform the production of sandy alumina.

A few other plants finally have both, the classifiers and the filters, to handle the hydrate delivered from precipitation, separating the coarse from the fine material, and avoiding the recycle of spent liquor to the precipitators. In some cases the filters are located in the classification area, and the seed gets suspended with pregnant liquor in order to be pumped up to precipitation top. This operation often causes rapid scaling of the involved tank and piping necessitating frequent cleaning. This at least was the experience in Eurallumina plant for the tertiary seed after the seed washing operation. The same operation with the secondary seed was thought to be much more troublesome and with success unlikely. Therefore, in order to recover retention time and allow seed charge it was decided to adopt the filtration process which was based on the following stages.

5.1 *Choice of the filter*

For the type of filter to deliquor the seed charge before adding it to the precipitation pregnant liquor the modernised version of Dorr Oliver — Gaudfrin vertical disc was chosen.

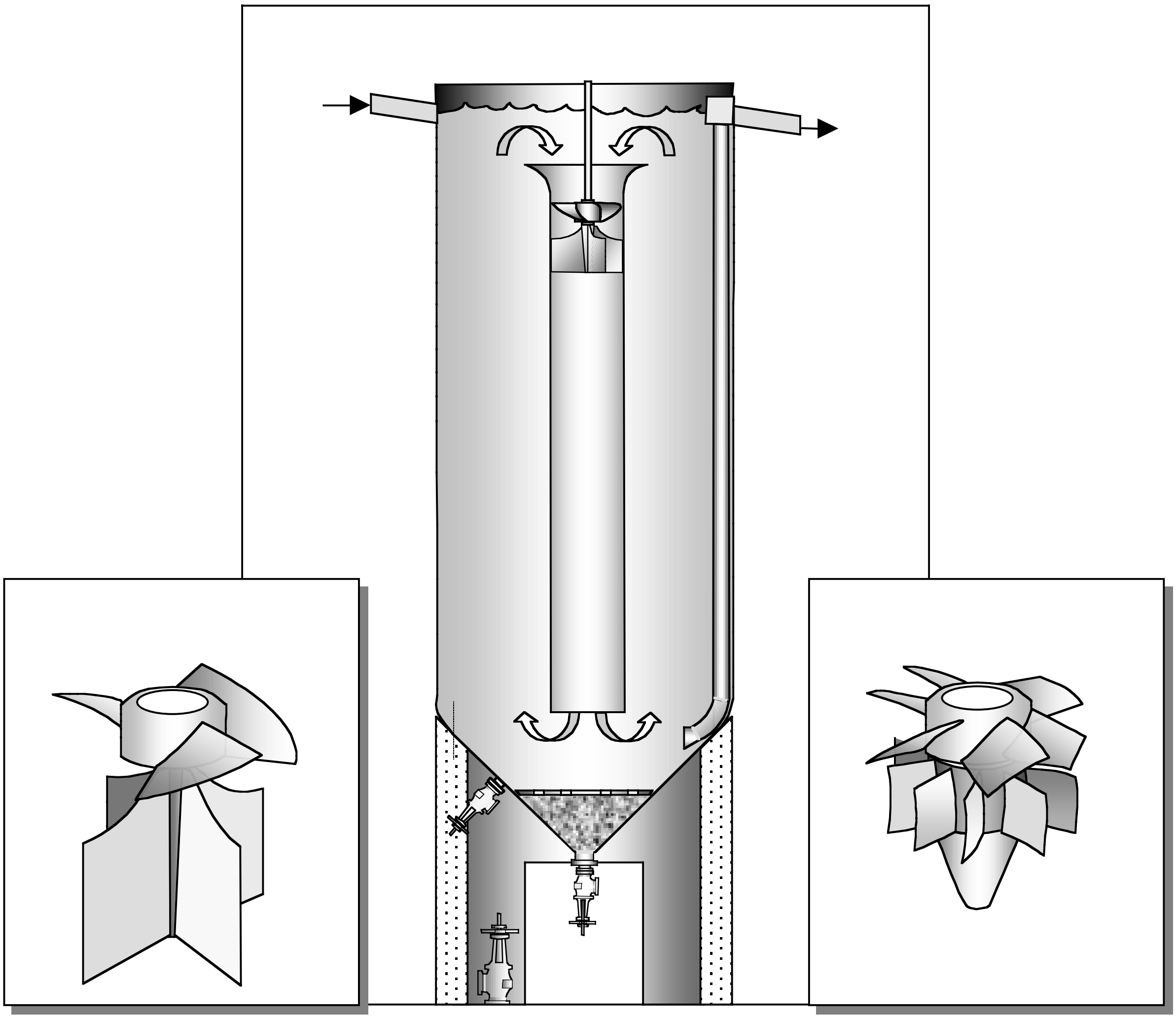


Figure 1 — The modified precipitator and the two agitators

The filter design was characterised by a single disc of 38 m^2 surface, which when compared with older types showed the following improved characteristics:

