ADVANCED PREGNANT LIQUOR PURIFICATION WITH A NEW BACKFLUSH FILTER

Bott R*, Langeloh T and Hahn J

BOKELA GmbH; Gottesauer Strasse 28, 76131 Karlsruhe, Germany

Abstract

Encouraged by feedback from customers, BOKELA has developed a completely new generation of polishing filters – the Liquor Cleaner. This filter offers improved performance, lower investment capital and lower maintenance costs. The new filter is designed for high pressures of up to 12 bar (abs.) which offer new options for liquor polishing filtration. These high pressures and temperatures allow filter operation with reduced viscosity, improving filter performance and reducing loss of product due to reduced crystallization. A specially developed laboratory test-rig has also been developed which provides reliable data for process design and filter up-scaling.

1. Introduction

The purification of turbid pregnant liquor in Alumina refineries is usually performed on Kelly Filters, vertical pressure filters or backflush filters. These 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 has developed an improved backflush filter with advanced design and has developed a completely new generation of polishing filters – the Liquor Cleaner.

2. Typical Product and Process Data of Pregnant Liquor Filtration

Filtration of pregnant liquor is characterized by high flow rates, very low solids contents in the liquor of some 100 to 300mg/L, high slurry temperatures of 95 – 110 °C and operating pressures of 4 – 5 bar absolute. Coming from the red mud settler overflow the turbid pregnant liquor 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. Filtration is performed with pressure differences (Δp) of some 1 – 4 bar. Average particle size is below 1 µm. Therefore, tricalciumaluminate (TCA) is added to the filter feed slurry as filter aid to improve the filtration behaviour and removal of impurities. Typical specific liquor flow rates V_L are in the range of 0.8 – 1.5 m^3/m^{2}h, solids content of filter discharge $c_{S,\ discharge}$ is some 75 – 150g/L.

3. Status quo technologies

At present the three polishing filter technologies dominating the market are the Kelly filters, the Vertical Pressure filters (VPF) and the Backwashing filter (BF). The main differences between these filter types are in respect to the filter area per vessel volume, filter element arrangement, cake discharge and specific throughput. The weak points of these status quo technologies are:

- low filter performance
- crystallisation and cloth blinding, nozzles & valves (especially with the Kelly filter and VPF filter type)
- short cloth lifetime
- long idle times
- high manpower required (especially with Kelly filters which provide serious OHS problems for operators).

4. Advanced Designs

Encouraged by feedback of customers expressing criticism on the status quo technologies as well as inquiries for a new design, BOKELA offers an improved backflush filter with advanced design and has developed a completely new generation of polishing filters – the Liquor Cleaner.

4.1 BOKELA Backflush Filter

4.1.1 Design and Operation

The design and arrangement of the BOKELA Backflush Filter is similar to the backflush filter /1/ and comprises mainly a vessel, filter elements arranged in a star-shape, a top reservoir, pneumatic valves with fast opening/closing characteristics and an autocontrol system with excellent mechanical-electrical integration (Figures 1 and 2). Vertical filter elements inside the vessel are connected to an external manifold via syphons each equipped with an isolating valve, sampling valve and sight glass, by which filtrate quality can be monitored. In case of turbidity the relevant isolating valve can be closed, so that filtrate quality can be guaranteed. The filter runs in completely closed operation to prevent exposure to air which provides for limited crust formation over the bags and for long lifetime of filter bags. Fully automatic operation makes handling easy.

