OLD-FASHIONED PROCESS EQUIPMENT IN NEW CLOTHES: FILTER REVAMPING IN RUNNING BROWNFIELD PLANTS

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Abstract

The capacity increase of alumina production plants can be achieved by either investing in new production lines or by de-bottlenecking of the running plants. Numerous studies in the past have proven that the de-bottlenecking of existing production capacities is the most feasible and the least risky method.

The revamping process for de-bottlenecking and upgrading of running equipment is characterised by features like short-termed preplanning phases, fast realisation, step-by-step engineering, involvement of own know-how and own plant technologies and exact cost control. Contrary to this the investing in new equipment means long-termed pre-engineering, technology screening and claiming for financing, decelerated realisation (at least by delivery times), complex engineering related to building, piping and wiring, overcoming of acceptance barriers by operators and maintenance people, high additional cost for new peripheral equipment and risky claiming for new investment funds depending on outside decision makers and on market factors. The implementation of used but suitable filter equipment from other plants for de-bottlenecking purposes offers additional interesting chances. The careful revamping and adaptation of used filters to the new process conditions ensure an improved performance.

Against this background a successful concept has been developed for de-bottlenecking and revamping of existing brownfield filtration plants for each kind of filtration in the scope of an alumina refinery. Numerous projects in many alumina plants all over the world prove the attractive feasibility of this revamping concept.

1. Introduction

New production targets in alumina refineries usually aim at increasing of the plant capacity, at improving of the product quality and/or the plant profitability. For achieving the new targets it has to be decided whether a new investment or a de-bottlenecking and optimisation of the running process and equipment is the more feasible and less risky way. This situation faces decision makers with the question, to which extent the process design and the running equipment do still meet the state of the art and to which extent revamping measures will improve its capability. This is of special relevance for the filter equipment since alumina production is a very filtration-intensive process.

In many cases the revamping of running filtration plants improves the filter capability to such an extent that the required targets can be achieved as good and reliable as with new equipment — provided that the revamping is carried out with know how and experience concerning the filtration process and the filtration apparatus. The upgrading of running filter plants is realised much quicker and impairs the whole production process quite less than the planning and implementation of new equipment. Thereby, capacity increases of 50% up to 150% can be achieved.

Investing in new equipment usually means a prolonged multistage procedure including

- a long-termed pre-engineering phase to specify and pre-plan rebuilding measures, to work out a specification of the new technology, etc.
- technology screening to find out the best suited new technology available on the market which often needs the performance of test trials
- OEM screening which means to screen the market, to inquire for bids, to compare and to evaluate the competitive offers with respect to technical and economic aspects and to carry out negotiations
- complex engineering since new equipment needs a lot of modifications in the filter building or even a new building is required which both means comprehensive modifications at the piping or installation of a complete new piping, wiring, etc.
- decelerated implementation of the new equipment by unforeseen delays e.g. delayed delivery of one or more components
- overcoming of acceptance barriers by the operators and the maintenance people which needs a training period (with increased danger of malfunctions) to get familiar with the new equipment
- high additional costs for additional peripheral equipment
- claiming for financing for the new investment.

Compared to this comprehensive and "administrative" procedure of a new investment project the revamping of existing filter equipment is carried out much simpler and much straighter as numerous revamping projects have proven. The modernisation and upgrading measures of a filter revamping project normally causes less or no changes to the building and the repercussions on the periphery of

Figure 1 — Typical filter types of an alumina refinery: seed disc filter, product pan filter, red mud drum filter, red mud drum filter plant

the filter plant are widely reduced. The existing equipment is upgraded at the site and stays on its place, so, the efforts for pre-engineering, logistical planning, inquiring and ordering of supplementary peripheral equipment etc. are minimum compared to the installation of new equipment. The revamping of running filter plants can be realised fast, short-termed and with significantly less costs. As main advantages of a revamping process are to be named

- reduced planning and engineering efforts
- short-termed and fast realisation
- step-by-step engineering
- involving of the own know-how and plant technologies
- usage of the well known and operator-accepted equipment
- minimal costs for peripheral & supplementary equipment
- coverage of the costs by the maintenance budget

The optimisation of running processes and equipment, however, demands a fundamental understanding of the dependencies between:

product to be filtered ⇔ applied filtration process ⇔ used filter equipment.