a) Smaller size of the filtering sectors to make the operation of sector extraction and re-clothing easier.
b) Narrow trough without any agitator, with the disc itself acting as an agitator to eliminate a critical element and to simplify the design
c) Rapid drainage of the trough, in case of a disc stoppage via an automatic valve installed in the trough bottom to avoid undesired solid accumulation in the trough.
d) Possibility to operate the filter trough at its full level (at the disc centreline) with increased percentage of the disc submergence, i.e. with larger filtering area in the trough.

5.2 *Choice of the installation and layout details*

The location of where to install the filter was chosen to be the nearest to the point in which the hydrate seed had to be introduced, i.e. the top of the precipitators. To this purpose the top side of the tanks n°1 and n°2 of each line were reinforced by welding all around a 2nd line of upper plates and vertical half-tubes, 3m high/1 every 2 metres of circumference. This was to stiffen the top part of the precipitators on which the filter with its structure, was to be installed. Then, two horizontal girders were placed over the precipitators 1 and 2, and an elevated structure was erected to accept the trough with the vertical disc and the relevant vacuum filtrate pots. Two vertical chutes convey the filtered hydrate cake directly from the discharge point at the filter blow-back down to the precipitator liquid surface.

In order to simplify the project and to minimise the height of the structure over the precipitators, it was decided to dedicate the filter just to the 1st tank, and not extend it to the 2nd. The filtrate delivered by the filter due to its very low solid content is addressed by a barometric discharge leg to the Tertiary thickeners that are located close to precipitation.

The vacuum pumps, in order to avoid generating vibrations on precipitation top floor, were positioned at the ground floor connected to the filters via a long vacuum header.

5.3 *Filter Performance*

The filter was provided with a capacity well above the required rate. This in order to take into consideration possible changes in the hydrate granulometry and/or possible increase of the flow requirement made necessary for future production increases. The rated filter capacity at a given material coarseness was stated to be around 120 t/h of hydrate at a rotational speed below 2 rpm. At the maximum possible velocity of 5 rpm the filter capacity can exceed 200 t/h. The residual cake moisture, depending upon the hydrate coarseness, is around 10–13%. The hydrate cake falling down in the annular zone of the precipitator around the draft-tube gets wetted by the slurry flowing upwards and it is suspended without any problem of settling inside the precipitator. After a period of operation with the secondary seed alone the filter was fed also with the tertiary seed produced by the process which was until now conveyed by re-suspension in pregnant liquor. This helped in eliminating the problem of scale in pipes and pumps dedicated to tertiary seed addition.

5.4 *Saving of retention time, yield gain*

The installation of the filter to avoid spent liquor returning with the seed charge spared a part of the precipitation retention time from being wasted. The reduction of flow recycle is around 100–150 m^3/h each precipitation chain. The corresponding save in the liquor productivity is evaluated in the order of 4 g/l of precipitated alumina.

Additionally, the lower liquor re-circulation involves a reduced amount of oxalate participating potentially to the precipitation phase. And another benefit consists on the lowered flow of slurry to be treated in the Intermediate cooling stages often operating at their limit capacity.