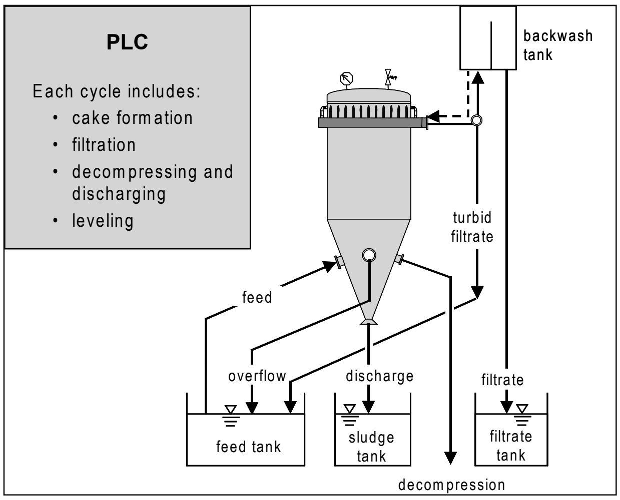

Figure 1. Schematic view of the BOKELA Backflush Filter

Figure 2. View of BOKELA Backflush Filters with backwash tanks (left), view into the filter with star-shape arranged filter elements (right)

4.1.2 Design and Operation Improvements

The main important improvements in design and operation of the BOKELA Backflush Filter are

- comprehensive PC-PLC control, excellent mechanical-electrical integration and user-friendly man-machine interface
- strong filter elements
  - double-layered stainless metal
  - firm mechanical properties
- special reliable pneumatic valves with fine dynamic characteristics (e.g. half-ball valve for sludge discharge with fast opening/closing characteristics)
- improved cake discharge by uniform backwashing in all filter elements
- individual cone angle of 65 – 75° depending on product instead of fixed cone angle

4.1.3 Filter Elements

The filter elements are of strong design and made of double-layered stainless metal providing firm mechanical properties. Reduction of the flow profile during operation is minimized which is a precondition for high capacity (Figure 3). The flow patterns inside the filter element prevents solids that have passed through the filter cloth at the beginning of the filtration cycle during turbid filtrate recycling depositing on the bottom. Solid deposits at the bottom of the filter elements often lead to increasing weight and cloth destruction. Furthermore, solids from this deposit are carried away into the filtrate during filtration i.e. after turbid filtrate recycling.

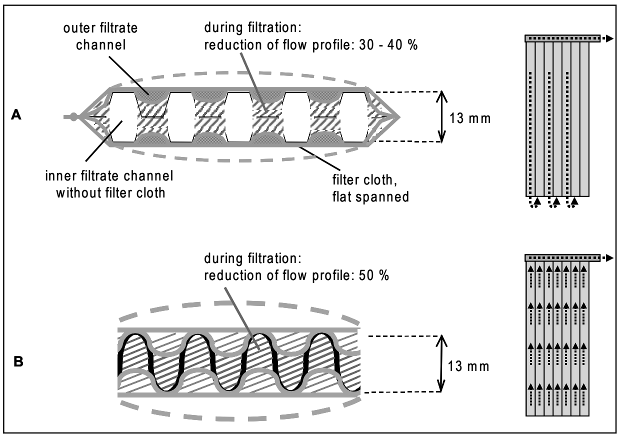

Figure 3. Free flow channel during filter operation of different filter element designs (A: BOKELA Backflush Filter)

4.1.4 Performance Data

The main performance data of the BOKELA Backflush Filter can be listed as:

- filter sizes: up to 500m² filter area
- filter area per volume: up to 8 m²/m³
- cycle time: ca. 1 h, online time 50 - 55 minutes
- throughput capacity: 1.4 - 2.0 m³/m²·h
- solids in filtrate: ≤ 15mg/L
- concentration of discharged sludge: 150g/l
- lifetime of filter cloth: 90 days.

Reference operations can be found in pregnant liquor purification in the Bayer process, aluminate liquor in the Sinter process, mother liquor recovery (seed disc filter filtrate), fine hydrate reclaiming or in filter aid production.

4.2 BOKELA Liquor Cleaner

The Liquor Cleaner is a new generation of polishing filters. 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 weak points and bottlenecks of running polishing filter types and the experience and knowledge gained from these filter upgrades influenced the new filter design.

4.2.1 The filter design

The Liquor Cleaner filter is a fully automated backflush filter with cylindrical pressure vessel, a flanged spherical cover and a conical outlet for the settled filter cake (Figure 4). 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.

