EFFECTIVE BAYER LIQUOR CLARIFICATION: RETROFIT OR NEW WITH DRM FUNDABAC® FILTER INTERNALS

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Abstract

The presentation will introduce the DrM Fundabac® filter, which has replaced Kelly and other clarification filters in many industries, primarily in Europe. The patented, simple and effective filter design allows superior performance preliminary due to candle design and back-flushing. The filter design and the process parameters and details will be presented, including the advanced Contibac® system which does not require the filter to go off line for cake discharge.

Bench scale and pilot scale trials in an Australian refinery will be shown. In comparison to conventional Kelly type leaf filters. The Fundabac® demonstrated:

- Double the filtration rate due to shorter cycle times and shorter down-time for cake discharge.
- Significantly reduced cloth blinding due to back-flush and back-wash through the cloth against the filtration direction.
- No emptying required for cake discharge.

Testwork results on Bayer liquor will be presented in comparison to a Kelly filter installation. Indication for full scale will be given together with the operational parameters such as cycle sequence and cycle time.

Further advantages on full scale expected are longer cloth life due to lower mechanical stresses and larger filter area for same vessel size. Compared to other back-flush type filters, the Fundabac® has endless cloth without stitching and other weak points, a smooth circular filter surface preventing scale and cloth failure, high back-flush pressure of up to 5 bar and circular cake giving thinner cakes at similar cake volume and thus, higher filtration rates.

1. Introduction

Liquor clarification is an essential part of the Bayer process after the extraction stage and prior precipitation. The insoluble bauxite residue (red mud) is separated from the liquor by settling. Thereafter, the settler overflow is further clarified and polished, using filters. Retractable Shell Filters (Kelly) have been used initially, and were mainly replaced by Vertical Pressure Filters (VPF). Max Rogers (Rogers 1996) covers vertical pressure filters and their advantages in comparison to the older style retractable shell (Kelly) filters. Specific filtration rates are 0.8m3/m2/h for Kelly and 1.5 m3/m2/h for VPF. TCA (Tricalcium aluminate) is used as precoat and/or bodyfeed. Filter feed has a solids content of up to 200mg/L and discharge 1 – 10mg/L. Particle size is specified as 0.05 to 10 micron.

In the meantime, various plants have adapted a technology already in operation since decades in other industries, back-flushing the filtrate against the filtration direction to dislodge the cake. This mode of operation is not possible in Kelly or VPF as their filter media around the leafs forms a bag and thus, would not allow back-flushing. New plants and upgraded plants have partly installed those back-flushing filters, while the majority of existing plants and a few newly installed plants still use vertical pressure filters.

After the filtration cycle, a sluicing cycle is required to remove the filter cake from the filter element, consisting of a leaf covered with filter cloth. Depending on filter geometry and design, the sluicing of the filter cake can either occur inside the filter or the filter is opened, the filter leafs removed for external washing. External washing is not preferred as it usually requires significant manual labour and time. Internal washing requires the filter to be emptied, and pressurised wash liquor to be sprayed onto the leafs. The cake discharge by spraying the cake off the leaf is inefficient and can be problematic as the cake discharge might not be complete, a significant amount of wash liquor is required and the cycle takes significant time, which increases filter down time.

Leaf filters have been used for decades and have flat leafs, which require filter bags made out of filter cloth (either mono or multi-filament) with a rectangular shape of significant size, typically in the order of 4 x 4m. Liquor remaining inside the filter bag can cause filter sagging and reduces the life of the filter cloth.

More recently, the first back-flushing filters were introduced in the Bayer industry. The cake discharge in those filters occurs by back-flushing either filtrate or another liquid back through the filter cloth towards the filter cake. The main advantage is that the filter cake is discharged more efficiently, in shorter time and the filter cloth is back-flushed and thus, cleaned. Current commercial back-flushing filters installed in Bayer refineries have leaf / star shaped filter elements and thus, making filter cloth design complicated and fault-prone due to the seams and need of stitching.

A well proven filter, the DrM Fundabac® filter, combines the back-flushing for cake discharge with a simple and effective filter design (Müller 2003). The filter element is a candle which allows endless filter media to be used without any seams or stitching.

