How to choose a wine crossflow microfiltration system

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Crossflow technology has been around for many years. The technology started life with little refinement or sophistication, but showed plenty of potential. With refinement and development, this technology is now well able to meet the needs of the wine industry for wine clarification.

The industry now has a choice of many different crossflow microfiltration systems, all of which work; if the definition of "work" means cloudy wine goes into the system, polished wine comes out, and something happens in the middle. However, there is a vast difference between a system which merely works and one which provides state-of-the-art design, versatility and performance. This article describes some of the things you should look for when choosing a crossflow microfiltration system for wine.

The main parameters which should be evaluated when comparing crossflow systems include:

- membrane type and configuration
- plant design and function
- protection of wine quality
- operating costs
- supplier support.

Membrane type and configuration

Ceramic and stainless steel

Ceramic and stainless steel membranes are robust and durable, except that ceramics are sensitive to physical and temperature shocks, and have a service life of approximately 10 years. Both are back-flushable and may be cleaned and sanitised with hot water and various chemical agents including caustic. However, the membrane cost is up to four times higher than other options. The capillary diameter and cross-sectional area is medium to high. High crossflow velocities are required, consequently large pumps and a high energy input into the wine. As a result, while many suppliers offer ceramic membranes and membrane systems for other applications, few offer them for wine clarification.

Spiral-wound polymeric

Spiral-wound membranes (as commonly used for reverse osmosis) have a low cost per m^2, however, they suffer from a non-uniform flow distribution across the membrane surface, are prone to fouling, are difficult to clean, and cannot be back-flushed. Hence they are rarely used for wine clarification.

Tubular polymeric

Tubular membranes with an internal bore diameter of 10-25mm have a relatively high cost per m^2 because of the need for the membrane to be cast onto a supporting material to provide strength and because of the low surface area per module (0.7-2m^2). Large pumps are needed to supply the crossflow velocity, hence energy consumption is high. The ▸

membranes are usually not back-washable, and the plants have a large footprint. Consequently they are rarely used for wine clarification.

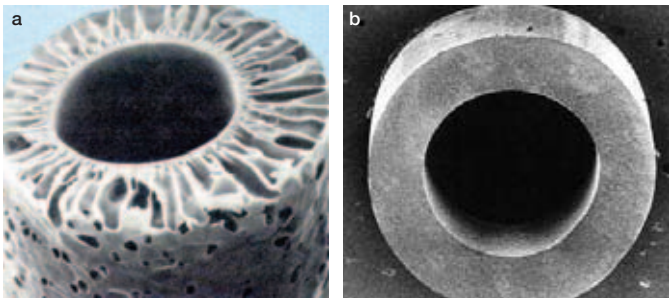

Fig. 1a. Asymmetric polymeric membrane with thin skin membrane and highly porous support structure. Fig 1b. Pall OenoFlow symmetrical PVDF membrane with uniform porosity across capillary wall thickness.

Hollow fibre "outside to inside" polymeric

Hollow fibre membranes with an internal bore diameter typically less than 0.5mm and a flow path from outside to inside (as commonly used in water microfiltration plants) have little or no crossflow velocity and are prone to fouling by turbid materials in wine. Hence their use is restricted to final polishing filtration of wines which are already well clarified.

Hollow capillary polymeric

Hollow capillary membranes with an internal bore diameter of 1-3mm are utilised in many microfiltration applications, with those for wine clarification having an optimised internal bore diameter of 1.3-1.8mm. At this bore diameter, the necessary linear crossflow velocity across the membrane surface can be generated with a relatively low volumetric circulation rate, hence with small pumps, low energy consumption and low energy input into the wine. With a surface area of typically 8-10m^2 per module, the plants have a small footprint. The membranes can be manufactured from a variety of polymers, hence chemical and temperature compatibility and membrane life vary. The new PVDF membranes may be hot water sanitised, are compatible with a large range of cleaning chemicals with a pH ranging from 1-14, and have a service life of six to eight years. Depending on the membrane geometry (see below), they may be back-washed vigorously. This type of membrane is used in more than 90% of the estimated 1500 wine filtration plants operating worldwide.

