NEW PERFORMANCES IN SEED FILTRATION BY MODERN DISC FILTERS: A FEASIBILITY REVIEW

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Abstract

The filtration of coarse and fine seed downstream the secondary or tertiary thickener or in continuation of hydrocyclones, respectively, influence remarkably the effectiveness, the operational cost and the quality of the final product in Alumina precipitation plants. The filtered solids are normally reslurried in stirred tanks or given directly to the precipitation tank, if the filter is installed on top of the precipitators.

For seed filtration mainly rotary vacuum disc filters are used. In the last five years a new generation of big diameter disc filters (type 'Boozer') has been developed and installed world-wide, characterised by:

- very high specific throughput rates
- reliable, 100% cake discharge
- high operational availability and low maintenance cost
- easy and safe handling of the filter components
- low operational cost for vacuum, pressurised air and filter cloth consumption
- safe operation due to a superior process philosophy applied in a PLC/LCP system

The "Boozer" filter generation is in operation for more than five years for different duties and has been developed permanently since.

Based on the latest installation in an Indian Alumina refinery the report will show the integration of the Boozer filters in the precipitation and calcination plant and summarise the practical experiences from the standpoint of the user and the operators, respectively. The reasons and the arguments which led to the order for the Boozer filters will be discussed.

1. Introduction

Big diameter disc filters are the most advanced filter technology for seed filtration which were developed and installed for the first time in the early 70s. With the High Performance Disc Filter Type "Boozer" BOKELA has developed a new generation of big diameter disc filters which set a new standard for coarse and fine seed filtration. The outstanding hydraulic characteristics of the "Boozer" disc filter were achieved by improving each detail of the vacuum disc filter design leading to extraordinary high performance capacity, high operational safety and reliability as well as to low maintenance and operation costs.

Beginning with the first supply in 1995 the "Boozer" started a string of successes. In the meantime "Boozer" disc filters are operated for fine seed, coarse seed and even for product filtration in Alumina refineries world wide. The most important performance data and features characterising this High Performance Disc Filter can be listed as follows:

- up to 100% throughput increase compared to conventional disc filters with slurry throughput rates V_{SL} as follows:
  V_{SL} = 6–7 m^3/h (fine seed), V_{SL} = 12–13 m^2/h (coarse seed), V_{SL} = 16–18 m^3/h (product)
- 100% cake discharge even at a high filter speed (at conventional disc filters max. 75% of the cake is discharged)
- high filter speed of 5 rpm (conventional disc filters: 3 rpm maximum)
- high operational availability and low maintenance cost
- low operational cost for vacuum, pressurised air and filter cloth consumption
- safe operation due to a superior process philosophy applied in a PLC/LCP system

The "Boozer" is usually manufactured as single, double or triple disc filter. Each disc has a diameter of 5.6 m and consists of 30 segments forming a filter area of 40 m^2 per disc. The immersion depth of the discs in the slurry is 50%. The filter trough of the "Boozer" is carried out as "joint single trough" design which combines the advantages of the former common trough design and of the standard single trough design. The cake is discharged by blow back air which is exactly timed by snap blow valves. The design and outstanding hydraulic capacity of the "Boozer" are the basis for the excellent performance, for the improved filter operation and a new process philosophy.

The operation experience with the running "Boozer" seed filters led to various design improvements and to new developments in the last five years. The most important are reported about in this paper.

2. Arrangement and Installation of Seed Disc Filters

2.1 *Arrangement Variants of Seed Disc Filters in Alumina Refineries*

Seed filtration in Alumina refineries is mainly characterised by the tremendous flow rates which have to be