The DrM Fundabac® filter has replaced Kelly and other leaf and clarification filters in many industries, preliminary in Europe. The patented, simple and effective filter design allows superior performance preliminary due to candle design and back-flushing. More than 1600 DrM Fundabac® filters are in operation world wide in a wide range of applications. The filter design also allows the advanced Contibac® system which does not require the filter to go off line for cake discharge. First bench and pilot scale results proving the effectiveness of this filter for Bayer liquor clarification is discussed.

2. DrM Fundabac® Filter Description

The DrM Fundabac® filter is a patented candle type filter especially designed for effective polishing applications. The filter can perform various process steps within one single process equipment. The filtration principle is basically similar to a leaf filter: a filter media, either a mono- or multi-filament filter cloth is supported by a metal structure, in this case candle and not leaf shaped. The candles are inside a pressure vessel full of feed slurry so that the feed pressure provides the filtration driving force. Figure 1 shows the schematics of the filter.

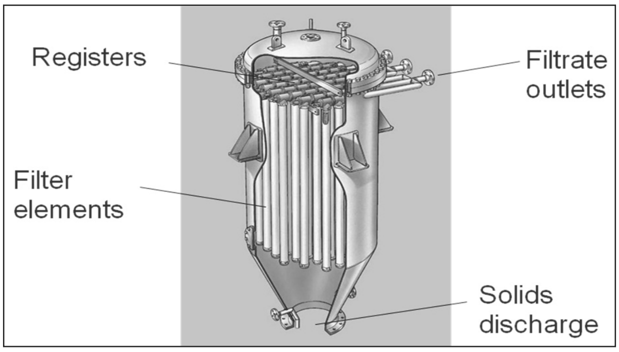

Figure 1. Schematics of the Fundabac® filter

The filter elements in the Fundabac® filter essentially consist of either six tubes placed around a central tube. A variation is an outer filter body with a removable inner tube. Different candle designs are available, for Bayer liquor applications modified to reduce scale building and to improve cleaning.

Essential is a corrugated shape of the candle, to allow a filter cloth of larger diameter to be used. This enables the cloth to blow-up, break the cake and thus, enhances the cake discharge. Figure 2 shows a picture of different candle designs for different applications. The filter candle is closed at the bottom, has a flat section for filter cloth fixing at the bottom and top and a top connector. The candle can be fitted with a screw at the closed bottom to enable internal cleaning by a high pressure gurney for mechanical de-scaling. The closed bottom allows a cylindrical filter sock, the most stable cloth design. The filter candles are fastened to horizontal collection tubes, called registers.

Figure 2. Filter candle design with Bayer liquor candle on the right.

The filter housing is a vertical, cylindrical pressure vessel, equipped with a bolted-on lid at the top for mounting the filter elements, and a conical bottom part for the discharge of cake. Because of the automatic operation, the lid needs only being opened for filter cloth changes.

The pressure vessel design is similar to conventional vertical Kelly-type pressure leaf filters so that existing vertical filters can easily be retro-fitted with DrM Fundabac® internals.

3. DrM Fundabac® Filter Operation

The pressure vessel of the filter with the candles inside is filled and during filtration, the liquid phase passes from the outside through the filter media into the candle. All liquid flows downwards to the bottom of the candle into the optional centre tube. The filtrate flows up into the horizontal register and out of the pressure vessel through the filtrate outlets. The centre tube is essential for effective candle drainage and optional drying of the cake.

The cake is discharged by back-flushing of filtrate or another liquid, reversing the flow through the filter cloth. The reversing flow blows up the filter media around the tubular element. This sudden expansion of the media brakes the cake which is thereafter removed from the filter media by the reversing flow. The cake drops or settles downwards into the conical section of the pressure vessel and can be discharged. Figure 3 shows the cake discharge schematically.

The general process steps of the CONTIBAC®Mode can be summarised as follows:

1. Filling
2. Pre-filtration (Optional)
3. Filtration
4. Part-Drain
5. Back wash / back flush
6. Sedimentation
7. Sediment discharge