Membrane structure

Asymmetric membranes. These have only a thin membrane skin of around 10-30micron thickness, with the balance of the capillary wall comprising a highly porous support structure. Such membranes are mechanically weak, not suitable for long-term back-flushing, and prone to failure when exposed to harsh contaminants such as tartrate crystals, (see Figure 1a).

Symmetric membranes. These have a uniform pore structure throughout the complete capillary wall thickness, which can range from 300-600µ. Consequently they are mechanically stronger, and may be vigorously back-flushed to maintain a more stable filtration performance. As the whole membrane thickness has the separating pore size (generally 0.1-0.2µ), they can be used for abrasive contaminants, including tartrate crystals, (see Figure 1b).

Plant design and function

Capacity and membrane surface area

One of the most basic requirements is to process a given volume of wine within a given number of hours. Means of comparing potential systems are by membrane area and/or by output.

Membrane surface area is a very basic measure, however, not all membrane types perform identically. There are some fundamental design differences, allowing one to perform at a higher output compared with the other. This is then further influenced by the system design and operating parameters.

LMH, or the litres of filtered wine generated per square metre of membrane per hour, is a more useful measure. Systems should be compared side by side, on the same wine source. LMH comparisons should be the based on the average over a day's production, as all systems start at a relatively higher flow rate, and then reduce over time as they foul. Furthermore, cleaning frequency and cleaning cycle duration vary, thus influencing the number of hours for filtration verses hours of downtime. When talking LMH, make sure your potential supplier is not quoting initial LMH over a short cycle, or "best" figures for easily filtered wines. The easiest method of comparison is to talk to people using existing plants.

System feed tank

Gravity is the cheapest form of filtration, hence settling and racking before filtration is beneficial. Some crossflow systems return a proportion of the concentrated stream (retentate) to the source tank, which may stir up the deposits on the tank bottom and reduce the filtration rate, and may also have an effect on the organoleptic properties. This also introduces the danger of oxidation as often a long return line has to be used for transporting the bleed back to the main tank.

The use of a pre-run or concentration tank (with transfer pump) as part of the system has many advantages. The bleed from the circulation loop is to this tank, and the concentration process only takes place in this tank. There is no return to the source tank, hence no disruption to any settled sediment. The pre-run tank may easily be inert gas blanketed to minimise oxidation. This tank is also used as the feed tank for water and cleaning solutions for cleaning the filtration plant, and is itself cleaned during the cycle.

Filtrate tank and pump

Installation of a filtrate tank and transfer pump is advantageous as it allows the filtered wine to be pumped to a destination tank that may be 200m or more away, or pumped against a high head of a high-capacity tank, without slowing the system. The filtration part of the system is isolated from variations in back-pressure, and hence operates under optimum conditions. The filtrate tank also provides the ability to back-flush the membrane with clean wine.

Back-flush system

During wine filtration, a contamination layer (gel layer) is collected on the inner membrane surface and generates a cascade of negative effects. The filtration flow rate is reduced, consequently the wine remains in the recirculation loop longer, hence there is more filtration stress, more temperature pick-up, and more oxygen pick-up. The contamination creates a second separation layer finer than the membrane, increasing the separation characteristics and moving the removal rating from the microfiltration range down to a finer range, with negative consequences on the wine quality.

If a back-flush is created by opening and closing various valves and rigorously pumping a small proportion of filtered wine through the membranes in the reverse direction; this breaks the gel layer, clears the pores and allows the contamination to be swept away by the crossflow. The filtrate flow rate (flux) is increased to a lesser or greater extent. As the restoration of flux lasts only for a relatively short period, the back-flush should be repeated at frequent intervals for maximum effect. The main advantages are:

- faster filtration process
- more filtration capacity
- less filtration stress
- less temperature and oxygen pick up
- minimum impact on the wine quality
- overall performance increase of up to 60%.

Mobility and footprint

It is often important that the system can be easily moved around the winery, or even between wineries if sharing equipment, hence the physical size and weight are important. These can vary greatly in relation to the filtration output, for example, comparing two similar capacity systems currently on the market, one weighs 1.3tonnes, and the other 4.5tonnes. The footprint, or the physical space the system occupies in your winery, may also

vary greatly. Design for operator input on one side only or for location in a corner offers significant space savings. All components should be easily accessible for operation and maintenance.