Only a superior know how and understanding of these dependencies allow to engineer the optimal measures and to finally guarantee a new, improved performance. Against this background BOKELA has developed a successful concept to de-bottleneck and to revamp existing brown field filtration plants. The concept is split in three phases and allows a maximum of cost control, involvement of own plant technology and a minimum risk.

In the following the successful revamping of the red mud drum filters of the Zhengzhou Alumina Refinery of China Great Wall Aluminium Corporation (CGWAC) is presented. The excellent performance of the improved filters and the close and productive co-operation between the experts of CGWAC and the BOKELA engineers demonstrate in an exemplary way the rolling down of a revamping project.

2. The 3-Phase Filter Optimisation Program

On the basis of numerous filter revamping projects in nearly all industries BOKELA developed a specialist program for filter optimisation in three steps. It is carried out with the know how and the experience which have been gained by upgrading of drum, belt, disc and plate filters, filter presses, Niagara filters Kelly filters etc. of nearly all OEMs.

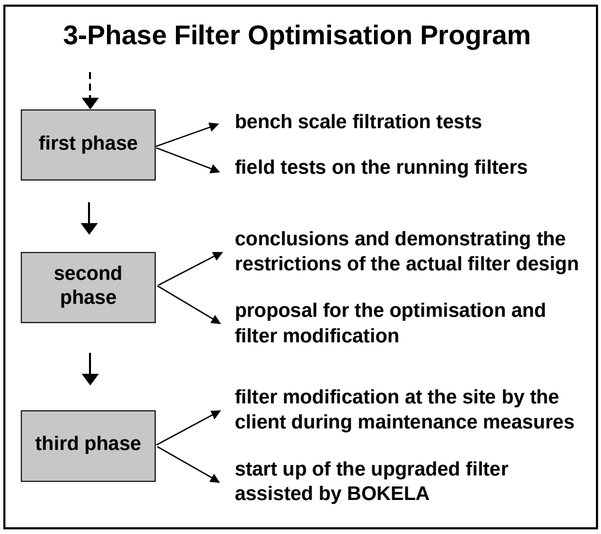

Figure 2 — General schedule of the filter optimisation program

For the red mud drum filter optimisation at the Zhengzhou Alumina Refinery of China Great Wall Aluminium Corporation (CGWAC) the program was carried out together with the experts of CGWAC according to the following schedule:

- *diagnostic step:* determination of the optimisation potential of the red mud drum filters
- *engineering step:* elaboration of upgrading measures and creation of specifications and drawings, presentation of a detailed manual for "how to do it" and discussion with the CGWAC experts
- *realisation step:* implementation of these measures by modification of at first one red mud drum filter

Generally, a filter revamping project includes the following performances:

In the *first phase*, the filtration behaviour of the product and the filter performance are examined in lab and field tests. This analysis of the actual state defines the real capacity of the filtration plant and exposes the “bottlenecks”. A “Test Report” gives very concrete details about the optimisation potential and first costs estimates and profitability estimates can be made.

In the *second phase* modification measures for the re-engineering of the filtration plant are worked out, presented in a “Modification report” and discussed with the customer. According to these suggestions it can be decided, which of the recommended measures shall be realised. BOKELA then works out the required specifications and drawings.

The *third phase* — i.e. the modification works and the commissioning of the filtration plant — starts when the specifications and drawings are checked. If the filtration plant consists of several filter units, at first only one filter unit will be modified. Most of the purchases are organised and made by the customer itself and the modifications are carried out in the customer’s workshops as far as possible while BOKELA supervises the re-building.

When the first filter modification is finished, the improved filter performance is determined in a test run and compared with the calculated data obtained from the tests made in the first phase. Now all further filter units can be modified by the customer itself in an analogous way.

