Filtration – the facts

A survey of systems and methods

When I first started in the brewing industry, filtration was something carried out down in the cellars or across in the 'packaging store'. Even in France where I worked in my first brewery, it was '*dans les caves*'. Today, with take-home beer beginning to outstrip on-sales, beer with a 12 month shelf life required closer attention to filtration and stabilisation. With consolidation of breweries and focus on capacity utilisation and efficiency of packaging lines, beer quality and filter problems are no longer acceptable. 'Right first time' is the requirement.

"In my early Whitbread days, it was always 'Process and Packaging' but when the bigger breweries were built it became part of the brewing area, mainly because filtration problems were often pushed back up-stream in the brewery. We were brewing lager and had to deal with beta glucans which gummed up the works and yeast that refused to settle to the bottom of tall cylindroconical tanks."

By **Paul Buttrick**
Beer Dimensions

I have been an examiner for the IBD Master Brewer examinations for many years, and questions on filtration were often poorly answered and showed a lack of experience and understanding, compared to other areas such as brewhouse and fermentation. This may have been due to where responsibilities lie for filtration and there were debates about whether it was a brewing or packaging responsibility. In my early Whitbread days, it was always 'Process and Packaging' but when the bigger breweries were built it became part of the brewing area – mainly because filtration problems were often pushed back up-stream in the brewery. We were brewing lager and had to deal with beta glucans which gummed up the works and yeast that refused to settle to the bottom of tall cylindroconical tanks.

The diverse nature of kieselguhr as seen under a microscope.

The basics

Like all things, the laws of science dictate performance and Darcy from way back in 1856 still shows the way. The table below develops his law and applies it to filtration : Applying this equation, it is easy to see how filter design affects beer filtration.

$$\text{Flow rate} = \frac{\text{Permeability factor} \times \text{Pressure drop} \times \text{Area of filtration surface}}{\text{Filter bed thickness} \times \text{Liquid viscosity}}$$

$$\text{Pressure Drop} = \frac{\text{Flow rate} \times \text{Filter bed thickness} \times \text{Liquid viscosity}}{\text{Permeability factor} \times \text{Area of filtration surface}}$$

Maximum pressure drop allowed across a filter

On early 60cm plate and frame filters, the maximum allowable inlet pressure was 3 bar, for later versions and 100cm frames, this went up to 7 bar, so the newer filters gave a large potential increase in filter run lengths. It is easy to see how one of the easiest and most cost effective ways to increase filtration capacity in a small brewery was to replace an old 60cm filter with a more modern 100cm version.

Filter area:

The 100 cm plate and frame filter gave the possibility of large filtration areas, so pressure drops were low and filter runs long. However with a flow-rates of 2.5–3.5 hl/m^2/h, the area needed to be large to get a fast flow-rate compared to vessel filters designed for 5–10 hl/m^2/h, although flow on vessel filters tend now to be nearer the lower rate. On vessel filters, the filtration area is dictated by the number of candles or screens. Flowrates on *kieselguhr*-free crossflow filters are slower at 0.5 – 1.0 hl/m^2/h

Filter cake thickness:

This is dependent on the solids content of the beer and dosing rate of body-feed powder. Breweries which install centrifuges reduce the solids presented to the filter, are able to make large increases in filtration performance and capacity. The 'sludge capacity', that is the amount of powder that can be put into a filter will dictate the filter run length and reducing the body-feed dosing rate enables more beer to be filtered. The frames of the larger plate and frame

filters have comparatively more capacity than vessel filters. The standard frame was 40mm deep, and some companies increased this to 50mm to increase filtration run lengths

Beer viscosity:
I can remember, over 25 years ago, spending many hours in the Samlesbury Brewery brewhouse doing starch tests on wort – with my fellow brewer – the late Bill Barker – we were known as 'Starchy and Husk' after a well know pair of American detectives. Better brewhouse procedures and a malt specification to reduce beta glucans in the wort, sometimes with the aid of added beta glucanase, made sure we were able to filter plenty of lager in the hot summers of the late seventies.