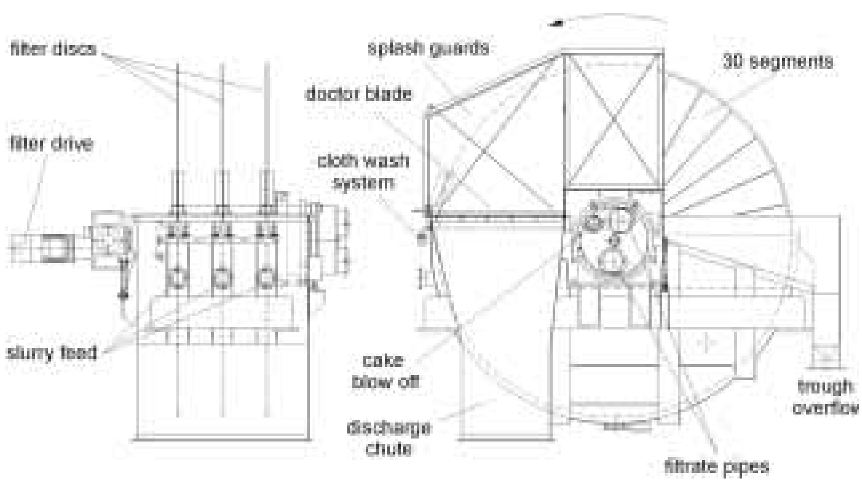

Figure 1 — Principle flow sheet of Al $(OH)_3$ precipitation and filtration in Alumina refineries

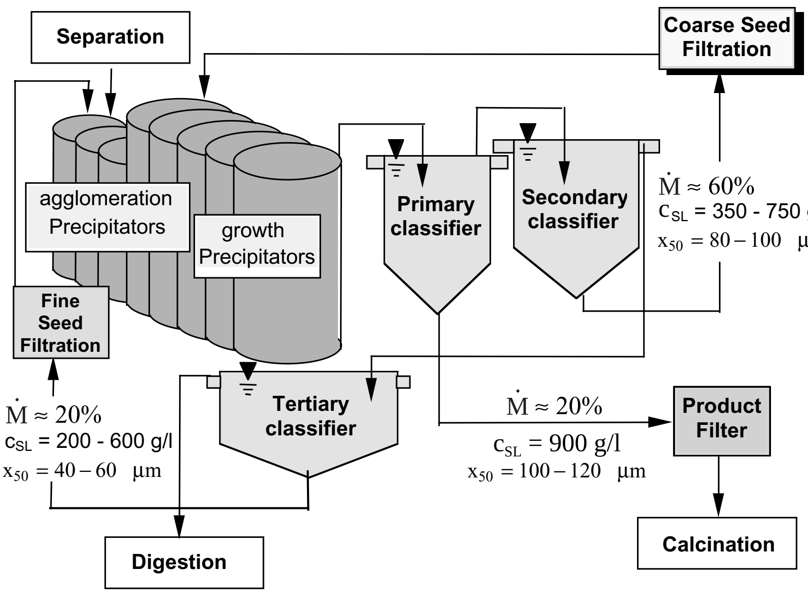

Figure 2 — Principle flow sheet of Al $(OH)_3$ precipitation and filtration in Alumina refineries

processed on the filters. As shown in figure 2 only about 20% of the Al-hydrate is withdrawn as product stream from the primary classifier downstream of the precipitators whereas about 80 % is withdrawn from the secondary and the tertiary classifier and recycled as seed.

Figure 3 — Five triple-disc "Boozer" disc filters arranged in the filter building of an Alumina refinery

Typically, the seed filters are installed in a separate filter building. The filter cake or the seed solids, respectively, have to be re-slurried with pregnant liquor after being separated from the spent liquor and the slurry is then pumped into the precipitators to support the Al-hydrate precipitation. Therefore, this kind of filter arrangement needs a comprehensive logistic for handling and processing of the seed filter cake including transportation systems like belt conveyors, a re-slurry station with all necessary installations, pumps and piping with insulation for pumping the slurry to the precipitators. Since the seed is re-slurried with pregnant liquor all components of this logistic are faced with serious problems due to scaling. Especially at the conveyors and at the installations of the re-slurry tank as well as in the piping system the incrustations cause operation problems and complicate the maintenance work.