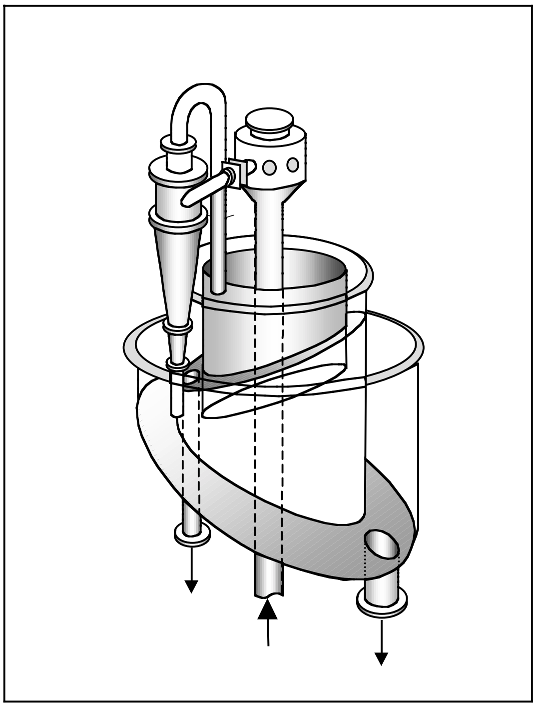


Figure 2 — One cyclone mounted on the trough

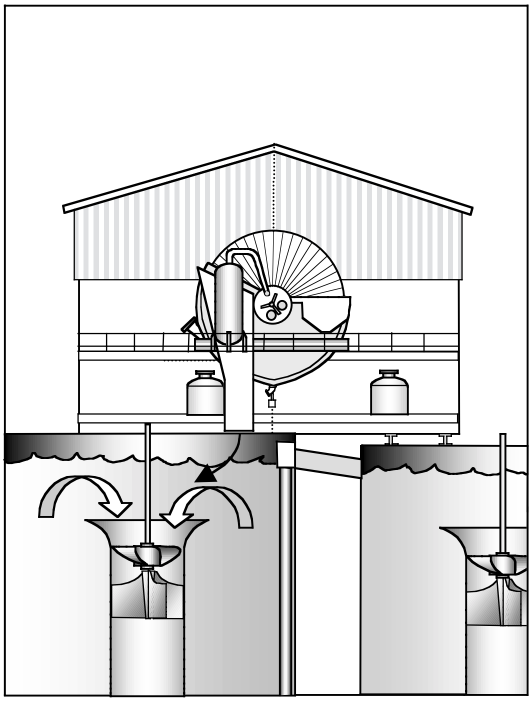


Figure 3 — The disc filter installed on top of precipitation

6. Discussion on oxalate removal

The efficiency of the oxalate removal operation by Kaiser Aluminum technology is very much related with the existence in the process of a stream concentrated enough in oxalate. This is accomplished by washing with hot water the tertiary or the portion of finest hydrate seed produced. If the classification units do not perform properly or overloaded, the quantity of tertiary seed can be higher, and the relevant oxalate concentration in the seed correspondingly lower. The greater hydrate quantity to be washed results in a lower oxalate concentration in the liquor to be further treated with lime. As a consequence of this, the transformation to calcium oxalate is more difficult causing additional lime consumption and increased alumina losses. A less efficient oxalate removal causes a higher oxalate concentration in the liquor with associated problems in the precipitation process and in the hydrate granulometry.

6.1 *The Basics*

The testwork done by Kaiser Aluminum laboratories had shown how the best of the oxalate removal efficiency can be obtained when the oxalate/caustic ratio (Ox/C) achieved in the filtrate liquor produced by the seed washing is ‡ 0.7. This can be reached by a good removal of caustic liquor from the seed and a proper utilization of water in the filters. The operation is however dependent on the classification performance as clear from the plant data.

6.2 *The plant data*

The following graphs show the trend of the process data related to classification and oxalate removal for the last 10 years of plant operation. It can be observed that the improved operation of oxalate removal in the last three years coincides with the time when the hydrate cyclones have been in operation. The effect of the cyclones was a relief of the classification units, such that the Secondary thickeners' solid overflow decreased. The lower quantity of fine seed, being richer in oxalate, promotes a better performance of the oxalate removal. This in spite of the higher plant liquor flow (+10% approx in last 5 years) and the higher seed charge (approx doubled since the beginning, from 10 to 20 m^2/l).