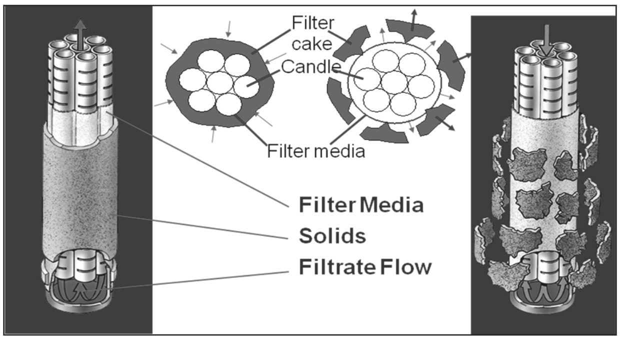

Figure 3. Schematic of the filter cake discharge by flash-back of filtrate

The Fundabac® filter is fed from the bottom with an overflow, which improves the even cake formation. The Fundabac® filter can be either used as dry cake or wet cake discharge. As Bayer liquor clarification re-slurries the cake, wet cake discharge is the preferred method. The wet cake discharge can be by two methods: either back-flushing the cake into the filled vessel or first emptying the vessel. Back-flushing into the filled vessel requires the cake to sediment to the conical bottom of the vessel before the thickened slurry can be discharged. Back-flushing into an empty vessel requires full draining the vessel after filtration and washing out the cake with back-flush liquid. Both options are possible for Bayer liquor clarification, while back-flushing into the full vessel has shorter down-time and thus is preferred.

Another enhanced operation mode is available, the Contibac®Mode. This mode allows a single filter to be on-line 100% as only parts of the filter are back-flushed while the majority of filter area is on-line continuously. This design is not necessary in large refineries where more than two or three clarification filters are required. This filter type, due to its thickened slurry discharge at the bottom in intervals is fed from the top.

The back-flushing liquid can be pressurised to several bars. This is possible due to the rugged and still candle design, a significant advantage compared to back-washing leaf or star type filters. The reverse flow for back-flush can be provided either by elevated filtrate buffer tanks, elevated filtrate buffer tanks driven by compressed air to allow up to 4 bar back-flush pressure or by suitable pumps to provide the pressure and flow.

Filter cloth is fixed by specially designed quick fixing devices. This allows a simple and quick cloth installation. Clothing should occur outside the filter with a spare set of internals, so that clothed registers are changed after opening the filter for cloth change.

It should be noted, that the Fundbac® filter is NOT a Funda® filter and is quite different. The Funda® filter was developed also by Dr Müller about 50 years ago is a horizontal plate centrifugal discharge filter which has been unsuccessful in red mud filtration. Although the names are similar, the filter designs are totally different and the Funda® filter is not any more distributed by DrM due to the superiority of the Fundabac® design.

4. Bench Scale Trials

DrM has more than 50 bench and pilot filters available for trials. A Fundabac® TSD Bench Pressure Filter of 316L stainless steel with 950ml filling volume was used (Figure 4). This mono candle bench scale filter has 0.012m^2 filter area provided by one candle with 30mm diameter. The full scale candles are 82mm diameter. Identical filter media can be used with the same fixing method.

preliminary trials confirmed that the filter is well suited for Bayer liquor clarification.

It was assumed that the results on bench scale were worst case as the filtration occurred at reduced temperature. The filtrate temperature could not be kept as high in the bench scale unit compared to the commercial Kelly filters even with the water heated jacket of the bench scale unit. The filtrate had a temperature of only 65 to 89 °C after discharge. Thus, the temperature in the filter was probably the average of the temperature in the feed tank (98 to 103 °C) and the filtrate (65 to 89 °C).

Different filter cloths were tested with a multi-filament cloth quite similar, but denser compared to the one used on the full scale Kelly filters. This is the best selection, combining process results (filtrate clarity) with economics.

Table 1 summarises the results from one test. The filter feed had a feed solids concentration of approx 2.15g/l.

The cake solids are measured from the cake remaining in the conical part which was not discharged as slurry. Thus, the total