As an alternative to this standard arrangement the seed filters can be installed on the top of the precipitators (see fig. 4). At this variant the filtered seed solids have not to be re-slurried because the discharged filter cake can be fed into the respective precipitators directly from above. This means that neither a separate filter building nor a re-slurry station nor pumps and slurry piping are needed. The transportation distance for distribution of the seed filter cake from the filters to the respective precipitators is even shorter which reduces the length of installed conveyor systems. Therefore, this alternative variant of filter arrangement improves the operation conditions because it strongly simplifies the handling of seed recycling and reduces the maintenance. Consequently, the operation costs and especially the investment costs reduce. Since main peripheric components like filter building, re-slurry station, pumps, piping and pipe heating etc. are not needed the total invest costs reduce significantly. Often only about 20% from the invest costs are apportioned to the filters while 80% are required for the filter building, the re-slurry station, pumps and piping. This share can be reduced by one half in case of a filter arrangement on the top of the precipitators so that the total invest costs reduce to some 60% compared to the standard variant of seed filter arrangement.

At another variant it is intended that each precipitator to which seed is recycled is equipped on the top with an own disc filter of appropriate filter area. This variant of filter arrangement needs no logistic for handling of the filter cake, so problems with scaling are reduced to its utmost.

2.2 *Installation of High Performance Seed Disc Filters*

The "Boozer" disc filter is designed consequently according to flow requirements in order to avoid flow restrictions as far as possible for minimizing the pressure loss in the whole flow route from the filter segments up to the filtrate receivers. The two phase flow caused by the filtrate and the suction air which displaces the mother liquor in the cake pores as well as the high flow velocity are the important factors for the pressure loss.

Especially between the control head and the receivers this two phase flow can lead to a high pressure loss value Δp that is up to ten times as high as for a one-phase flow. Therefore, the installation of the filter and the receivers influences the filter operation and the filter performance. In order to comply with these physical relations a "Boozer" disc filter and the receivers are located as close and straight as possible to keep this flow section very short (fig. 5). Furthermore, the pipe layout between control head and receivers are made to avoid any bend as far as possible and the receiver inlet is carried out tangentially. The receivers are designed according to layout calculations including the calculation e.g. of the proper receiver volume and flow velocities.

3. Operating Experiences with Seed Disc Filters

3.1 *Experiences with Common Trough Design*

With the common trough design all filter discs run in one trough which means that all discs run with the same slurry level. The filter is equipped with an agitator that ensures a reliable homogenisation of the slurry in the trough. Both aspects are a precondition for the formation of an even and homogeneous filter cake on each disc which in turn is a precondition for a good cake dewatering and a secure cake discharge. On the other hand the agitator is a problem focus of the common trough design mainly due to the agitator seals. Stuffing-box packings which are normally used as agitator seals do not securely prevent leakage and have to be exchanged regularly, which complicates the maintenance work. This can be overcome by using mechanical seals which securely prevent trough leakage but which are much more expansive than stuffing-box packings and need to be scavenged steadily.

Figure 4 — "Boozer" seed filters on the top of the precipitators

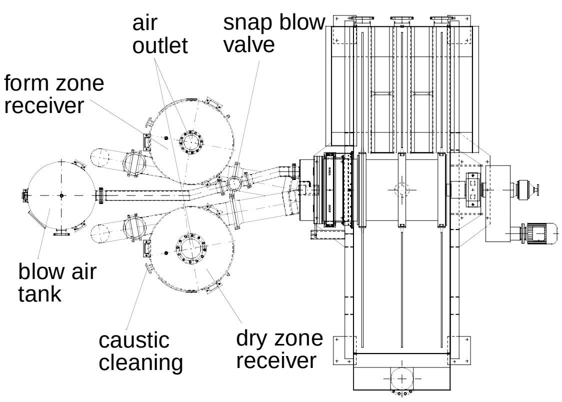

Figure 5 — Top view of a triple-disc "Boozer" filter with receivers, blow air tank and filtrate piping

3.2 *Experiences with Single Trough Design (Standard Design)*

The single trough design is applicable for the filtration of slurries with high to medium solids concentration like Al-hydrate slurries where the danger of particle classification is widely reduced. Then, the slurry is homogenised by the filter discs itself if each disc rotates in an own narrow channel, a so-called single trough.