Permeability:
The pressure differential across a filter bed is determined by the permeability of the filter bed, which is dictated by the size and porosity of the filter powder. Very fine powder produces a quicker pressure build up than coarser powder. A compromise was needed because the finer the powder used, the better and brighter the filtered beer. It is also important to remember that vessel filters which are run at faster flow rates generally use coarser filter powders to keep the pressure differential down.

When all is considered, it is easy to see why some companies continue to use 100cm plate and

(Photo: Puresep.)

frame filters. At Magor, now part of InBev, long runs of very high quality filtered beer are achieved using high area filters run at slow flow rates with quite low porosity powders. With these regimes it is possible to achieve yeast-free filtrate on a 100ml aerobic plating of beer from the outlet of the filter.

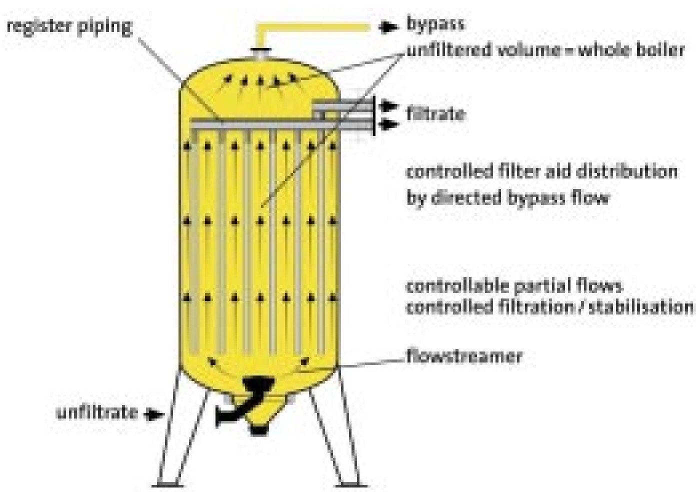
Choice of powders

The choice of filter powders has not changed much over the years in that *kieselguhr* (diatomaceous earth) is still the preferred material. No other material gives quite the same filtration performance. Perlites made from volcanic rock are increasingly used for a first precoat, but few use it for second precoat and bodyfeed. The main driver for brewers moving away from *kieselguhrs* is health and safety, where particularly flux calcined-white powders (heated in the presence of caustic soda) contain high levels of crystalline quartz (crystoballite) which is known to cause serious lung diseases.

The white flux calcined powders

MAIN PICTURE: Four fully automated 600 hl/h Filtrox kieselguhr and PVPP candle filter lines installed in Becks brewery Germany in 2002.

ABOVE: A 100 cm plate and frame filter, still used in many UK breweries.



(Schematic: Krones.)

Schematic of the Steinecker TFS filter. This filter is specifically designed to give an even powder coating over the whole candle.

The Pall 'Big Bag' bulk handling system, using 0.5 tonne bags of filter powder at Reissdorf in Köln.

"The Pall ZHF - Primus is equipped with 'Durafil' screens of 30-micron size that only requires the equivalent of a working precoat. Other filters including some candle filters also have 30-micron gaps, although Filtrox have remained with a 70 micron gap which is said to be less prone to blocking and has better cleanability."

have larger particles and are generally used for the first precoat. Perlites are now used for this purpose in many UK breweries. Perlites are difficult to manufacture in fine grades and do not have the absorptive properties of *kieselguhrs* which give brilliant beers. There are very few breweries who use a complete perlite regime and these use sheet filtration afterwards to give their beer its final brilliance. Many filters using *kieselguhr* do not use polishing filters, but go straight to packaging which includes either flash or tunnel pasteurisation.

Some filter manufacturers have designed their filters to work without a 'first' precoat.

The Pall ZHF – Primus is equipped with 'Durafil' screens of 30- micron size that only requires the equivalent of a working precoat. Other filters including some candle filters also have 30-micron gaps, although Filtrox have remained with a 70- micron gap which is said to be less prone to blocking and has better cleanability.