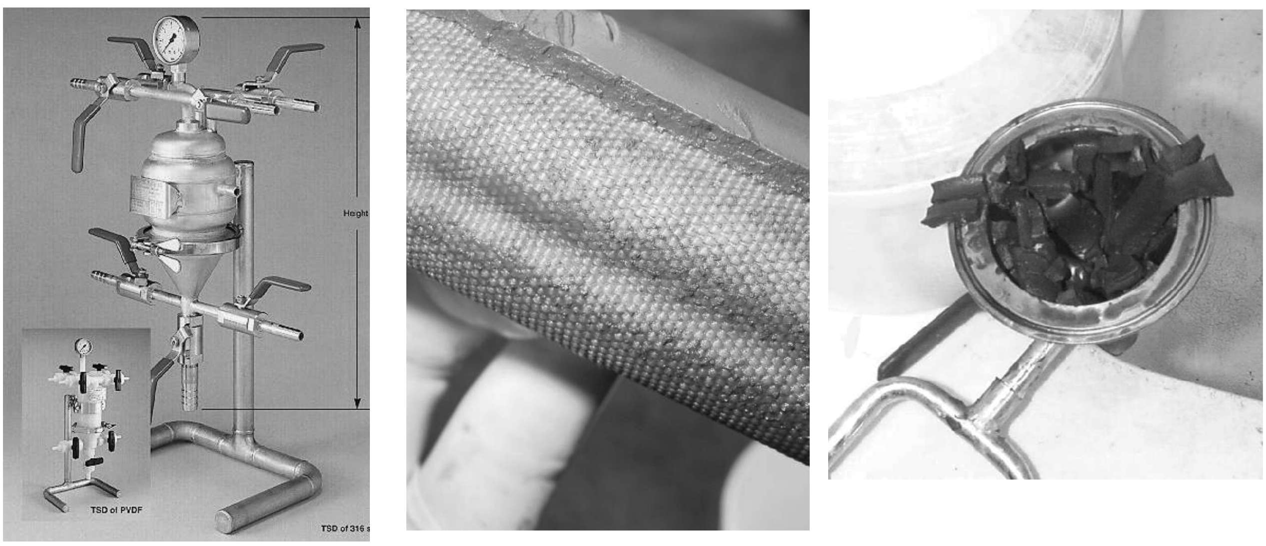

Figure 4. Picture of the bench scale unit (left) with red mud filter cake on candle (middle) and discharged cake (right).

The main advantages of the Fundabac® are the increased throughput due to reduced cake discharge down time, the improved filtration due to the candle shape and the superior cake discharge and cloth life characteristics. The bench scale trails with a Kelly filter feed from an Australian Alumina refinery at typical elevated temperature should provide first insights into expected filtration rates and filtrate clarity.

Approx. 100 litre of Kelly filter feed were processed through the bench scale filter. The filtration was continued for 60 to 90 minutes to achieve a cake of 1.5 to 5mm thickness. The specific solids throughput which is in the order of 1.0m^3/m^2/h achieved at the full scale Kelly filters of the plant, were 0.9 to 3 m^3/m^2/h on bench scale. The cake discharged well, and thus the

cake solids might be higher. The cake moisture is the moisture in the cake achieved without cake drying / blowing but the cake discharged with slurry in the vessel which remained after draining the vessel.

5. Pilot Scale Trials

These bench scale results were promising and provided verification for going to the next stage, pilot scale trials. A mono-candle pilot scale filter with 0.32m^2 filter area and full scale candle diameter and design was used. A filter cloth with a mean pore size of 10 µm was used, similar in weave to the filter media on the full scale Kelly filters.

Table 1. Bench scale test results

Temp (°C)	Inlet Pressure (bar g)	Filtration time (min)	Total Filtrate (kg)	Dry solids in cake (g)	Solids in filtrate (ppm)	Average flow rate (m^3/m^2/h)	Cake thickness (mm)	Cake moisture (%)
88	3.2	60	47.5	110	9-29*	3.0	6	32

* The sample analysis for filtrate clarity was done at lower temperature, so it is unclear if solids precipitated out and increased the solids concentration. The produced filtrate did not show any solids on the filter paper after 100ml were filtered at 5 micron. This is considered a high filtrate clarity. Thus, the filtrate clarity requirement is achieved.

The pilot scale filter was installed parallel to the existing Kelly type filters to compare performance. Thus, the filter feed was similar in slurry properties, feed pressure and temperature to the full scale filter. The trials were performed for 60 minutes with one trial (#3) having 150 minutes filtration time at the same filter feed temperature as the full scale filters, being 89 – 103 °C. The feeding pressure similar to the full scale filter was in the range of 210 to 330 kPa and mostly 320 kPa.

5.1 Pilot Scale Procedure

The test series was started with a new filter cloth. Each test consisted of the following steps:

1. Feeding at available pressure and temperature from bypass to Kelly filter No 1. Feeding/filtering time was either 60min or for some trials 150min.
2. Stopping feed and draining vessel.
3. Back-flushing for 5 – 10 seconds of spent liquor from the spent liquor line at limited pressure (200kPa is required while only 100 kPa were available).
4. Draining the filter cake with the spent liquor from back-flush.