7. Conclusions and recommendations

The above described improvements put in place in Eurallumina refinery into the last 5 years were able to change the situation from a condition in which the white area was susceptible to run into crisis with hydrate imbalance,

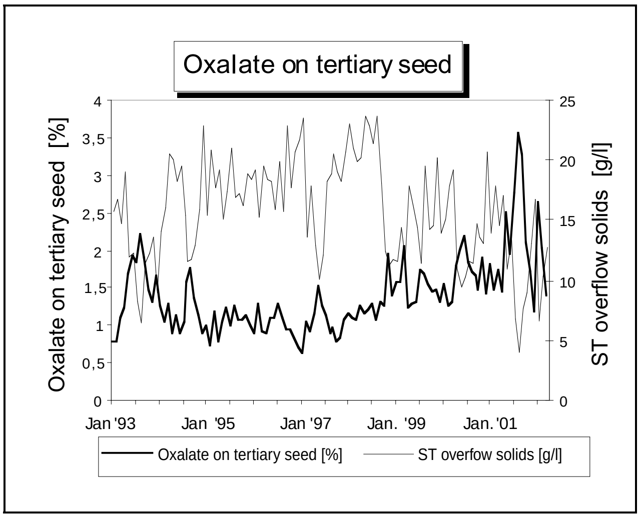
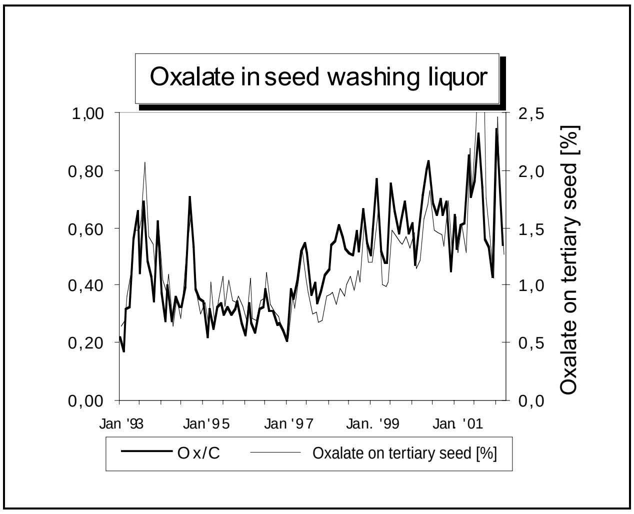


Figure 4



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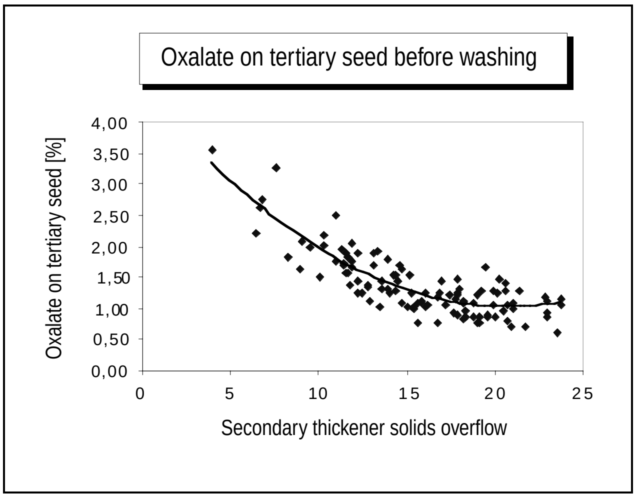

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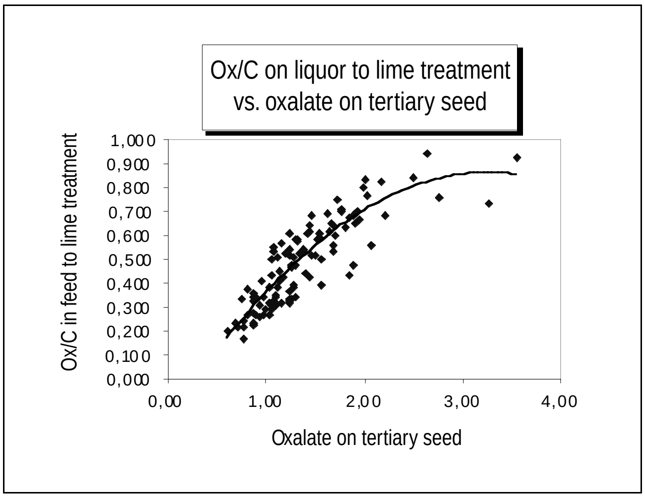