3. Revamping of Red Mud Drum Filters of the Zhengzhou Alumina Refinery

China Great Wall Aluminium Corporation (CGWAC) operates a combination of Bayer Process and Sinter Process in the Zhengzhou Alumina refinery. In the Bayer Process the bauxite is ground, digested and diluted. Then, in a settler the solid residuals (underflow) are separated from the liquid (overflow) and the underflow with the red mud is pumped to two lines (line 1 and line 2) of counter current washers/decanters (4 units each line).

The total underflow of Line 1 (figure 3) is separated and washed in a two step filtration process consisting of seven drum filters. On the first filtration stage four filters are available and typically 3–4 filters are in operation. The filtrate is returned to the last washer/decanter and the filter cake is discharged with a cake moisture of MC = 42–45 wt%. This cake is re-slurried with water in a mixer tank and given to a settling tank. The underflow of this settler is fed to the second filter stage with a solids content of some 200–250 g/l. Here, three filters are installed of which typically two are in operation. The filter cake is discharged with a cake moisture of MC = 42–44 wt% and a soluble soda content which is only some 30% of the soda content from the first filter station cake. It is re-slurried with water again and pumped to the pond for disposal.

Line 2 also consists of four washers and the underflow is fed to seven drum filters. On these filters the red mud filter cake is not washed, because it is returned to the Sinter Process which requires caustic. There it is milled together with new bauxite, lime stone, coal and Na_2CO_3 and the mixture is sintered in rotary kilns. After digestion and dilution, the slurry is then separated into the pregnant liquor which goes to precipitation and into red mud which is washed in a multi-step washing stage and then pumped to the pond for final disposal.

3.1 *Targets of the filter optimization*

China Great Wall Aluminium Corporation intends to increase the total plant capacity and therefore has the necessity to increase the filter capacity and to improve the performance of both filter lines. In order to achieve these objectives CGWAC decided to engage BOKELA as a highly competent filter engineering company to perform the filter plant de-bottlenecking instead of investing in new drum filters. So, BOKELA was requested to upgrade the red mud filters according to the 3-step filter optimisation programme which is well proved by references world wide in the mineral industry.

The new milestones of CGWAC for the filter revamping are:

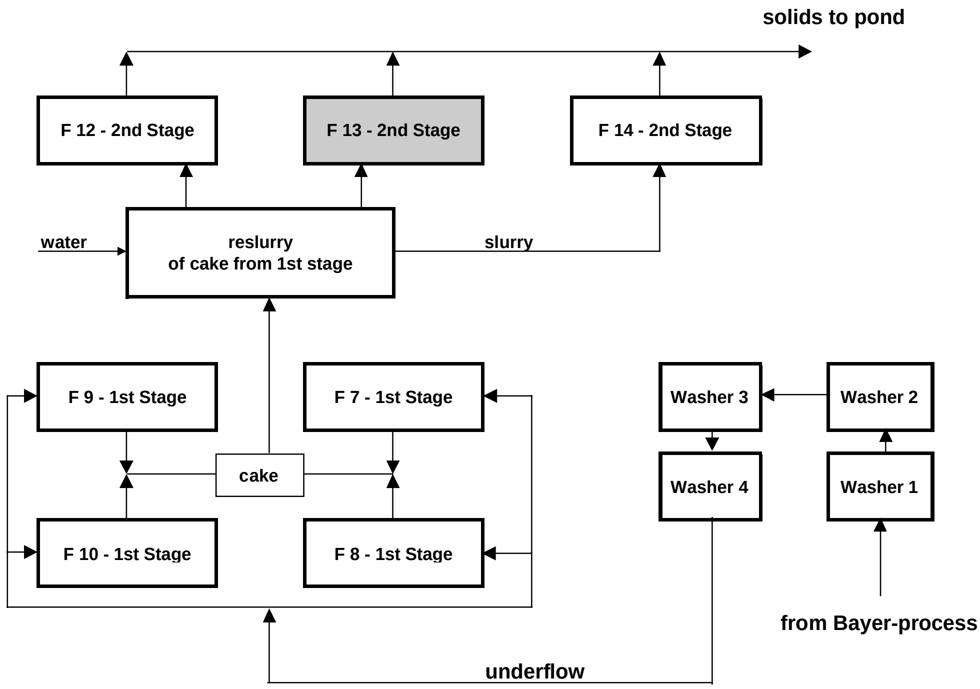

Figure 3 — Flow sheet of the red mud filtration Line 1 (solids to pond)

- 30 % throughput increase
- whereby the soda content and moisture content has to remain on the same level
- secure and complete (100%) cake discharge
- improved filter availability
- reduced filter operation costs

In case of a successful optimisation of a first drum filter all fourteen red mud drum filters (40 m^2 each) shall then be modified one after one.

