Essential Readings in Light Metals: Alumina and Bauxite.
Edited by Don Donaldson and Benny E. Raahauge.
© 2013 The Minerals, Metals & Materials Society. Published 2013 by John Wiley & Sons, Inc.

ADVANCED FILTRATION METHODS FOR PREGNANT LIQUOR PURIFICATION

Reinhard Bott; Thomas Langeloh; Jürgen Hahn
BOKELA gMBh; Gottesauer Strasse 28, 76131 Karlsruhe, Germany

Keywords: polishing filtration, pregnant liquor filtration, Kelly filter, vertical pressure filter, backflush filter

Introduction

The purification of turbid pregnant liquor by filtration is an important process step in the alumina refining process. This filtration step is characterized by high flow rates, very low solids contents in the liquor of some 100 to 300 mg/l, high slurry temperatures of 95 – 110°C and operating pressures of 4 – 5 bar absolute. Usually, pregnant liquor filtration is performed on Kelly Filters, vertical pressure filters or backflush filters which are established technologies for this process but which leave many improvements to be desired with respect to filter performance and filter operation.

A new generation of backflush filters now offers the possibility of improved pregnant liquor filtration. BOKELA have developed a continuous pressure filter of advanced mechanical and process design with newly designed vertical filter elements, which are all of same size and arranged parallel inside the vessel. The design and the special arrangement of the filter elements provide for high specific filtrate flow rates and for large filtration area per vessel volume, which exceeds status quo values.

The new backflush filter runs in completely automated operation due to automatic and complete cake discharge and compared to the status quo technologies it provides for an improved filter performance and filter operation with higher specific throughput rates, improved filtrate clarity, higher concentrated solids discharge and lower idle times. The new design also leads to an easy and secure mounting of filter elements and filter cloth and to a long lifetime of both filter elements and filter cloth. Thus, the new backflush filter offers the possibility of pregnant liquor filtration with improved performance, lower invest and operating cost.

The lecture highlights modern demands on pregnant liquor filtration and presents the design characteristics of the new BOKELA Backflush Filter.

2. Demands on Pregnant Liquor Filtration

Turbid pregnant liquor coming from the red mud settler overflow contains solids, colloids and dissolved substances such as iron oxide, carbonates, silicates and titanium compounds that have to be removed by a polishing filtration process before the pregnant liquor enters the precipitators. To improve the filtration behavior and to improve removal of the turbidities filter aid such as Tricalciumaluminate TCA is added to the filter feed slurry.

Established technologies in turbid pregnant liquor filtration are Kelly filters, vertical pressure filters or vertical Kelly filters, respectively, and backflush filters.

Typical conditions and process parameters for the polishing filtration are given in table 1.

Turbid Pregnant Liquor Feed Slurry	
Temperature T	95 - 110°C
Pressure p	4 - 5 bar absolute
Filtratio pressure difference Δp	1- 4 bar
Solids content $c_{S,\ feed}$	200 - 300 mg/l
Dosage of Tricalciumaluminate TCA	< 1 g/l
Viscosity η	2 mPas
Avarage particle size x	< 1 µm
Filtration results	
Specific liquor flow rate V_L	0.8 – 1.5 m^3/m^2h
Filtrate solids c_S	20 mg/l
Solids content of filter discharge $c_{S,\ discharge}$	75 – 150 g/l

Table 1: Process conditions and process parameters of polishing filtration and results of status quo polishing filters

Modern polishing filters have to respond to today's demands and requirements with respect to filter performance, filter operation and maintenance which include:

- improved performance capability i.e.
- increased specific throughput
- better filtrate clarity i.e filtrate solids content complete separation of iron
- fully automatic and complete cake discharge from filter cloth
- no scale inside the filter by crystallization due to, vaporization or cooling-down
- good flow patterns and homogeneous slurry distribution inside the filter
- high solids content of the discharged sludge
- ease of maintenance i.e.
- simple cloth exchange and simple filter cloth fixing
- simple confectioning of the filter cloth
- tough design of filter elements and filtrate pipes
- long lifetime of filter cloth
- low operator demand
- low wear and tear
- capability to respond on new process demands i.e
- higher pressures and temperatures (lower viscosities)
- various qualities of TCA (tricalciumaluminate), no usage of TCA or alternatives to TCA.
- higher filter areas A_F per unit
- health and safety issues

3. Status quo technologies

At present there are three polishing filter technologies dominating the market, the Kelly filters, the Vertical Pressure filters (VPF) and the Backwashing filter (BF). Main weakpoints of these status quo technologies are

- low filter performance
- short cloth lifetime
- long idle times
- high manpower required (especially with Kelly filters)

Comparison of the different characteristics of these filter types elucidates their advantages and disadvantages. Typical apparatus and performance data for the polishing filter types are shown in table 2.