With filter powders, being classed as hazardous materials, companies have sought to protect their people from the dust. There have been many designs for handling 20kg paper sacks in a special cabinet with bag splitters and vacuum dust removers. Some have been more successful than others and some have been more dust dispersers than offering personal protection. The level of protection tends to go with the amount of powder used, with smaller users still putting powder directly into the dosing tanks, the operator being protected with a face mask specific for *kieselguhr* dust.

Filter powders are only hazardous in powder form, so it is quite common to see powder slurries mixed with water in a separate area from the filter room and then transferred to the dosing tank when needed. Another method is to have a separate area above the filter room with powders sent directly into the dosing tanks below.

A little advice from experience – when designing slurry tanks, it is best not to make them too big (say a maximum of a day's supply) because continual stirring can degrade particles which will block the filter rather than keep the bed open. Also because it is very abrasive, slurry pump design and maintenance is key to operations. It is also important to make sure that the stirrer in the tank is either backed up with a spare or alarmed because powders settle and set like concrete if they are not kept in suspension – digging them out is not fun.

Big Bags

Any reasonable size brewery should be thinking of using bulk powder supply rather than paper sacks. Health and safety issues are greatly reduced and man power in big plants can be redeployed. With approx 10hl filtered per kg of filter aid, a brewery of 500,000 hl will be using 50 tonnes of powder per year; about 100 half-tonne 'big bags' a year. I don't know of any brewery currently using tanker delivery and bulk silo storage of filter powders, the main problem here is the availability and cost of bulk powder tankers and the capital cost of a silo system.

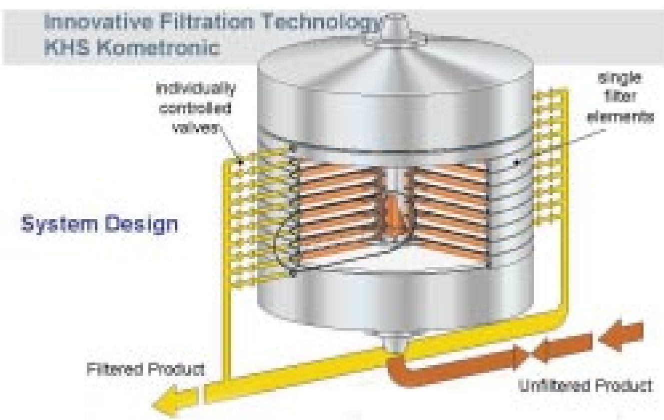
Even for 'big bag' handling, the number of powders used should be kept to a minimum, in most cases a 'first precoat', 'second precoat' and 'body feed' should be enough, and very often the second precoat and body feed is the same powder. Some filter aid suppliers recommend mixing powders, not something I am too keen on – to me it is a bit too much of a 'black art' or a 'three of sand plus one of cement' approach.

The cost of supplying *kieselguhr* in 'big bags' is similar to that of paper sacks. Some quite cost effective powder fluidising and transfer systems have been installed and can be justified on health and safety as well as manpower savings for sack handling, although civil costs can be high. A large brewery