3.2 *Diagnostic Step — Field and Lab-Tests (Step 1)*

In the first step BOKELA determined the status quo performance of the line 1 red mud drum filters both of the first and the second filter stage and carried out investigations with the lab filter apparatus FILTRATEST for determining the optimisation potential. The results showed that on the first stage filters an increase of the solids throughput from currently 7,6 t/h to 12,3 t/h can be expected which means 62% capacity increase and on the second stage filters an increase of the solids throughput from currently 10,8 t/h to 18 t/h can be expected which means 60% capacity increase.

At the same time the soluble soda content of the filter cake can be reduced by 15–25% in case of an optimised cake wash system which allows more wash water and which will make the cake wash more efficient. The moisture of the cake will remain on the same level of 42–44 wt%.

3.3 *Optimisation Potential for the Second Filtration Stage*

After evaluation of the bench scale testwork at the site CGWAC decided that Filter No. 13 at the second filtration stage (fig. 2) should be the first filter to be modified. The second filtration stage is of special importance, because this cake is pumped for final disposal to the pond and any soda in the cake is a loss to the process.

The typical current operation data of filter 13 are as follows:

- solids throughput: 10,8 t/h
- cake moisture: 42–44 weight %
- soluble soda content of cake: actual value set to 100%
- typical wash ratio (t ww / t dry solids): 0,07–0,10 t/t
- measured feed solids: 200–250 g/l (average 241 g/l)
- temperature of feed slurry: 70–75°C
- filter speed: 2,0 rpm

Filter 13 is operated with permanent slurry overflow in order to keep the slurry level in the trough constant. The cake is washed with one spray bar and discharged by a 3-roller cloth discharge system. The discharged cake is re-slurried and pumped to the pond for final disposal.

3.3.1 *Solids Throughput*

In figure 4 the measured operation value of the solids throughput and the lab test values indicating the optimisation potential are shown versus the square root of the filter speed. According to the filtration theory (equation 1) the solids throughput is directly linear to the square root of the filter speed. Thus the accuracy can be checked easily and the scale up and interpretation of the testwork results is easy to handle:

$$\dot{m}_s = \sqrt{\frac{2}{\eta_L \cdot r_c}} \cdot \sqrt{\kappa} \cdot \sqrt{n} \cdot \sqrt{\alpha_1} \qquad (1)$$

Δp [bar] = filtration pressure difference; κ [-] = concentration parameter
n [rpm] = filter speed; η [kg/ms] = viscosity
α_1 [°] = cake formation angle; r_c [1/m] = cake resistance

It can be seen that a solids throughput of 18 t/h can be expected which means that an optimisation potential of some 60% exists which may be realised in case of some design modifications. The filter has not reached this theoretically feasible performance mainly due to restrictions

- in the control head and
- problems with the cake discharge system.

But there are also some other design weak points which are responsible for the not optimum performance and which prevent a higher filter speed — the most important measure for increasing the throughput rate of a rotary filter.

3.3.2 *Cake Wash*

In figure 5 the measured operation value of the soluble soda content in the cake and the expected value are shown