3.1 Kelly Filter

The Kelly filter has a cylindrical and horizontally aligned pressure vessel with a lateral opening header plate. The parallel arranged filter elements are of different size. For cake discharge the filter is emptied and opened every cycle and the leaves are withdrawn by means of hydraulic rams. Cake discharge takes place manually with spray bars and crowbars. This exposure to water and air causes scale in the filter cloth reducing performance and cloth life. Caustic wash is necessary every cycle. Kelly filters are available with filtration areas up to 250 m², filtration area per volume ranges up to 4,5 m²/m³ and specific filtrate performance is up to 0.8 m³/m²h. The cycle times are some 10 – 20 h, online times are some 8 – 16 h.

3.2 The Vertical Pressure Filter (VPF)

The vertical pressure filter or vertical Kelly filter, respectively has a cylindrical vessel, which is lined up vertically, with a conical outlet. The VPF filter elements are of different sizes and arranged in parallel. The filter runs fully automatic, for cake discharge the vessel is emptied and the cake is discharged from the cloth with spray nozzles and then discharged via the cone. Caustic wash takes place every 10 cycles. Vertical pressure filters are available with filtration areas up to 440 m², filtration area per volume ranges up to 8 m²/m³ and specific filtrate performance is up to 1 m³/m²h. The cycle times are some 4 – 6 h, online times are some 3 – 5 h. The filter is opened every three months for re-clothing.

3.3 The Backflush Filter (BF)

The pressure vessel of the backflush filter (BF) is a cylindrical vessel, which is lined up vertically, with a conical outlet which is taller than the VPF conus to improve solids consolidation. The BF filter has filter elements of same size which are arranged in a star-shape. The filter runs fully automatic and cake is discharged from the cloth by backwashing of filtrate from a backwash head tank. Backwashing is performed without emptying of the vessel and is also used for cleaning which both reduces scaling. Water is only used when the filter is opened for re-clothing every three months. The filter cake is discharged from the vessel via the cone. Caustic wash takes place every 3 -10 days. Backflush filters are available with filtration areas up to 500 m², filtration area per volume ranges up to 8 m²/m³ and specific filtrate performance is up to 1.5 m³/m²h. Cycle time is some 1 h, online time is some 50 - 55 minutes.

4. BOKELA Backflush Filter BPF

Encouraged by large feedback of customers expressing criticism on the status quo technologies as well as inquiries for a new design BOKELA have developed a continuous pressure filter of advanced mechanical and process design.

The development was based on comprehensive know-how from filter revamping and on thorough testwork with a specially developed laboratory cross-flow filter-cell. Filter revamping is a modern method of BOKELA for optimising running filters of old design to the latest technology and latest demands from maintenance and operating personnel. BOKELA have improved performance and operation of polishing filters in alumina refineries and numerous other filter types such as disc, drum and pan filters with great success. These projects revealed weakpoints and bottlenecks of running polishing filter types and the experience and know-how gained from these filter upgradings influenced the new filter design.

4.1 The filter design

The BOKELA polishing filter is a fully automatic backflush filter with cylindrical pressure vessel, a flanged spherical cover and a conical outlet for the settled filter cake. Internal pipes with flange connections at the outside provide for slurry feed, filtrate outlet, filtrate backflush, slurry overflow and vessel ventilation. Peripheral vessels include slurry feed vessel, sludge discharge vessel, pressurized filtrate backflush vessel (no header tank), filtrate recycling vessel, overflow receiver and wash liquor vessel.

The filter pressure vessel is designed for a maximum operating pressure of $p_{,max}$ = 12 bar, abs. All inserts are designed and arranged in a way that the conditions for filter operation, maintenance and for the filtration process i.e. filtration, backflushing of filter cake from the cloth and settling of backflushed solids are optimum.

The filter elements are arranged parallel in two separate wing-shaped modules (see fig 1). This geometric arrangement provides for the highest filter area per vessel volume ranging to more than 10 m²/m³. Each filter module has a separate filtrate collecting pipe to which each filter element of the respective module is connected. The two filtrate collecting pipes provide for filtrate outlet during filtration mode and for backflushing of the filter cake by reverse flow of filtrate during the backflush mode.