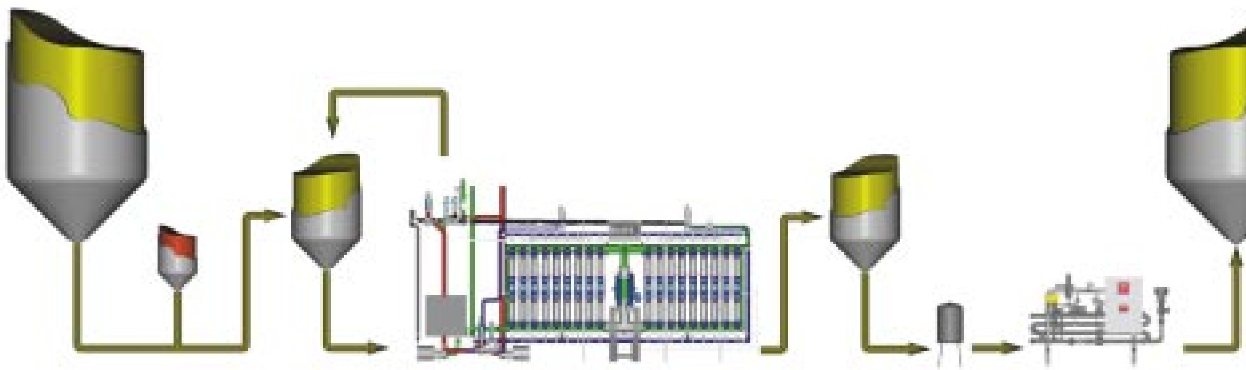
The KHS Kometronic system

RIGHT: Diagram of a KHS Kometronic precoat filter using regenerable cellulose fibres instead of kieselguhr

FAR RIGHT: A KHS Kometronic precoat filter using regenerable cellulose fibres on trial with only one chamber in the stack.



(Diagram and photo: KHS.)



(Diagram and photo: Norit.)

using 200 tonnes of filter aid per year, would be handling 10,000 × 20kg paper sacks so it must make sense to reduce this to 400 half-tonne ‘big bags’. The ‘big bags’ are made from woven poly-propylene. They are not re-used in the food industry, but may be collected ‘free of charge’ or for a small fee for use in non-food applications. Robinsons of Stockport use ‘big bag’ supplied by Flexibulk, and Thwaites are about to install a ‘big bag’ powder handling system to be supplied by Mass Measuring Ltd.

Norit BMS.
ABOVE: Schematic of a 600 hl/h Norit BMF, showing from left to right: cold store tank, stabilisation dosing, recirc/retentate tank, filter, buffer tank, carbonator, bright beer tank.

LEFT: A 600 hl/hr (72 module) Norit BMF installed in a brewery in Belgium.

Disposal

Disposal costs for spent *kieselguhr* is an increasing part of the total filtration costs. With landfill being carefully controlled, costs will only increase. Soil injection is used by many companies in the UK. In parts of Germany spent *kieselguhr* is already considered as a ‘chemical waste’ which is extremely expensive to dispose of and more countries will follow suit.

KHS are in final stages of developing a filter system called Kometronic incorporating a precoat filter replacing *kieselguhr* with regenerable cellulose fibres.

I know that a number of companies are looking at manufacturing a replacement powder but they are not at the commercial stage yet. I am sure there will be long queues of interested brewers when they eventually come on the market as long as the economics are sound and the material can be used on existing filters.

Regeneration

Pall Food and Beverage has developed a *kieselguhr* regeneration system called Befis which is used in conjunction with their Primus filter. This system works on the principle of regenerating and cleaning the spent *kieselguhr* from a filter with caustic, acid and an enzyme preparation. This material is used as the body feed for subsequent filtrations. A fresh, new precoat is needed on each filter run. Overall *kieselguhr* savings of 70-80% are possible.

Which filter is best for me?

In the UK, plate and frame filters were used extensively until the 1970s. The plates and frames were mostly 60 cm with flow rates limited to 100hl/hr. This gave a typical run length of 1000 hl in ten hours. The introduction of the Seitz Orion 100 cm^2 filters enabled a step change in throughputs where flow rates over 320 hl/hr were possible. A maximum 6–7 bar inlet pressure allowed a differential pressure of 5 Bar (75 psi) and gave run lengths of over 4000 hl and with centrifuges and optimisation runs over 24 hours are achieved. The large sludge volume enabled much longer runs and even some 200 cm^2 frame filters were introduced. The problem was that the downtime to wash off, clean and sterilise the filters was 4–6 hours and required a lot of manual input. Although attempts were made to automate cleaning of plate and frame filters, they were not successful, so automated vessel filters were introduced.