With the standard single trough design, which is known since about 30 years, each filter disc runs in a trough which is a completely separated unit. The benefits of this design result from the fact that no agitator is needed due to the stirring effect of the discs, which consequently means that also no sealings, no power for the agitator drive and no maintenance measures for these items are required. As main problems with standard single trough filters are to be mentioned unequal slurry levels in the different troughs, uneven filter cake, incomplete cake discharge, overflow problems, flow exchange between the troughs etc. Especially at the last disc/trough unit often the cake is not completely discharged from the disc so that solids are steadily brought back into the slurry and the concentration in the respective trough increases. This may effect a bogging of the trough which then leads to a filter shut down.

Unequal slurry levels in the single troughs occur as a consequence of performance differences of the different filter discs and due to an unequal slurry feeding since an absolutely equal feed flow can not be achieved. The splitter box outside the trough for distributing the feed to the single troughs is normally designed for a specific slurry. If the characteristic or flow rate of the slurry changes, the solids may then be classified in the splitter box which results in unequal cake formation, different slurry levels in the single troughs, poor homogenization, blinded filter cloths and reduced cloth life time. The performance of the discs may differ due to poor and unequal cake discharge which increases the solids concentration in the slurry and favours the forming of a thick filter cake which blocks the narrow gap between disc and trough wall. Then, the slurry can not flow to the overflow located at the sides of the single trough opposite to the slurry inlet and the slurry spills over and floods the filter floor.

Different filter cloth qualities on the discs, which lead to different disc performances, as well as different feed flow rates can effect that one filter trough overflows while in the neighboured trough the level sinks which then leads to a vacuum drop as a consequence of the high air throughput through the uncovered disc area.

3.3 *Consequences of Operation Experiences with Common and Single Trough Design*

As consequences of the above reported operation experiences at coarse and fine seed filtration with big diameter disc filters BOKELA developed for the “Boozer” disc filter technology an unique trough design, the so-called “joint single trough”, and a special control philosophy.

The “joint single trough” design (see 5.) combines the advantages of the former “Boozer” common trough and of the standard single trough design. The “joint single trough” needs no agitator and ensures that all filter discs run with the same slurry level which helps to prevent the above described operation problems with standard single trough filters. The control philosophy of BOKELA (see 4) ensures a secure and improved filter operation and prevents operation problems and emergencies. For this, all important functions like the vacuum, the filter speed, the slurry level, the pressure in the cake blow off tank, the lubrication pump etc. are supervised and integrated in a filter control system.

3.4 *Control Head*

The control head of the “Boozer” disc filter is pressed against the wear plate via a central tightening which means that the control head is not supported on the trough construction as usually at standard filter design but on the shaft center which leads to a short closed linkage. The “Boozer” wear plate is made of a soft and smooth material with excellent anti-friction properties. Therefore, the wear plate runs without lubrication and protects the much more valuable control plate.

3.5 *Vacuum System*

For the layout of the vacuum system two alternatives are possible. Each filter can be connected to an own, separate vacuum pump which may be called a “single vacuum system”. The other possibility is that all filters are connected to a common vacuum line which may be called a “common vacuum system” as schematically shown in figure 7.

At the “single vacuum system” the failure of a pump can not be compensated by the other vacuum pumps and leads consequently to the failure of the respective filter and to a decrease of the overall filter performance. The “single vacuum system” allows the optimal flexibility of the plant operation if there are stand-by filters available.

At the “common vacuum system”, however the failure of a pump is compensated by the other parallel working pumps. This means that a vacuum pump can go off the line