The frames of the filter element modules form an oval central compartment that provides for specially guided flow patterns and that serves as buffer store for small filter cake pieces. All solids and cake pieces that did reach the bottom cone during backflushing mode are forced into the central compartment by the special flow patterns during backflushing. From there the solids can settle into the bottom cone during the next filtration cycle and are not filtered again since space between the filter elements is free of solids from the preceding filtration cycle .

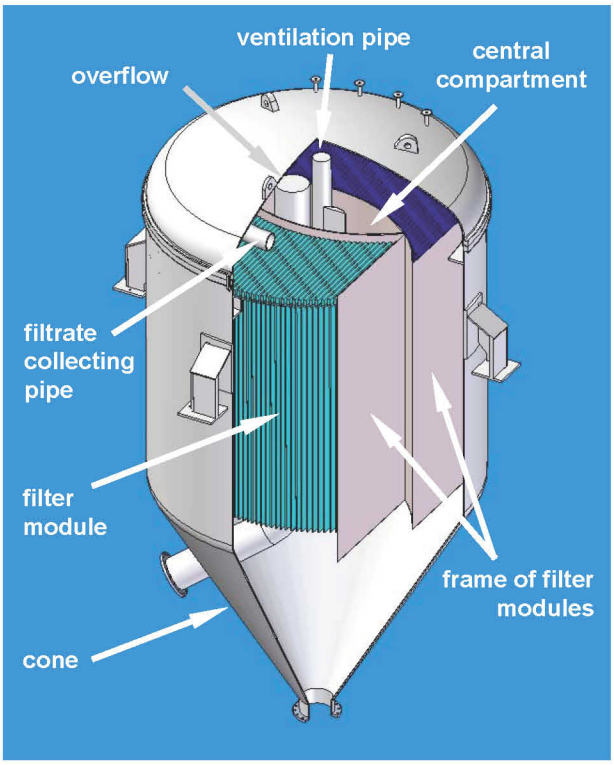

Figure 1: Schematic view of the BOKELA Backflush Filter BPF

4.2 Filter elements

The filter elements of the BOKELA Backflush Filter BPF are all of same size and have excellent hydraulic characteristics. The new, innovative filter element design provides for

- low pressure loss i.e. fast filtrate flow
- even distribution of backflush filtrate over the whole filter element leading to complete cake discharge even with very thin filter cakes
- short filtrate recycling time
- high stability
- smooth and even cloth support area
- simple and cost saving confectioning of filter cloth
- easy mounting of cloth
- long cloth lifetime.

Each filter element consists of a plate-like drainage element and a therewith connected filtrate pipe at the upper side (fig. 2). Frames between the filter elements hold down the filter cloth during backflushing ("plate and frame system").

The drainage element is a hollow body somewhat similar to the filter segment design of rotary disc filters. It is a stable weld-construction made of perforated plates with vertical division strips inside forming internal vertical flow channels emptying into the filtrate pipe of the filter element. The small width of the drainage elements enables installation of a large filter area in the filter vessel and the specific filtration area ranges to more than 10 m² per m³ vessel volume. The small volume of a filter element minimizes the volume of turbid filtrate that has to be displaced at the beginning of each filtration cycle leading to short filtrate recycling time. The large free area of the perforated plates and the cross section of the internal flow channels which are of large and constant size ensure an unhindered filtrate flow and an effective backflush for cake discharge over the whole filter area.

The drainage element design provides for a smooth, even and firm cloth support which enables an easy and fast mounting of the filter cloth without folds and which prevents creasing or mechanically lengthening of the filter cloth during filter operation. Folds in the cloth effect enlargement of cloth pores in the bends through which an increasing amount of solids can pass and reach the filtrate. Also the volume of filtrate required for backflush increases with formation of folds. Prevention of folds in the cloth by the new drainage element design is therfore a precondition for a short filtrate recycling time and a constant low filtrate solids content.