Candle filters and other screen filters were already in use on the continent. In the 1980s, candle filters and horizontal screen filters were most popular. Candle filters had comparatively small sludge volumes which restricted filter run lengths, they were the answer for breweries who wanted large volumes filtered in a short time. Also, because the vessel volume was large, losses were high because of the water-beer interfaces at the start and end of the run. A problem also associated with the large plate and frame filters.

The introduction of large horizontal screen filters was a major step forward. This enabled long filter runs at fast flow rate and because the filter cake sat on a horizontal screen the filters could be emptied using carbon dioxide gas through low level ‘rest elements’ which were not used during the main filtration. The beginning and end of filter runs could be free of beer-water interfaces, so losses were greatly reduced.

Because of the horizontal screens, the filtration could be halted – the bed was stable, whereas the bed on a candle would slip off. The same was true during a power interruption. The main manufacturers with the exception of Filtrox concentrated on

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Membrane modules (each of $12m^2$) on a Pall Profi filter installed at Carlsberg in Fredericia which processes up to 480hl per hour.

(Photo: © Pall Corporation 2007.)

horizontal-screen filters. It seemed that the candle filter was becoming outclassed. Horizontal-screen filters had many advantages, but changes to brewing practice and a need for simplicity has seen a come back by the candle filter, with many of the concerns being answered.

Candle filters make a comeback

The complexity of moving parts and seals on the screen filters produced engineering headaches for some, so the simplicity and lack of moving parts in the candle filter again became attractive. Filtrox (Synox), KHS (Getra Eco) and Steinecker (TFS) all looked at the more negative aspects of candle filters and came out with innovations, to improve the efficiency and running cost. New wedgewire designs replaced the scalloped ring candle which are easier to keep clean and give a more even powder coating. For example, in the Filtrox Synox PF candle filter launched at Brau 2004, an optimised version of the successful Filtrojet filter, the filter area was increased by introducing a 25 mm instead of a 33mm diameter candle. The smaller diameter candle enabled more units to be put into the housing. The overall effect was to allow more filtration area and sludge space and less relative 'void' volume which contributed to losses in the form of water-beer interfaces at the beginning and end of a filter run. The increased use of high gravity brewing meant that beer at the beginning of a filter run could be run into a tank at very low gravity (assuming deaerated water is used to charge and pre-coat the filter) which could be compensated for by running in a precalculated volume of high gravity beer, thereby eliminating losses at start up.

Similarly, at the end of the run, the blending water can be shut down early to compensate for weaker beer being run at the end of the run – although care should be taken to ensure proper mixing. The same system could also be applied to a large plate and frame filter and some brewers who installed horizontal screen filters never use the blow down facility. It must also be remembered that when a filter is blown down with CO_2, the filter cake contains full gravity (often high gravity) beer, so the losses are not zero as some have claimed.

Another development by Steinecker (Krones) is the TFS-Twin Flow System candle filter introduced in 2000. This filter is different in that there is no filtered beer section of the filter vessel. The rough beer comes into the vessel, filtered beer comes out through the candles into a manifold within the body of the filter which feeds directly into the filter outlet pipe. Ten percent of the flow through the filter is recirculated from the bright back to the rough side in order to give an improved distribution of filter aid particularly at the top of the candle. The TFS is also designed to be used without a 'first' precoat.

So which powder filters are available and who makes them? The main filter suppliers have consolidated over the years, with only Filtrox remaining independent and having the same ownership. Pall bought Seitz-Schenk in 2002, while Steinecker became part of Krones and SEN became part of KHS. Table 1 shows the main manufacturers and brand name of various powder filters.

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Kieselguhr-free filtration

The issues associated with powder handling and disposal of spent filter powder have led to companies developing *kieselguhr*-free systems based on cross flow technology. This technology is extensively used for cider and wine, so what is the situation with beer? Early attempts by APV in the 1980s to filter beer using ceramic membranes were unsuccessful, but at least three major players currently have systems in use in breweries. The 0.7- 1.0 hl/m^2 flow rates on cross flow filters are slow compared with powder filters. The principal of cross flow filtration is straight forward with the unfiltered beer circulating across a polymeric 0.45–0.6 micron membrane. A cross-flow rate of approx 1.2 m/s has a pressure which is above the pressure on the filtered beer side of the membrane (this is called the trans-membrane differential pressure).