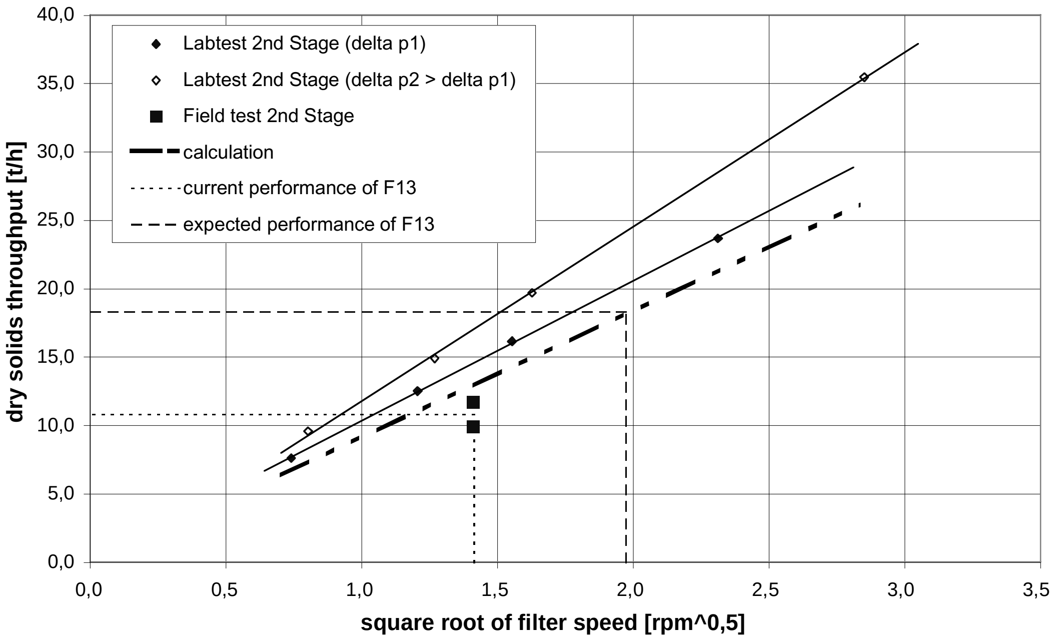

Figure 4 — Operation value and expected value for solids throughput versus square root of filter speed

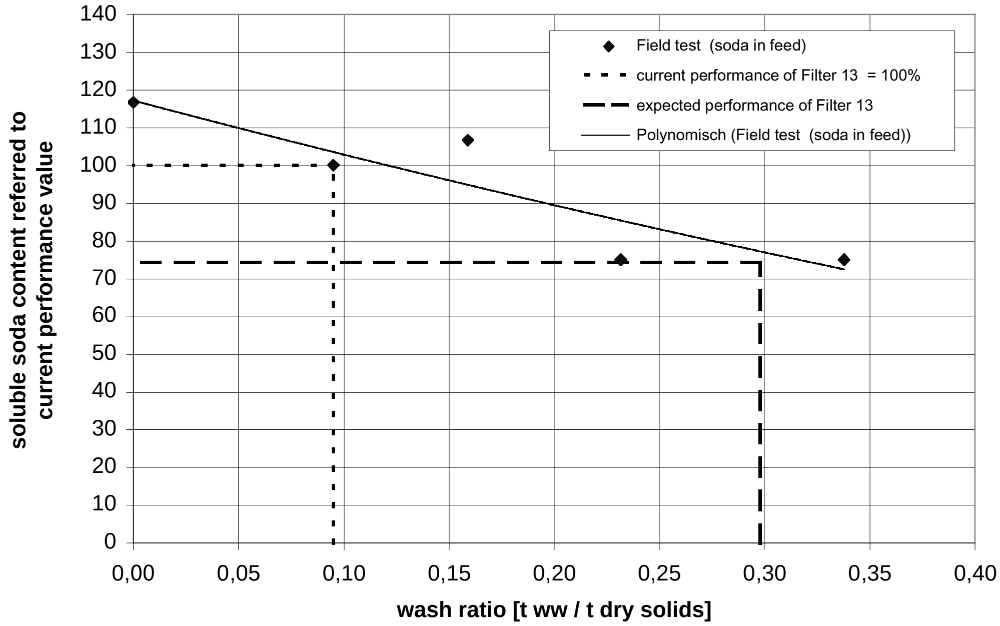

Figure 5 — Operation value and expected value of soluble soda content in the cake versus wash ratio

versus the wash ratio which is defined as: t wash water per t of dry solids. It can be seen that increasing the wash ratio from some 0,09 to 0,3 reduces the soluble soda content in the filter cake by some 25%. This can be realised by improving the cake wash system.