For some trials, the vessel was opened after draining to visually inspect the filter candle and the cake. The same applied to some trials after back-flushing.

5.2 Pilot Scale Filtrate Clarity

The filtrate was sampled at the start (5min after commencing), mid point (30min for a 60min trial and 90min for 150min trial), and at the end.

Only 20% of all samples had a filtrate solids content of more than 4mg/kg. Most of those off-spec results could be explained either by different filter cloth, incorrect cloth installation or analytical errors. Thus the filter cloth selected was suitable to guarantee filtrate clarity. In particular it was surprising that filtrate clarity measured often declined, while an increased clarity with time would be expected, as the forming cake acts as a deep bed filter and enhances the separation of the filter media. The reason could be analytical inaccuracy as mg/kg are not easily measured. However, those trials confirmed that the filter provides sufficient filter clarity. This was expected as the same filter cloth was used as installed on full scale.

5.3 Pilot Scale Filtration Rate

The filtrate flow rate was measured for the full period of the trials. The following graph shows the filtrate collected as a function of time for all tests undertaken. In total, 14 tests showed a quite wide spread in filtration rate, with the solid dots presenting the geometric average of all trials. The full scale filter had an average specific filtrate flow rate of 1.0 $m^3/m^2/h$ (Figure 5).

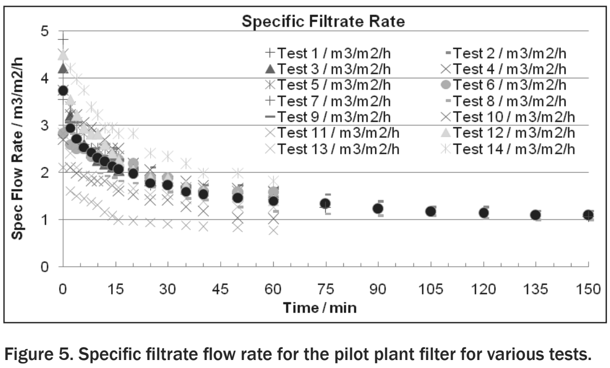

Figure 5. Specific filtrate flow rate for the pilot plant filter for various tests.

As expected, the filtrate flow starts off high, decreases further and further, until after approx 100min the filtrate flow rate is almost constant. The shape of the curve, indicating the decrease in flow rate, is almost similar for all tests, while the actual level is different caused by filter cloth blinding and other variations (pressure, temperature, feed properties).

The filtrate flow starts off very high, partly above 3 and 4 $m^3/m^2/h$. This is not practical in full scale operation. A full scale filter would have a reduced filtration rate during the first part of the cycle, as filtrate flow rates above 3 – 4 $m^3/m^2/h$ would not be feasible due to pressure loss in pipes and high flow velocities in pipes and inside the vessel and filtrate system.

Those results demonstrate that the filter tested has a significant higher specific filtration rate compared to the installed conventional Kelly type filters. On average, the filtration rate for the first 60minutes could be increased by 83% compared to the conventional full scale filters. However, one major benefit of the presented filter is its significantly shorter down time for cake discharge and thus, possible reduced cycle time. This leads to an increase in total throughput as the initial high filtration rates can be utilized more often while the very low filtration rates after long times do not occur.

5.4 Pilot Scale Filter Cloth Blinding

One objective of the pilot plant trials was to evaluate the filter cloth blinding and its effect on filtration rate (Figure 6). Most trials were performed for 60 minutes, mainly as total testwork time was limited. Further, the cloth blinding happens in the first part of the cycle, when the first layers of cake are formed. For the most part thereafter, the cake acts as filter media so that the cloth blinding per filter cycle can be simulated by shorter trials.

No reproducible drop in filtration was observed for the first 9 trials. While trial 8 gave a low specific filtration rate, the next trial No 9 gave again higher filtration rates. Only from trial 9 onwards, the filtration rate dropped again for 2 consecutive trials.

Eight cycles are common for the full scale filters before caustic cleaning in this particular plant.