The pressure difference between the rough and bright side of the membrane provides the force to push the beer through the membrane and take out any particles. Because there is a 'fast' flow across the membrane perpendicular to the flow through the membrane, there is little build up of solids. There is no 'dead end' filter bed to go through as in a conventional filter, so there is no static filter bed build up and hence little pressure build up. There will be some build up of solid material on the membrane which will cause a rise in the trans-membrane pressure, and the process will continue until a pressure difference of about 1.5 bar is reached. The manufacturers of cross-flow filters all use an interim 'pulsing' or 'backwashing' technique to disturb any solid build up and reduce the trans membrane pressure. A stage is reached when the trans membrane pressure will not reduce, in which case a chemical clean is carried out.

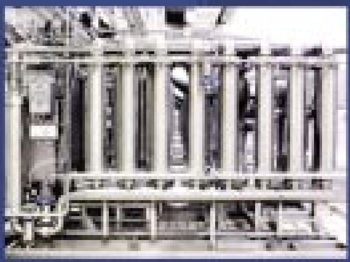
If we are looking at the physics of filtration, the same principles apply – crossflow filtration is enhanced by a large surface area, thin filter bed, and slow flow rate/m^2, so there is slower pressure build up compared with conventional filtration.

The three systems presented by Pall, Norit and Alfa Laval, all use polyethersulphone membranes put together in a series of modules.

PALL Food and Beverage

reliability

ri-li-ə-bil-ət-ē\ *n*:
to consistently produce the same results; meeting or exceeding specification



Often, **reliability** is a necessity – not merely desirable. In your production process key operations demand reliability. Inconsistency is not an option.

Filtration, being a critical clarification or product protection step, is one area where reproducible performance is a must. Your product quality depends on it.

Reliability is the primary design quality in all **Pall** filtration products. Our customers depend on it. We are proud to be the leading food and beverage filtration company in the world; this achievement is only possible by ensuring reliability in our customers' processes.

When your production process demands filtration reliability, contact Pall.

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Filtration. Separation. Solution. SM

Alfa Laval systems.

RIGHT: A 300 hl/h Alfafine membrane filter in operation in a brewery in Western Europe since 2005

FAR RIGHT: A 0.7m² 'Sartocon' membrane cartridge used on a Alfabright membrane filter.

(Photos: Alfa Laval.)

Norit and Pall use hollow fibre modules and Alfa Laval use a series of cassettes to make up the filter. A large recirculation pump is used to provide the fluid flow across the membrane. Table 2 compares the systems' features (previous page).

Cross-flow membrane filters produce a yeast free filtrate (due to 0.4-0.65 micron pore size) Suppliers have also reported improved hazes in bright beer as well as better flavour and haze stability due to reduced oxygen and iron pick up from filter powders. This is a good start, but only with longer term use and experience will these improvements be substantiated.

The cross-flow players

Norit is a Dutch company which specialises in purification technology, including water and other beverages. The BMF-200 beer filter was introduced to the market at Drinktec 2001, and extensive work has been carried out with Heineken. A filter with the capability of up to 200 hl/h has 24 filtration modules of 9.8m² filtration area each. The membranes are 0.5 micron PTS (polyethersulphone), each consisting of 2800 × 1.5 mm diameter fibres. In process terms, the filtration flow rate is 0.8hl/m²/h and the cross flow rate is 1.2 m/s. A system pressure of 3 bar gives a maximum trans membrane pressure of 1.2 bar. The filters have a typical average run length of 20 hours which includes a small number of backflushes, to reduce the trans membrane pressure and allow CIP. The chemical based clean using an oxidising agent and membrane cleaner takes 2.5 hrs and is carried out when the membranes become partially blinded.