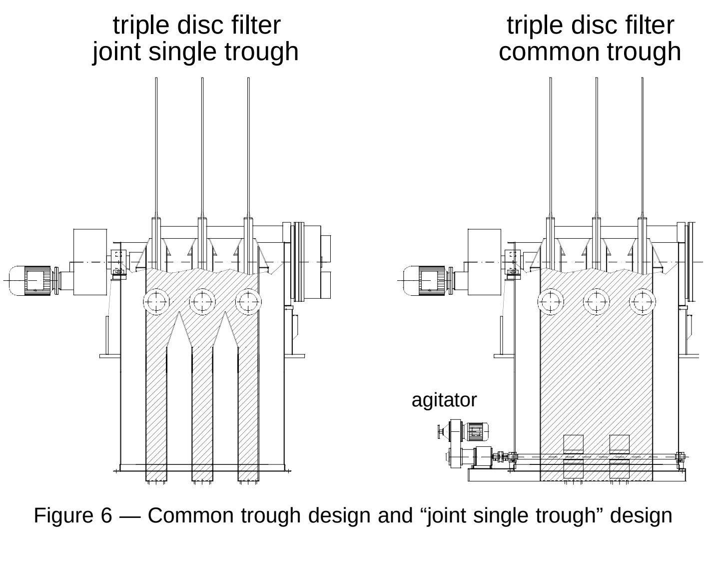

Figure 6 — Common trough design and “joint single trough” design

without affecting the overall filter performance which significantly improves the availability and the operation security of the filter plant. Another important advantage of this alternative is the better profitability compared to the "single vacuum system" because less pump units of larger size can be installed which are relatively cheaper than smaller sized pumps. So, less invest costs are required for the "common vacuum system" and also the costs and manpower for maintenance reduce. An important disadvantage of the "common vacuum system", however, is the fact that the failure of one filter — eg if a filter sucks air due to sinking slurry level in the trough etc. — affects the whole vacuum line and can lead to a breakdown of the complete filter station. This means that the above mentioned advantages of the superior "common vacuum system" can only be used in combination with a filter control system as developed and implemented by BOKELA (see chapter 3).

3.6 *Filter cloth*

The life time of the filter cloth influences the throughput rate and the operation costs of the filter significantly. A long cloth life time reduces the filter downtimes and manpower for cloth changing which is a main part of maintenance, increases the production rates and reduces the operation costs since the filter cloth is a considerable cost factor.

Normally, needle felt which is a tough material of low price is used as standard material for filter bags on seed disc filters. The high throughput rate of the new needle felt bags, however, deteriorates rapidly due to particle deposits in the felt which are removed only incompletely even in case of a long and careful condensate wash. So, within 3–4 days the throughput just decreases to some 70% of the start value and then decreases more and more with every wash cycle.

Contrary to needle felt bags the use of monofilament filter cloths together with monofilament backing cloths show a much more even throughput characteristic and a higher net throughput rate over their lifetime period, but monofilaments are more fragile and more sensitive against mechanical wear and let pass a somewhat higher portion of fines into the filtrate. The "Boozer", however, allows the economical use of monofilament bags due to its improved filter design. The most important features of the "Boozer" having influence on the cloth life time are the perfect cake discharge, the excellent slurry homogenisation in the trough, the confectioning of the filter bags and the improved segment design (avoiding of sharp edges). The blow-back air for cake discharge has the exact timing and the cloth is sucked back shortly before the scraper, which both prevents that the cloth can be damaged at the scraper. The effective cake discharge and the excellent slurry homogenisation, which prevents particle classification in the trough, both minimise particle deposits in the cloth. These features and the excellent washing of the bags on the "Boozer" ensure that the monofilaments have a long lifetime and a high and even throughput rate of always 90% to 100%.

In table 1 typical values for the cloth life time are shown for standard disc filters and for the "Boozer" disc filters. A very interesting figure in table 1 is the solids throughput per filter cloth which for the monofilament equipped "Boozer" is nearly the fourfold as for standard disc filters with conventional needle felt bags. This advanced life time is reached if the "Boozer" is run with following pre-conditions: a periodical on-line washing of the cloth by means of spray bars underneath the scraper and a special segment design and back sucking of the filter cloth shortly before the segment passes the scraper.

3.7 *Maintenance*

The clever design and the tough construction make the "Boozer" disc filter resistant against repair and ensure a reliable operation of the coarse and fine seed filtration with high filter availability. The maintenance work is simplified and the required manpower and costs for the maintenance are widely reduced compared to disc filters of standard design due to a lot of special design features and improved details.