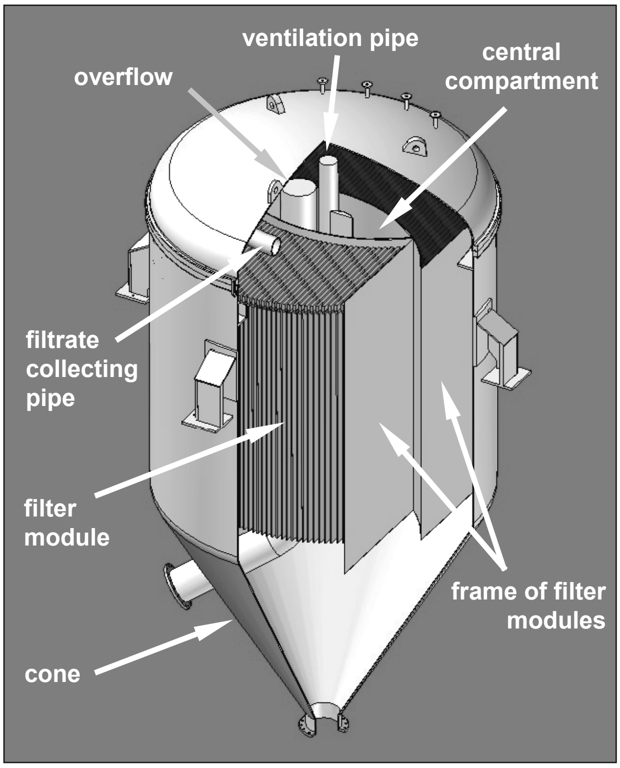

Figure 4. Schematic view of the Liquor Cleaner

4.2.2 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 (Figure 4). The filter elements of each module are arranged parallel in a wing-shaped orientation. This geometry and the small width of the elements enable a very large specific filter area in the filter vessel of more than 10m² per m³ 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 centre 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 frames of the filter element modules form an oval central compartment (Figure 4) which is of essential importance for the advanced filter operation. It causes special flow patterns and serves as a buffer store for small filter cake pieces. All solids and cake pieces that reach the bottom cone during backflushing mode are forced into this central compartment by the special flow patterns. From here the solids can settle into the bottom cone during the next filtration cycle and are not filtered again.

For re-clothing and maintenance, the filter modules are lifted out of the vessel as a complete unit.

4.2.3 Filter elements

The filter elements of the Liquor Cleaner are of uniform 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-effective confectioning of filter cloth
- easy mounting of cloth
- long cloth lifetime.

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, which prevents creasing or mechanical lengthening of the 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 backflushing increases if folds are present. Prevention of folds in the cloth by the new drainage element design is therefore a precondition for a short filtrate recycling time and a constant low solids content in the filtrate.

The frames between the filter elements consist of vertical struts separated by 100 mm which hold down the filter cloth during backflushing. This way the filter cloth only bulges slightly during filtrate back flow, leading to a high impulse for cake discharge with minimal amount of required backflush filtrate. Hindered cake discharge resulting from collapse of filter cloths of two neighbouring filter elements is not possible with the small cloth bulges guaranteed 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 cloths have to be divided in small finger-like elements.