Pall Food and Beverage is a global company, well known to the brewing industry, which specialises in filtration technology. The Profi system was developed in conjunction with GEA Westfalia Separators and a great deal of development work has been carried out with Carlsberg. A filter with the capability of up to 240 hl/h has 20 filtration modules of 12 m² filtration area each.

The membranes are 0.65 micron PTS (polyethersulphone). In process terms, the filtration flow rate is up to 1.0 hl/m2/h. The system is designed in blocks of modules, which are taken out in sequence for cleaning, thus allowing a continuous operation. Because the beer solids are mostly removed by the centrifuge, no retentate buffer tank is required, and the volume of beer involved in beer changes is low. Beer changes and the end of batch operations are carried out by blowing out the system with CO_2.

Like the Profi system, Alfabright is based on a combination of a centrifuge from Alfa Laval and a membrane system supplied by German filtration specialist Sartorious. A typical system

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Table 1: Main manufactures and brand name of their powder filters

Company	Plate and frame	Horizontal screen	Candle
Filtrox	Novox	Filter-o-mat	Synox PF
KHS	Orion	Cosmos	Getra Eco
Pall/Schenk	Niro	Primus	Ecoflux
Krones/Steinecker	-	Steineker FS 130K	Steineker TFS

Table 2 – Comparing available kieselguhr-free filtration systems

	Norit	Pall Alfa	Laval
Configuration	Batch or continuous	Continuous	Continuous
Module size	9.8 m²	12 m²	0.7 m² cassette
Size/modules etc	Blocks of 24 modules up to max of 72 (600 hl/h)	Blocks of 20 modules (up to 240 hl/h per block)	Up to 432 cassettes (up to 300 hl/h)
Membrane	Polyethersulphone	Polyethersulphone	Polyethersulphone
Pore size	0.5 micron	0.65 micron	0.6 micron
Flow rates	0.8 hl/m²/h	0.5 – 1hl/m²/h	0.7 hl/m²/h
Number in use	19	11	2

designed for 225 hl/hr based on 302m^2 of filtration area (0.75 hl/m^2/hr). The membrane filter is made up of a number of 0.7 m^2 'Sartocon' cassettes with a 0.6 micron PES membrane. This design is different from Norit and Pall in that the membrane cassettes have a very narrow distance between membranes – 120 microns, which according to Alfa Laval enables the filter to be run using lower powered, smaller recirculation pumps. The compact design of the cassette is also said to give a more stable membrane and optimium cleaning characteristics which have a positive impact on membrane life. The filter system works continuously, with sections taken out for cleaning every 2-5 hours.

Do you need a centrifuge?

There continues to be a debate about whether a centrifuge is required to clean beer before it is filtered on a crossflow filter. Pall and Alfa Laval recommend using a centrifuge to reduce yeast load on the membranes. Norit argue against the need for a centrifuge because they believe a separator does not remove the small particles (< 0.5 micron) which are responsible for blocking pores on the filter. The Norit system includes a 'retentate/recirculation' tank where the solids removed from the beer are collected. In the Alfabright and Profi systems, the solids are mostly removed by the upstream centrifuge.

Centrifuges are very costly to buy and operate and not having to include one in a new filtration scheme gives a big financial advantage to the Norit system. Like all new technologies, the debate will continue and only plant performance and experience will dictate whether centrifugation is necessary.

Another unknown is the robustness and reliability of the membranes and until better guarantees and replacement costs are substantiated, many brewers will not take the *kieselguhr*-free route. However there have been huge strides in membrane technology and it is widely used in other industries, so the time will come when brewers feel more confident to embrace the powder-free route. For companies with a longer term view of capital investment on strategic items, overall project lifetime costs may well be better on cross-flow than current powder systems, when everything including energy and environmental cost is considered. In the mean time, only continued development and experience will confirm whether crossflow is the future for beer filtration. ■

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● Acknowledgements

The author would like to thank those companies who supplied information and images in the preparation of this article