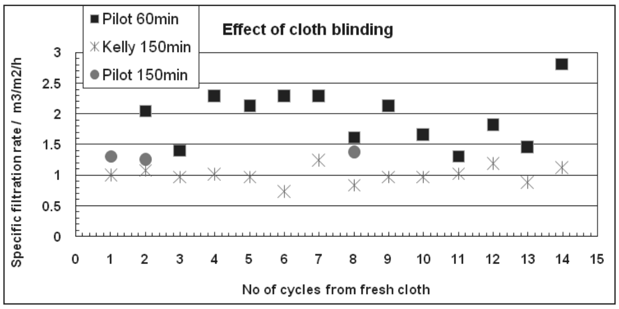

Figure 6. Specific filtrate flow rate after 60 and 150min for Pilot Plant as a number of cycles starting from a fresh cloth.

The cloth blinding of the pilot plant unit might be more severe compared to a continuous filter. The pilot plant was operated not continuously and the cloth was left (to dry) between trials and overnight in the closed but empty vessel. This could have increased the scale building, precipitation or crystallisation in the cloth.

A caustic wash was performed after trial 11. Caustic solution at 90°C and 200 kPa was pushed through the filter candles in the filtration direction for 30min. The flowrate was high, but the effect of the caustic wash is thought to be more time than flowrate dependent, so a caustic wash of 30 min is assumed to be less effective as in the full scale filters.

The above graph demonstrates that in average the flow rate after the caustic wash is similar to the first 7 trials. Thus, the filter cloth could be well cleaned by the caustic wash. Data for the 2 trials undertaken after caustic cleaning (No 12 & 14) scatter widely. While trial 12 had a low flow rate, trial 14 showed the highest filtration rate of all trials. The filtrate clarity for trial 12 and 14 was well below 10 mg/kg but a little bit higher than the average of all trials, the filter cloth might be a bit stretched. However, the cloth is PP multi-multi filament, similar to the cloth currently used. So no other effects are expected.

However, cloth blinding is not severe and can be reduced significantly by caustic washing, at least similar to the existing filters. However, it is believed that caustic washing on the Fundabac® Filter is more efficient, as the caustic cleaning can occur by back-washing caustic solution against the filtration direction. This reduces the quantity of caustic required and also should yield a more efficient cleaning as against the flow direction.

6. Scale up to Full Scale

The pilot trials provide sufficient data to engineer full scale filters and predict their performance. The operation of full scale filters should be compared to conventional Kelly type filters. Following typical Kelly type filter size is used for pure comparison (base case):

> 4m diameter vertical vessel with 4m long leaves and approximately 440 m^2 filter area in total. The vessel contains about 600 m^3 of slurry. Filtration time is 150min. The down time for draining to the cone, washing off the cake by spray nozzles and draining the washed cake takes about 20 – 25 minutes.

Such a filter can be relatively easy to convert into a Fundabac® Filter by replacing the internal leafs with DrM Fundabac® Filter candles and registers and modifying the process slightly.

The same filter vessel could be filled with approximately 520 m^2 filter area. This is by 520 of candles with 4m length and each about 1 m^2 filter area. Thus, the same pressure vessel houses already 18% more filter area by using Fundabac® Filter internals.

The Fundabac® Filter has a different process cycle, which provides shorter down-time for cake discharge. Typical process cycle times (of course slurry dependent) are given below:

Thus, compared to standard leaf type filters with the base case parameters, following quantitative improvements can be achieved through:

Improvement (up to)		Leaf Filter		Fundbac
18%higher filter area per vessel volume	from	440 m^2	to	520 m^2
80% higher specific filtration rate	from	1.0 $m^3/m^2/h$	to	1.8 $m^3/m^2/h$
5-10% through shorter down time	from	20 min	to	5 min

Therefore, a Fundabac® filter can achieve up to double the throughput compared to a conventional leaf filter. However, the state-of-the-art are back-flushing filters with leaf (start) arrangement. These filters have a filter geometry which does not allow high pressure back-flushing. The leaf design provides concave areas where cake discharge is more problematic and scaling can occur. Furthermore, their filter cloths are not endless socks but quite complicated stitched constructions with seams.

In summary, the Fundabac® filter has, in comparison to standard leaf type filters, the following advantages:

- Back – flush for Cake Discharge improves cake discharge, cleans cloth and reduces liquid required.
- No nozzles required to discharge cake. This reduces failure and maintenance.
- Drastically reduced cloth stretching due to cyclindrical cloth design without bottom.
- Increase in filter area per vessel volume, about 25% more filter area in vessel.
- Higher hydraulic efficiency due to shorter downtime and higher filtration rates.
- Shorter downtime due to back-flushing.
- Longer cloth life due to cloth cleaning by back-flushing, no seams or stitching and simple, compact cloth design.
- Fully continuous simple operation.