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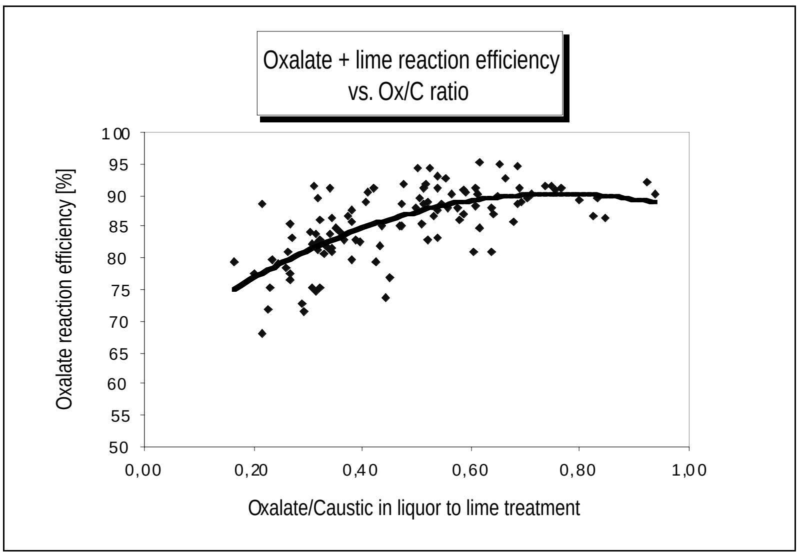

Figure 8

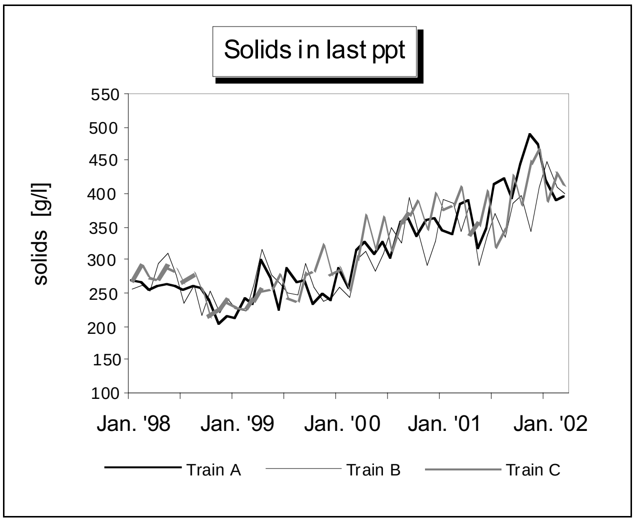

Figure 9

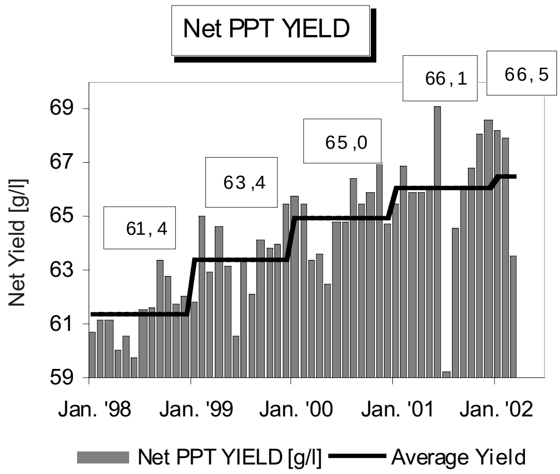

Figure 10

with excess production of tertiary seed caused by high solids overflowing from the Secondary Thickeners, and subsequent poor oxalate removal, into a much more comfortable condition of a unit capable to accept higher seed charge and higher flow, without running into problems. The said changes made production beyond the threshold of 1 Mtonnes/annum possible and have prepared the precipitation unit for further increases in future production rates.

In a future most alumina refineries will move towards higher circulating flows and also conditions to get higher precipitation yield. This inevitably involves seed charge increase. The corresponding higher circulation of solids may not be permitted by the capacity of the existing units, especially in the case of classification units. The utilization of hydrocyclones can represent a successful way to improve the capacity of the facilities by installing them in parallel with the existing classifiers obtaining the advantage of a variable seed charge by varying the number of cyclones or clusters operated.

An additional advantage can be obtained for oxalate removal as from the cyclone operation an enrichment of oxalate in the tertiary seed can be achieved.

The other described upgrade consists of installation of hydrate filters to charge the precipitators with a seed cake instead of a seed slurried with spent liquor. Location of the filters directly on top of precipitation tanks proved to be a simple and rational solution with positive effect also in the cooling capacity of the flash interstages of precipitation.