4. Engineering Step — Modification Report (Step 2)

On the basis of the field and lab tests BOKELA worked out modification measures which were presented to experts of CGWAC in a modification report. In order to realise the optimisation potential and to achieve the production targets the proposed list of modifications was discussed between the experts of CGWAC and BOKELA.

CGWAC then decided to carry out the following modifications at a first drum filter of the second filtration stage (filter 13 in fig 2):

- Modification of the cake discharge system from belt discharge to roller discharge
- Modification to the filtrate pipes / vacuum receiver
- Modification to the control head
- Modification to the control plate
- Modification to the filter drum
- Modification to the cake washing system
- Modification of the filter drive
- Filter operation without overflow

5. Realisation Step — Revamping of the First Drum Filter (Step 3)

When the decision was made to go on with the revamping project the technical experts of CGWAC decided due to their know-how and experience which modifications were best to be implemented. Then, the filter upgrading started short-termed.

All modifications were carried out in the CGWAC workshop according to specifications and drawings previously discussed between CGWAC and BOKELA and the complete filter rebuilding was supervised by a BOKELA engineer at the site. The increase of the filter speed to 4 rpm was the most important measure regarding the improvement of the solids throughput of the filter. The existing cake discharge system, however did not allow a filter speed above 2,5 rpm. Even at the speed of approx. 2 rpm the existing cake discharge system was already causing severe problems with a dis-aligning filter cloth. Therefore, several modifications as discussed below were a precondition for increasing the filter speed.

5.1 *Modification of the Cake Discharge System*

The filters were equipped with a belt discharge system (three rollers) which caused several filter operation problems. The most important problems were creeping of filter cloth which led to operation stops and vacuum decrease in the common system, wear out of filter cloth which made it necessary to change the filter cloth every 2 to 6 days and leaks between cloth and filter cells which led to slurry (original feed) flowing into the filtrate system.

In order to solve these problems and to allow a higher filter speed the discharge system was completely modified by mounting a roller discharge arrangement which is the most suitable discharge system for red mud filter cake. This made it also necessary to fix the cloth on the filter drum by using division strips (already existing on the filter drum) and sash cords which are hit into the division strips. The roller discharge system consists of a driven discharge roll and a cake scraper. The discharge roller is driven by the filter drive with a higher speed than the filter and the resulting shear stress in the filter cake ensures an optimal strip off of the cake from the cloth which is supported by a cake scraper.

5.2 *Modifications to the filtrate pipes/vacuum receiver*

The measured vacuum in the common vacuum system was about 0,5 bar while the effective pressure difference directly behind the filter cloth was more than 0,2 bar lower. The calculated filtrate velocity in the internal filtrate pipe system of the drum filter (between filter cells and control head), however, indicated a pressure loss of less than 0,05 bar which means that the major pressure loss is caused in the filtrate pipe between control head and receiver.

To minimize this pressure loss the existing piping between control head and receiver was modified in a first step. The next step was to modify the filtrate inlet into the receiver by tangential inlet nozzles.