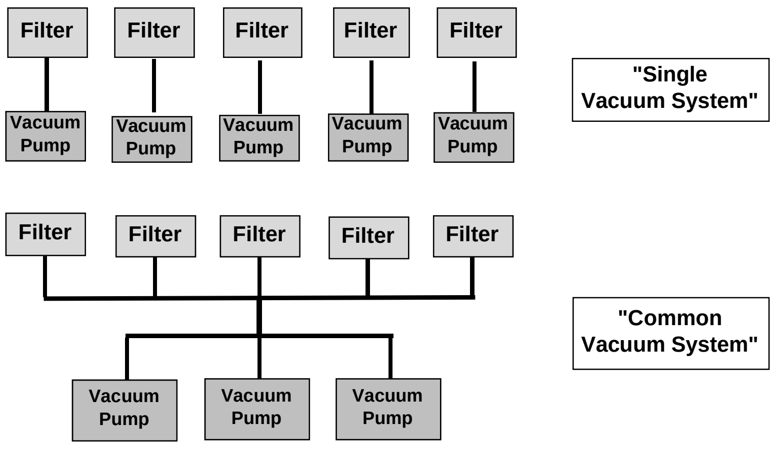

Figure 7 — Scheme of single and common vacuum system for a seed filter station

Table 1 — Typical operation values of cloth life time and solids throughput per filter cloth for standard disc filters and the High Performance Disc Filter "Boozer"

	Standard Disc Filter	High Performance Disc Filter "Boozer"	High Performance Disc Filter "Boozer" (Advanced Life Time*)
	needle felt	needle felt	monofilament cloth with backing cloth
Cloth Life Time [h]	800–1,000	1,100–1,200	1,800–2,200
Solids Throughput per Filter Cloth [t]	2,500–3,200	6,500–7,500	10,500–13,500

* Pre-conditions: periodical cloth on-line washing with spray bars, a special segment design and back sucking of the filter cloth before the segment passes the scraper.

Figure 8 — Walkways between the filter discs of the “Boozer” make maintenance easier and safer

An important simplification at the “Boozer” is caused by the fact that the cloth changing, which is a main part of maintenance work, is very simplified while the cloth lifetime is prolonged. Walkways between the filter discs (see fig. 8) make this duty even more comfortable as well as the use of light weight segments which have only 23 kg instead of 30 kg or even more than 30 kg. The bayonet fixing of the filter segments effects that neither tie rods nor rubber gaskets for connecting the segment feet with the inlet pipes of the centre barrel are necessary.

With “joint single trough” design the “Boozer” disc filter runs without agitator, so that no exchanging of the agitator sealings is necessary which normally is an important maintenance item. Also the barrel sealing of the “Boozer” has not to be exchanged but has only to be flushed during the filter cleaning.

4. Process and Control Philosophy of the High Performance Disc Filter Type “Boozer”

The design and the outstanding hydraulic capacity of the High Performance Disc Filter is the basis of the improved filter operation and of a new “Operation Philosophy” which means that the High Performance Disc Filter Type “Boozer” runs *without* continuous slurry overflow.

An automatic control of the filter operation enables to adapt the performance of the “Boozer” to changing slurry and process conditions and to avoid emergencies. Two circuits — a primary and a secondary control circuit — using the slurry level in the trough as the control variable and the filter speed and the pressure difference as control output ensure a self-regulating and secure filter operation as described below. The possibility to run the “Boozer” with a high filter speed of n = 5 rpm, which is twice the value of standard filters, and the high pressure difference, which is available at the filter cloth due to the improved hydraulic system of the “Boozer”, allow a control of the filter operation in a wide range of filter performance.

All important functions and peripheral components like vacuum pump, filter drive, trough level, blower, the vacuum in the receivers, pressure in the cake blow off tank, lubrication pump etc. are automatically supervised and integrated in the interlock schedule. In case of an emergency the PLC gives alarm and an adequate automatic procedure is started depends on the respective emergency case. In any case the trough drain valve opens, the filter is put off from the vacuum and the feed valve is closed in order to avoid that the slurry floods the filter floor.

4.1 *Primary control circuit — Trough Level Control by Adjusting of the Filter Speed*

The slurry level is measured continuously by a proven ultrasonic measurement device which is suitable even for foam on the slurry surface and mist/vapour in the air. The signal of the level measurement is used to adjust the variable filter speed by a variable frequency controller (fig. 9).