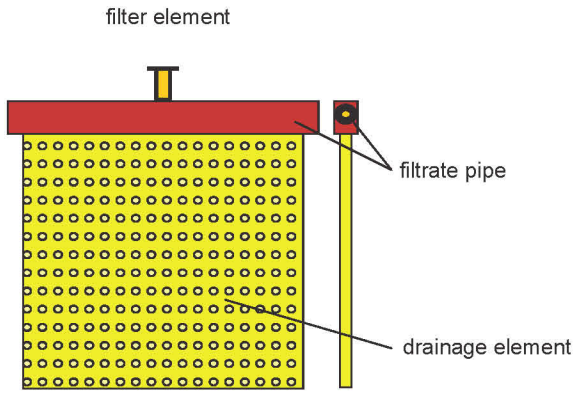

Figure 2: Schematic view the new filter element design

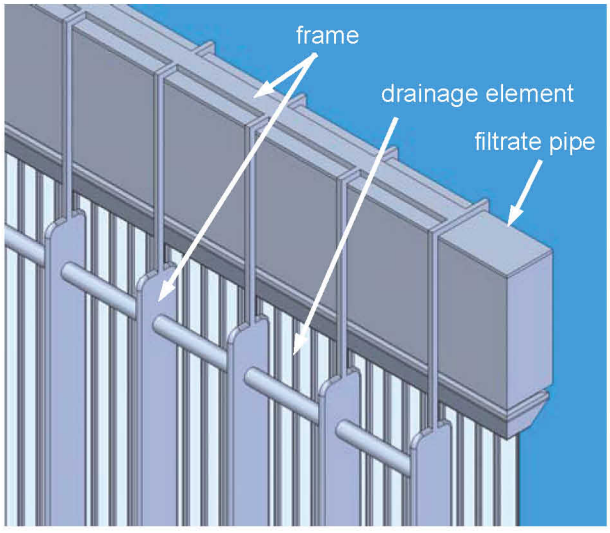

Figure 3: Schematic view of a filter element with frame

The frames between the filter elements consist of vertical struts of some 100 mm distance which hold down the filter cloth during backflushing. This way the filter cloth is only little bulged during filtrate back flow which leads to a high impulse for cake discharge with minimal amount of required backflush filtrate. Hindered cake discharge resulting from collapsing of the filter cloths of two neighbored filter elements is not possible with the small cloth bulges effected by the frames. This does not only improve cake discharge but also enables simple confectioning of the filter cloth.

Contrary to other filter designs, neither the drainage element nor the filter cloth have to be divided in small finger-like elements.

4.3 Filter modules

The filter elements are combined to two separate filter modules each containing up to 46 filter elements which are installed in a support frame (fig. 1). The filter elements of each module are arranged parallel in a wing shaped form. This geometry and the small with of the elements enable a very large specific filter area in the filter vessel ranging to more than 10 m^2 per m^3 vessel volume.

Each module has a filtrate collecting pipe for filtrate outlet and backflush inlet to which the filtrate pipes of the single filter elements are connected via sockets. These sockets are located in the center of the filter element pipes to ensure that flow distances in a filter element are as equal and short as possible. This is essential for an even backflush or a complete cake discharge over the whole filter element, respectively. The parallel arrangement and the distance between the filter elements ensure that discharged cake can settle down from the space between the elements fast and homogeneously.

The filter modules are arranged in the vessel in a way that the module frames form a central compartment in the filter vessel which is of essential importance for the advanced filter operation. For reclothing and maintenance the filter modules are lifted out of the vessel as complete unit.

4.4 Process design

A Filtration cycle of the Bokela Polishing Filter includes following subsequent process steps:

- preparation of filter (filling of pressure vessel, valve position, building of a fundamental layer, etc.)
- recycling of turbid filtrate (if necessary)
- filtrate production
- fully automatic and complete removal of filter cake from the filter cloth via back flush
- settling of solids and discharge of consolidated cake from the cone

Due to the advanced hydraulic design of the Bokela Polishing Filter each process step runs under improved conditions which allows short cycle times of 20 to 40 minutes per cycle. This means that filtration takes places with permanent thin filter cakes which have low flow resistance and filtrate throughput performance is permanently high.

The main conditions for this advanced filter operation are the low production of turbid filtrate and the short filtrate recycling time at the beginning of the filtration process and especially the effective cake discharge even with thin filter cakes due to the advanced backflush process.

4.4.1 Advanced backflush

The new filter element design provides for a fast and even distribution of the backflush filtrate and large bulging of the cloth is prevented which means that the required amount of backflow filtrate is minimal. These effects lead to a strong impulse on the filter cake and even thin filter cakes drop off from the cloth. The dropped off cake is then removed very fast from the space between the filter elements due to the special flow patterns in the filter which effect a forced flow in the filter vessel into the central compartment during backflushing. While backflush filtrate flows into the vessel (from the filtrate tank through the filtrate collecting pipes and the filter elements) the slurry overflow is open and the displaced liquid leaves the vessel through the overflow pipe. This introduces a forced flow of liquid from the space between the filter elements into the central compartment to the inlet of the overflow pipe. Not only the backflushed filtrate but also the slurry from above the filter modules flows through the filter elements.