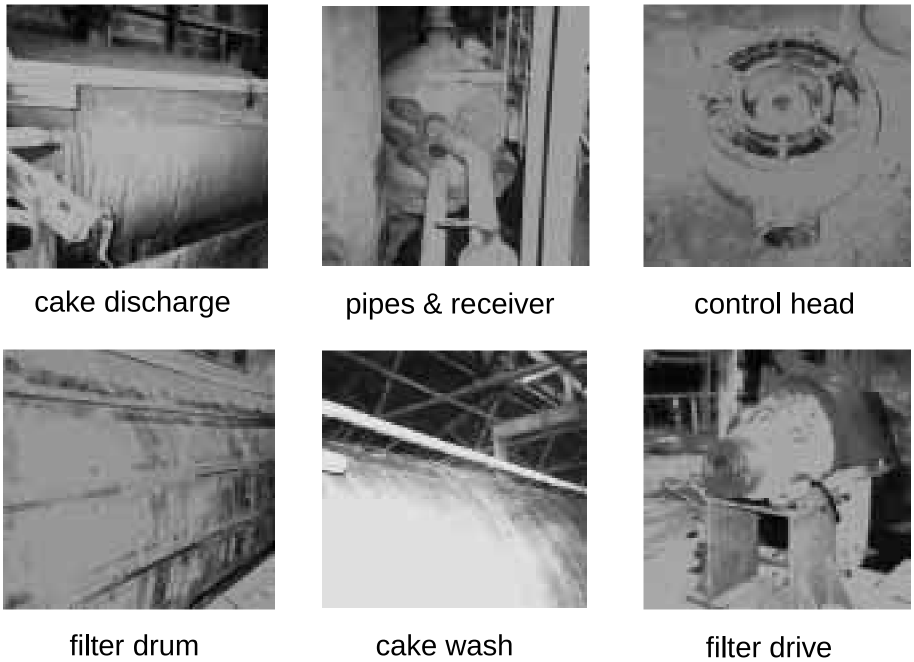

Figure 6 — View of some parts to modify for revamping of the red mud drum filter

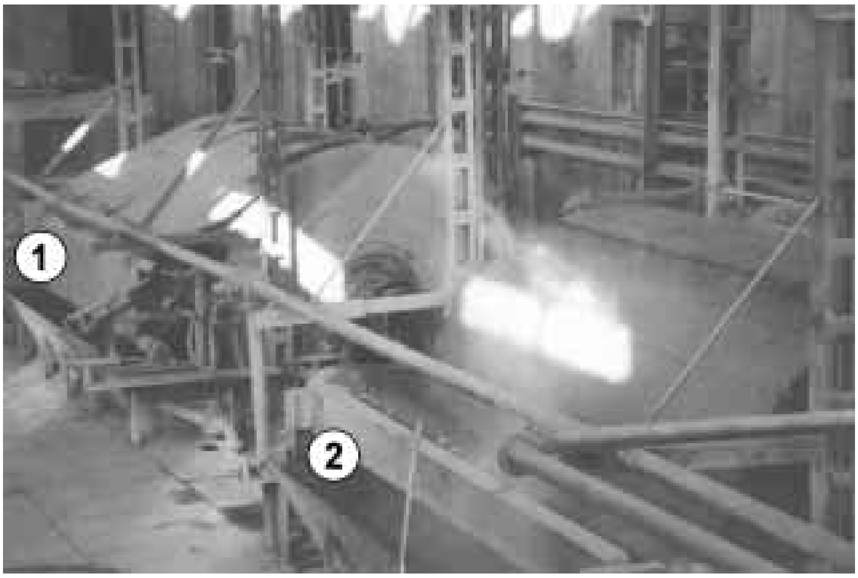

Figure 7 — Drum filter before the upgrading with belt discharge (1) and drum filter upgraded by BOKELA with roller discharge (2)

5.3 *Modification to the control head*

To get full benefit of the modification described above it was also necessary to modify the control head according to BOKELA's special concept of "air pre-separation" in the control head. In order to pre-separate the liquid and gaseous phase inside the control head the positions of the single process zones were changed.

The modifications to the control head also requested modifications of the control plate for increasing the cake dewatering zone (to reduce the residual cake moisture) and to ensure that the filter cells are under atmospheric conditions before reaching the cake discharge position. This is important in order to achieve complete cake discharge with the roller.

5.4 *Modification to the filter drum*

At the old drum design a considerable amount of filtrate retained in the filter cells which then re-moistured the solids during the cake discharge. This increased the cake moisture and the soluble soda content but it also deteriorates the cake discharge at the roller system. To prevent these negative influences the positions of the filtrate pipe were changed to a position which allows a complete filtrate emptying of the cells.

5.5 *Modification to the cake washing system*

At the old design one wash bar was installed on top of the drum which could not ensure an effective cake wash. Therefore, the cake wash system was improved by installing a new device which ensures an even distribution of the wash water on the cake and which allows a higher wash ratio of some 0,3 as recommended by the lab test results (figure 5).

5.6 *Modification of the filter drive*

The final key to improve the filter performance was the increase of the filter speed up to 4 rpm. As a precondition it was necessary to change the filter drive according to the new specification which means a required power of 7,5 kW for a filter speed of 2–4 rpm controlled by frequency converter.