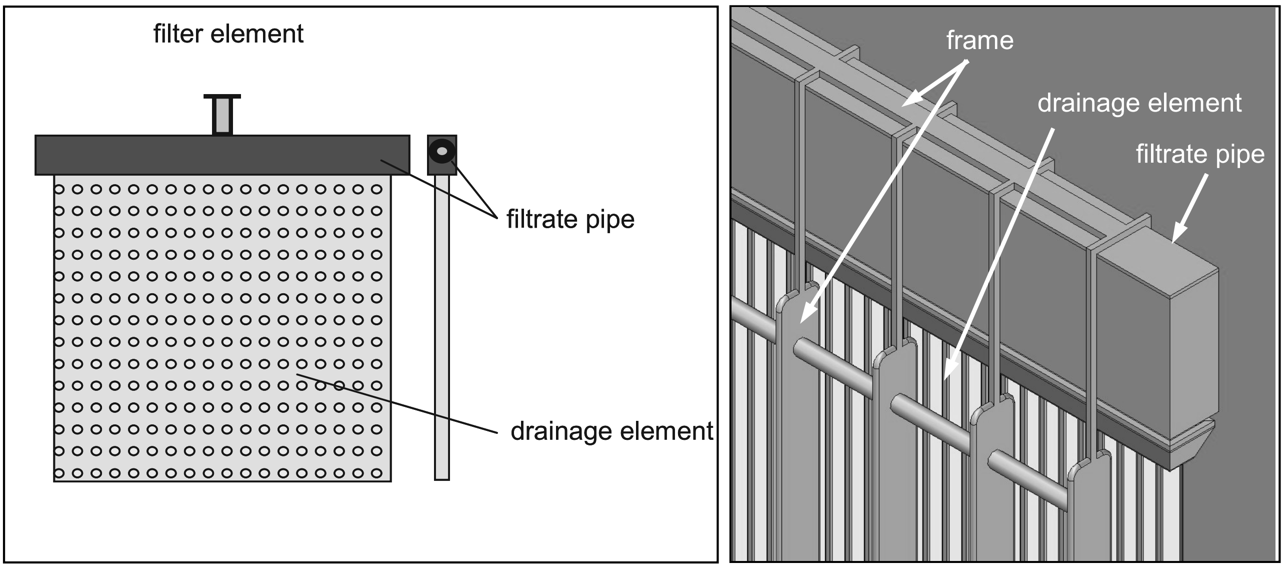

Figure 5. Schematic view the new filter element design (left) and frame design (right)

Each filter element consists of a plate-like drainage element and a connected filtrate pipe at the upper side (Figure 5). Frames between the filter elements hold down the filter cloth during backflushing (“plate and frame system” - Figures 5 and 6).

The drainage element is a hollow body 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 which empty into the filtrate pipe of the filter element. The small width of the drainage elements enables installation of a large filter area in the vessel and specific filtration area ranges to more than 10m² per m³ vessel volume. The small volume of a filter element minimizes the volume of

4.2.4 Process design

A filtration cycle of the Liquor Cleaner includes the following 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 Liquor Cleaner, each process step runs under improved conditions which allow short cycle times of 20 to 40 minutes per cycle. Therefore the filtration takes place with permanent thin filter cakes which have low flow resistance, meaning filtrate throughput performance is permanently high (Figure 6).

In Figure 6, filtrate flow and production are plotted as a function of cycle time resp. operation time. The recycling time of turbid filtrate t_{turbid} is 5 minutes and time for backflush and solids discharge $t_{backflush\ and\ discharge}$ is 1 minute. The filtrate production curve gives the filtrate volume as a function of operation time and the filtrate flow curve gives the filtrate production after 1 hour of operation for the respective cycle time. If the cycle time is 30 minutes, then the filtrate production after 1 hour of operation (two cycles) is 1,200 m^3. This is twice the filtrate production after 30 minutes and about 33% higher than filtrate production after 60 minutes (Figure 6 and Table 1). It becomes apparent that filtrate productivity is much better for short cycle times. Short cycle times, however, require advanced filter operation with short idle times. This also requires an effective cake discharge from the filter cloth by backflush. The shorter the cycle time, the thinner the filter cake will be, meaning cycle times shorter than 20 minutes are problematic because filter cakes are too thin for backflushing. The advanced operation of the Liquor Cleaner, however, enables short cycle times in the range of 20 – 40 minutes which leads to some 20 – 50% higher performance compared to a cycle time of 60 minutes (Table 1). The main conditions for the 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.