This forced cross flow accelerates sedimentation and cake removal from the filtration area. Another benefit is the concurrent washing and cleaning of the surface of the filter cloth. Solids that are transported in the central compartment can settle then into the bottom cone during the next filtration cycle and are not filtered again. Hence less time is needed before the next filtration cycle can begin.

4.4.2 Operation with high pressures

Since the Bokela Polishing Filter is designed for high vessel pressures of up to 12 bar (abs.) filtration can be performed with high pressure differences of $\Delta p = 4 – 5$ bar but on a high pressure and temperature level ($T > 100$ °C) i.e. without danger of vaporization and crystallization if a corresponding counter pressure on the filtrate side is adjusted. A higher temperature means lower viscosity of the pregnant liquor which improves filter performance. A higher temperature also effects reduced loss of valuable product due to reduced crystallization.

4.5 Performance and benefits of the BPF

The advanced mechanical and process design of the Bokela Polishing Filter results in numerous advantages for pregnant liquor filtration with respect to filter performance, filter operation and economy.

Main benefits and characteristic values are listed below:

- high specific filter performance of $V_L > 2$ m^3/m^2h
- improved filtrate clarity i.e low solids content in the filtrate of $c_S < 10$ mg/l and for special products $c_S < 2$ mg/l
- high solids content in the filter discharge of $c_{S,\,discharge} >> 150$ g/l i.e reduced loss of valuable product with discharge
- ease of maintenance by
  - fast and easy re-clothing
  - extended cloth lifetime
  - reduced scaling
- reduced space demand and invest cost due to
- large filtration area per vessel volume of $A_F > 10$ m^2/m^3
- reduced height since a header tank is not necessary
- filtration with high pressure level and temperature level possible i.e.
  - improved filtration due to low viscosity of the pregnant liquor
  - reduced loss of valuable product due to reduced crystallization

Table 2 shows characteristics and performance values of the BOKELA polishing filter and of status quo technologies.

Table 2: Characteristics and performance values of the BOKELA polishing filter and of status quo technologies

	Kelly Filter	Vertical Pressure Filter (VPF)	Backwashing Filter	BOKELA Polishing Filter
Filter elements	different size	different size	same size	same size
Arrangement of filter elements	parallel	parallel	star shaped	parallel
Pressure vessel form	cylindrical (horizontal), lateral opening	cylindrical (vertical), conical outlet	cylindrical (vertical), conical outlet	cylindrical (vertical), conical outlet
Filtration area/ volume	4,5 m^2/m^3	$\leq$ 8 m^2/m^3	$\leq$ 8 m^2/m^3	$\geq$ 10 m^2/m^3
Filter size	$\leq$ 250 m^2	$\leq$ 440 m^2	$\leq$ 500 m^2	$\leq$ 660 m
Cake discharge	- emptying and opening of vessel - taking out of filter elements - manual with spray bar and crowbar	- emptying of vessel -discharge from cloth with spray nozzles - discharge via conus	- no emptying of vessel -cake discharge from cloth by back washing - solids discharge via conus	- no emptying of vessel -cake discharge from cloth by back washing - solids discharge via conus
Specific filtrate performance	< 0,8 m^3/m^2h	< 1 m^3/m^2h	< 1,8 m^3/m^2h	> 2 m^3/m^2h
Filtrate clarity	poor	poor	good	Excellent
Solids content of discharge	75 g/ l	100 g/ l	150 g/l	> 150 g/l

Summary

The BOKELA polishing filter is a new generation of backflush filters. Based on comprehensive know-how from filter revamping projects and on thorough testwork BOKELA have developed a completely automated continuous pressure filter of advanced mechanical and process design The new backflush filter offers the possibility of pregnant liquor filtration with improved performance, lower invest and lower operating and maintence cost.

The Bokela polishing filter is designed for high vessel pressures of up to 12 bar (abs.) which offer new options for pregnant liquor polishing filtration. High pressure and temperature level allow filter operation with reduced viscosity which improves filter performance and it reduces loss of valuable product due to reduced crystallization.