At normal operation the filter is fed with a more or less constant slurry flow and the “Boozer” operates with a medium filter speed of approx. 2.0–3.0 rpm and a fully open vacuum control valve in the vacuum line between vacuum receiver (form zone) and vacuum pump. The best performance of the filter is achieved if the slurry level in the filter trough is close to the overflow level (approx. 50% submergence of the filter disc). In this case the cake formation angle is maximum and an even filter cake with a constant cake thickness over each segment is formed which results in very constant operation conditions.

If the slurry level in the filter trough drops or increases due to a changing slurry flow or changing product characteristics, the filter speed is reduced or increased in order to maintain again a constant high slurry level in the trough. If the filter runs at maximum or minimum permitted speed and the slurry level in the trough still increases or drops, then the second control circuit — adaptation of the vacuum in the form zone vacuum receiver — becomes active.

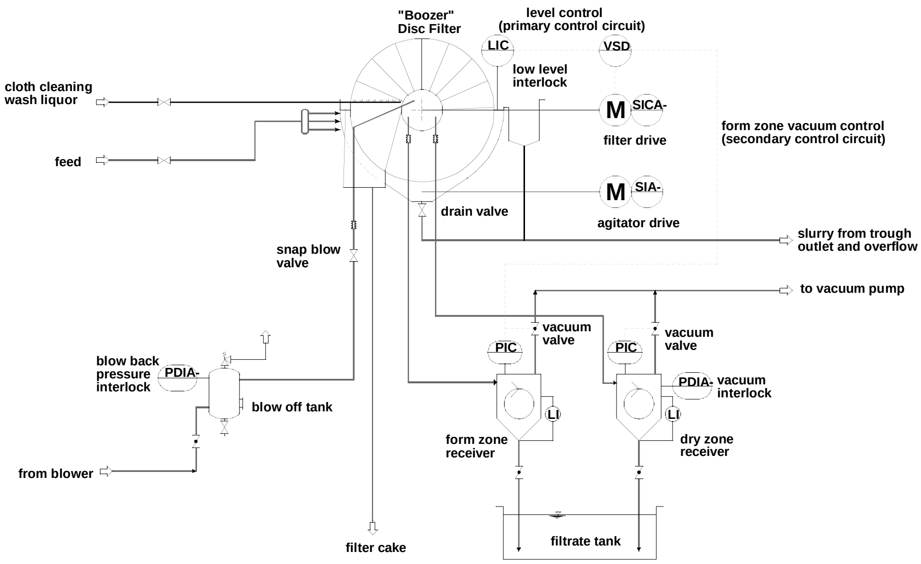

Figure 9 — Schematic P&I diagram of the High Performance Disc Filter “Boozer”

4.2 *Secondary Control Circuit — Trough Level Control by Adjusting of the Form Zone Vacuum*

The control of the form zone vacuum with the vacuum control valve is the second control circuit (fig. 9). The target is again to maintain a constant and high slurry level in the trough. This control circuit becomes active if the filter runs with minimum speed and the slurry level in the trough still drops. Then, the vacuum control valve in the vacuum pipe between receiver (form zone) and vacuum pump is closed as much as to maintain again a constant high slurry level in the trough. If the form zone vacuum control valve is fully closed and the filter speed is already at a minimum of 1.5 rpm but the slurry level still drops, then, the trough level itself can be used to influence the filter performance in a certain range as described below in 3.3.

If the filter runs at maximum speed and the slurry level still increases, the vacuum control valve has to be checked whether it is fully open or not. If the form zone vacuum control valve is fully open, further measures have to be taken to influence the filter performance.

4.3 *Variation of Slurry Level in the Trough*

If the slurry level in the trough still drops although the filter speed is already at a minimum and the vacuum control valve in the vacuum pipe is fully closed, it is possible to operate the filter with a minimum permitted slurry level in the filter trough which is lower than the control set point. If the slurry level drops further, the filtration area of the sectors are not longer fully submerged in the slurry and the sector parts close to the centre barrel are not covered with filter cake. Then, massive amounts of air are sucked in and the vacuum in the form zone breaks down with consequences as described above. Therefore, an operation below the minimum permitted level of the trough is protected by an interlock.