FUNDABAC®Mode:

Process	Volume	Flow Rate		Time	Note
Re- Filling	60 litre at	300 l/min	for	0.5 min	Start after only draining core
Filtration		200 - 75 l/min	for	30 – 150 min	
Draining	100 litre at	300 l/min	for	0.5 min	Make space for back-flush
Back wash	80 litre at	200 l/min	for	0.3-0.5 min	
Sedimentation			for	1-2min	Cake settles into cone
Discharge	100 litre at	200 l/min	for	0.5-1 min	
Filter down time per cycle approximately			for	< 5 min	

Thus, the significantly shorter back-flushing and cake discharge times compared to conventional filters with leaf arrangement and spray nozzles for cake discharge is significant. A reduction from about 20 – 25min for a cake discharge with inner vessel nozzle spray system for cake discharge in leaf filters to 8 min by back-flush enables a significant reduction of overall cycle time and in particular a reduction in filtration rate which improves the filtration efficiency drastically. During the trials, a filtration time of 60 minutes lead to an average accumulated specific filtration rate of 1.8 $m^3/m^2/h$, which declined to 1.4 $m^3/m^2/h$ for a total filtration time of 150 min. This reflects a 28% increase in filtration rate.

The reduction in filter down time from 20 min to conservatively assumed 10min provides for a filtration cycle of 150min another 5% increase in efficiency.

Compared to leaf (start) type back-flushing filters, the advantages are as follow:

- Simple filter element design.
- Simple seamless cloth design.
- High pressure back-flushing with > 3 bar possible for problematic cake discharge.
- Possible back-flush by elevated filtrate tanks or pressurised line.

7. Outlook: Full Scale Trials

A new pilot plant with four (4) of 4m long candles were built to reflect the exact design of a full scale filter and so demonstrate the full scale filtration with all equipment details. This includes full length candles to show that cake discharge can occur in the centre of the unit, where four candles restrict the volume for the cake to drop.

This pilot plant is currently being installed at an Australian refinery and results will be published in the next AQW.

8. Retro-fitting Conventional Kelly Type Filters

As the basic operation and design of the pressure vessel and the filtration is similar to conventional Kelly filters, a retro-fitting or upgrade from a conventional vertical Kelly filter to a Fundabac® filter is possible and has been done in other industries. Simplistically, the leafs of the pressure leaf or Kelly type filter are replaced by similar length registers (manifolds) holding a number of candles. The internal spray nozzles for cake discharge can be removed and a method for providing back-flushing liquor has to be provided.

Retro-fitting existing vertical Kelly type leaf filters is a simple and effective measure to improve filtration rates and de-bottlenecking existing clarification filter capacity.

9. Conclusions and/or Recommendations

The bench and pilot scale study undertaken confirms the suitability of a DrM Fundabac® candle type filter as a Bayer liquor clarification filter. The back-flushing action for cake discharge reduces the down-time, improves cake discharge and improves cloth cleaning and possibility for caustic washes. The back-flush filter is superior to conventional leaf Kelly type filters with nozzle cake discharge. The Fundabac® internals can be used to retro-fit existing vertical leaf filter installation and provide an excellent opportunity and de-bottleneck the clarification area. A 50 – 100% increase in filtration capacity is expected in a retro-fit.

For new refineries and upgrades, new Fundabac® filters provide a simple and efficient clarification method which has a number of advantages compared to the state-of-the-art. In comparison to existing back-flush filters with leafs (star arrangements), DrM Fundabac® filters have a simple filter element design with no extruding or significant concave parts where scale or filter cake can accumulate. The cloth is an endless cylindrical sock without a bottom, and thus is not prone to stretching due to the weight of filtrate still in the leaf. Furthermore, the candle type filter has robust filter elements and cloths so that high back-flushing pressures are allowed, providing safe cake discharge even for sticky and difficult to discharge red mud cakes.

The presented bench and pilot scale trials with a well proven filter, the DrM Fundabac® filter, demonstrate that this filter design is well suited to be applied in Bayer liquor applications. The simple and effective filter design provides process, operational and maintenance advantages and is well suited for today's fully automated alumina refinery.

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