Table 1. Influence of cycle time on filter performance (data correspond to Figure 6)

Filter design & process data:

1. Cake thickness: $h_{c,calc}$ = 1,52 mm for $t_{,cycle}$ = 60 min (h_c ~ squareroot(t,fil))
2. Specific filtrate flow: V_{spec} = 1,5 $m^3/m^2/h$ for $h_{c,calc}$ ($V_{spec,calc}$~$1/h_c$)

   Solids V_{spec} = 1,5 $m^3/m^2/h$; A_{Filter} = 507 m^2; $V_{,backwash}$ = 8 m^3

   $t_{filtration}$ = 54 min; t_{turbid} = 5 min; $t_{backwash\ and\ discharge}$ = 1 min

Parameter		**Filtration Cycle Time [min]**					
		20	30	40	60	90	120
Volume of filtrate production	[%]	151%	133%	119%	100%	83	73%
Spec. filtrate throughput	[$m^3/m^2/h$]	3,0	2,3	1,9	1,5	1,2	1,0
cake height	[mm]	0,8	1,1	1,2	1,5	1,9	2,2

4.2.4.1 Advanced Backflush with Accelerated Sedimentation

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 the required amount of backflow filtrate is minimal (Figure 7). 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 quickly from the space between the filter elements due to the special flow patterns inside the filter, forcing it into the central compartment during backflushing.