5. New Developments

The “Boozer” filter generation is in operation for more than five years for different duties and has been developed permanently since. The operation experience with these running filters led to many design improvements and new developments. The latest innovations which have already proved to be decisive improvements in operation praxis are the “joint single trough” design, a new high performance control head and the light weight segment.

5.1 *“Joint Single Trough”*

The “joint single trough“ design (see fig. 5) is made to combine the advantages of the common trough and the single trough design without the respective disadvantages and operation failures as described in chapter 3. Like the standard single trough design it works without agitator since the stirring effect of the discs rotating in narrow compartments homogenises the slurry. Like the common trough design the “joint single trough” ensures that all discs run with the same slurry level and it is equipped with a common and large sized overflow. The “joint single trough” is constructed like a common trough with installations between the discs at the slurry inlet side which subdivide the trough in narrow compartments for each disc. At the cake discharge side the same effect is reached by the cake discharge chutes. Since the compartment installations end below the slurry level there is always a free exchange of slurry between the single trough compartments which ensures one common level in the trough for all discs. The slurry inlet is located and designed in a way that patterns of the incoming slurry support the stirring effect of the rotating discs.

5.2 *Light Weight Segment*

With the light weight segment BOKELA has reduced the weight of a segment from 30 + x kg to only 23 kg which makes maintenance and especially the filter cloth change much easier for the operation staff. The rigidity of the light weight design is however as good as with the heavier segments as well as the hydraulic characteristic.

5.3 *High Performance Control Head*

The new high performance control head (fig. 10) continues BOKELA’s consequent improvements of the vacuum filter design. It is designed to work as a pre-receiver to pre-separate filtrate and air already inside the control head and the outlet nozzles are of specially streamlined shape which both helps to minimise flow restrictions and pressure loss, respectively.

Figure 10 — High performance control head of the “Boozer” (L4-Type)

Table 2 — Listing of some special user requests on filter construction from a practical view and the respective reply of the “Boozer” design

Detail	Focus/Request of User	Reply/Speciality of “Boozer”
filter trough	quick drainage system	joint single trough (see 3.3, 5.1)
filter discs	segment handling/stability	light weight segment (see 3.7, 5.2)
control head	big pipe outlets	high performance control head (see 3.4)
centre barrel	problem free sealing	maintenance free sealing, exchange only every 2 years
filter cloth	long lifetime	cloth washing, possibility for use of monofilaments (see 3.6)
filter drive	capacity reserve	filter speed up to 5 rpm
vacuum pumps	low energy consumption, no vacuum breakdown	“common vacuum system” (see 3.5)
cake discharge system	complete discharge, no cloth damage at the scraper	snap blow valve, 0.2 bar
filtrate receivers & entrainment separator	minimal pressure loss, secure drop separation	calculated and flow appropriate design and filter installation (see 2.2)
lubrication system	automation	centralised, automatic lubrication system

6. Evaluation Criterions

The decision for or against a filter equipment is based on both economical and technical aspects which to a wide extent depend on the practical experience with running filter equipment. The decision relevant factors are then applied on the evaluation of the scope of supply, the scope of services, the respective operation conditions and the construction details of the filter equipment. Table 2 shows a listing of decisive requests of users on filter details from a practical view and the reply of the “Boozer” disc filter.

Besides these design features of the “Boozer” there are some other decisive services and benefits such as:

- shop dry run
- partial indigenous supply
- same design for the product, coarse and fine seed filters
- advanced process philosophy (see 4) and
- comprehensive operator training.

7. Outlook

As special novelties BOKELA developed and manufactured a big diameter disc filter with four discs and a filtration area of 160 m^2, the “Boozer” L4, which is actually assembled in Guinea (Aluminium Company of Guinea).

The modular “Boozer”, which is actually designed, will have a filter trough that is built up in a modular way of separate trough segments for each disc which will then be assembled at the installation place. This simplifies the transport and the filter assembly at the site significantly.

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The authors would like to thank the clients for trusting in BOKELA’s solid/liquid separation technologies and engineering services.