5.7 *Filter operation without overflow*

Since the filters were operated without control of the level in the filter trough they were run with constant overflow of suspension back to the thickener. As a result a big amount of suspension enriched with fine particles (due to a classification in the trough) is steadily recirculated which deteriorates the filtration properties of the slurry. Therefore, the level in the filter trough is now measured by a supersonic sensor and controlled by adapting of the filter speed. The optimisation of the hydraulic system in the pipes and in the control valve has to be seen as a precondition for being able to adapt the filter speed to the feed flow.

5.8 *New filter cloth after modification of all filters*

After all filters are modified as described above the capacity of the red mud filtration plant can be further increased by using a more tight filter cloth which reduces filtrate solids. Regarding the actual filtration and the laboratory tests there is a considerable amount of solids (particle sizes below 45µm) in the filtrate. Compared with the solid content in the feed (200–240 g/l) some 30% of the solids (mainly fines) are re-circulated to the washers and are fed back to the filters. The reduction of these filtrate solids will improve the filtration characteristic of the slurry resulting in a reduction of the numbers of filters in operation (reduced energy, operation and maintenance cost).

6. Operation Data of the Modified Drum Filter

The solids throughput increased by 33%–47% which is monthly measured by CGWAC. This capacity improvement is significantly more than the desired target value of 30%. At the same time the soluble soda content of the filter cake is 10%–20% less than before due to the improved cake wash system which makes the cake wash quite more efficient. Although the wash ratio and consequently the wash water throughput increased the moisture content of the cake remains on the former level of 42 wt%–44 wt%. The totally modified cake discharge system ensures a secure and complete filter cake discharge and together with the other filter modifications the operation behaviour and availability of the filter is significantly improved. Consequently, the operation costs — e.g. for the filter cloth — and the maintenance efforts reduced.

The two steps-filtration-process with 7 running filters can now be replaced by a one-step-filtration with only 4 filters in operation due to the good washing efficiency of the upgraded filters and due to some changes in the process. Therefore, 3 filters can be used as stand-by units which means that CGWAC can have 75% additional performance available as capacity potential.

Table 1 — Performance values of the optimised red mud drum filter

New Performance Values of the Revamped Red Mud Drum Filter	
Increase of Solids Throughput	33%–47% (significantly more than the required 30% increase)
Decrease of Soluble Soda Content in the Filter Cake	10%–20%
Cake Moisture Content	same value as before in spite of enlarged wash zone

7. Summary

The revamping of the red mud drum filters of the Zhengzhou Alumina Refinery of China Great Wall Aluminium Corporation (CGWAC) was carried out with great success as a part of the plant capacity increase. All objectives of the filter optimisation like increased specific throughput, a better cake washing or less soda content in the cake, respectively without deteriorating the moisture content, a secure cake discharge, an improved filter availability and reduced operation costs have been achieved. The filter modifications were implemented at the site in a stringent way by the technical experts of CGWAC together with the BOKELA filter specialists. The complete project including all three steps of the filter revamping program was carried out very quick in only 6 months from project start to the filter start up.

The decision of CGWAC to upgrade the red mud drum filter station by revamping the running filters according to the 3-step filter optimisation program enabled CGWAC to improve the process performance and the profitability of the red mud filtration with significantly less time and with significantly less costs compared to investing in a new filter plant.

8. Outlook

The filter optimisation program is not restricted to the improving of filters for one and the same filtration task or product resp. before and after the revamping. BOKELA also succeeded in upgrading and adapting of filters for new filtration tasks.

For an Indian alumina refinery two drum filters, which were previously operated for magnesium hydroxide filtration, were rebuilt and adapted to red mud filtration. After finishing the modification works the rebuilt drum filters were transported to the new destination and installed in the red mud filter building. The costs for rebuilding, transport and commissioning of the filters came to some 30% compared to the investment costs for new drum filters which means cost savings of 70%.

The implementation of used but suitable filter equipment from other plants for de-bottlenecking purposes offers additional interesting chances.