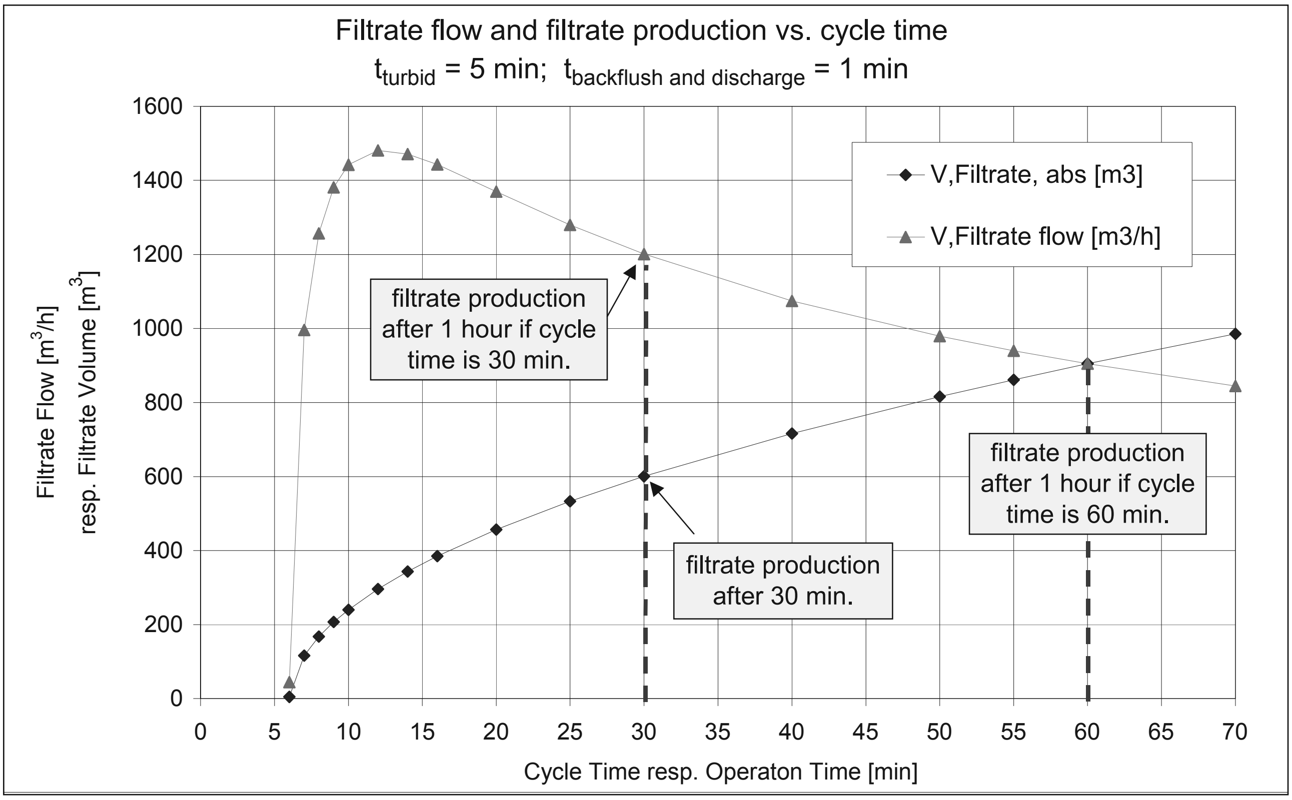

Figure 6. Filtrate flow and filtrate production as function of time

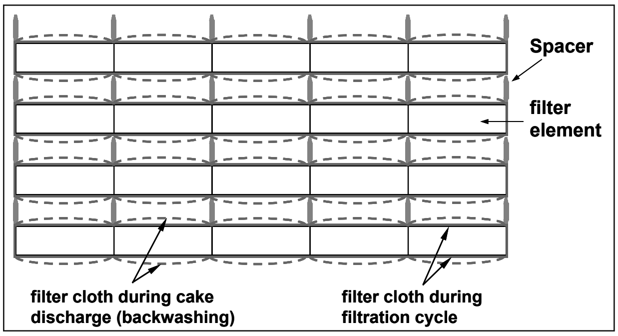

Figure 7. Plate and frame system – frames (spacers) between the filter elements hold down the cloth during backflushing to improve impulse on cake and to reduce amount of backflush filtrate

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. Both the backflushed filtrate and the slurry from above the filter modules flow 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 then settle 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.

4.2.4.2 Operation with high pressures

The BOKELA Polishing Filter is designed for use with high vessel pressures of up to 12 bar (abs.). Filtration can therefore be performed with high pressure differences (Δp = 4 – 5 bar) and temperatures (T > 100 °C) without the danger of vaporization and crystallization, provided the corresponding counter pressure on the filtrate side is adjusted. A higher temperature reduces loss of valuable product through reduced crystallization and it also means lower viscosity, which improves filter performance.

4.2.5 Performance and benefits

The advanced mechanical and process design of the Liquor Cleaner offers numerous advantages for pregnant liquor filtration. Main benefits and characteristic values are listed below:

- high specific filter performance of V_L > 2 m³/m²h
- improved filtrate clarity i.e. low solids content in the filtrate of c_S < 10mg/L and for special products, c_S < 2mg/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
- large filtration area per vessel volume, A_F > 9 m²/m³
- reduced height (no header tank)
- filtration with high pressure and temperatures possible
- improved filtration due to low viscosity of the pregnant liquor
- reduced loss of valuable product due to reduced crystallization.

5. Test equipment

Specially developed laboratory test equipment (Figure 8) enables comprehensive test work with small product volumes. The BOKELA test equipment allows testing of filtration characteristic of slurries as well as backflushing characteristics of the filter cake at pressures up to 16 bar and temperatures up to 200°C. For a single test, 10 – 15L of slurry is necessary which means that a representative test series requires only about 0.5 m³ of slurry.

This lab test equipment allows:

- test work before and during piloting
- up-scaled tests of tailor-made filter plants
- determination of optimum operation of the filtration process
- determination of the best suited filter cloth
- determination of appropriate filter aid and conditioning.

Figure 8. Laboratory test equipment for determination of filtration and backflush characteristics of slurries

Conclusions

Encouraged by feedback from customers expressing criticism on current technologies, as well as requests for a new design, BOKELA has developed a completely new generation of polishing filters with an improved backflush filter – the Liquor Cleaner. This filter offers the possibility of pregnant liquor filtration with improved performance, lower investment and lower operating and maintenance costs. The new 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 levels allow filter operation with reduced viscosity which improves filter performance and reduces loss of valuable product due to reduced crystallization.

Specially developed laboratory test equipment provides reliable data for process design and filter up-scaling.

References

1. Bott R., Langeloh T, Hahn J., "Advanced Filtration Methods for Pregnant Liquor Purification", TMS, 137th Annual Meeting & Exhibition, New Orleans, Louisiana, 9 – 13 March 2008.