Power consumption

When comparing installed kilowatts, or the size of the pumps, more is not better! In a closed recirculation system, all pumping energy can theoretically be transferred into heat input. This heat input can warm the wine, which in most cases has a negative impact on the quality and organoleptic aspects of that wine. If filtering off cold stabilisation, any significant temperature increase may result in redissolving of tartrate crystals and wine instability.

Large power consumption also costs money. In certain cases there are substantial differences in power consumption between systems from different suppliers with the same filtrate output. There are systems that require 20-30kwh more, which means for a system which operates for 5000 hours per year an extra power bill of 100,000-150,000kwh per year.

Automation

Suppliers have different interpretations to the word "automatic," therefore, this should be carefully defined. In summary:

- Manual means valves and pumps are activated manually, with some operator supervision required.
- Semi-automatic means the operator selects the desired sequence, eg. start, concentration, clean, etc. and then the system activates the necessary valves and pumps. Minimal supervision is required for normal operation. Note that some suppliers call this "fully automatic".
- Fully automatic system can operate 24/7, with little or no operator input required. The control system incorporates some logic, or can be programmed to choose when to concentrate/clean/restart, etc. or to link sequences.

Environmental impact

In addition to low power consumption, a well designed system should drain completely/have minimal wine hold-up volume. Water and cleaning chemical consumption should be as low as possible. Some plants use more than twice as much water and chemicals as others of equal wine output. Noise levels should be minimal.

Protection of wine quality

A well-designed crossflow system for wine respects and protects wine quality. The filtrate should meet all organoleptic requirements and should not be altered in any negative way. Systems that are designed specifically for wine filtration best meet this aim. Specific requirements include:

- the membrane material must be neutral and non-adsorptive
- the oxygen pick-up and loss of CO_2 from inlet to outlet of the system should be negligible (less than 0.3mg/L)
- the system should have the right pump types (low shear pumps) and pipe sizing
- the power consumption and heat input should be as low as possible
- the final hold-up volume should be as small as possible
- the system and membranes should be easy to clean after use
- the system including membrane modules should be a sanitary, food-grade design
- It should be possible to drain the system completely
- the system should be easily accessible for operation and maintenance.

Operating costs

This is an area often overlooked when purchasing, in the rush to obtain the lowest up-front price. A cheap piece of equipment will more than likely accrue substantially higher operating costs over the (hopefully long) service life, in comparison with a higher priced, better-designed system. Buying quality may cost more up-front, but saves money over the longer term. Factors that should be considered include:

- **Water and cleaning chemicals consumption.** The volume of water and chemicals required for cleaning and flushing of the system cost money, and will also end up in your effluent and require further cost to treat/remove.
- **Electrical consumption.** Large pumps cost money to run. Additional higher demand could push your winery over the limit of your electrical infrastructure's ability to supply, requiring expensive upgrades of transformers, switch boards, etc.
- **Start-up and cleaning times.** These are labour costs that need to be considered, however, a bigger cost is incurred when you can't complete the required daily filtration volume because of long cleaning cycles, and need to start alternative filtration systems.
- **Wine losses.** Getting the maximum percentage of your wine into the bottle rather than down the drain keeps accountants happy.

A patented Low Concentration Volume system developed by Pall to minimise the wine losses from a system allows recovery to be maximised (see figure 2). Depending on the level of solids in the wine, the residual volume may be reduced to 50 litres or less.

The following example for medium output systems illustrates the cost benefits of minimising wine losses.

System 'A' has a loss of 250 litres per batch. System 'B' has a loss of 50 litres per batch. The system operates for two cycles per day, for 100 days per year. The difference between systems A and B is 400 litres of wine losses per day. This equates to an additional 40,000 litres of wine per year that would end up in the bottle using system B in place of system A. At $2.50 per litre of wine, this amounts to a saving of $100,000 per year. You have just paid for one-third to one-half of your system with these savings.

Supplier support

Key points to consider and ask of a potential supplier include:

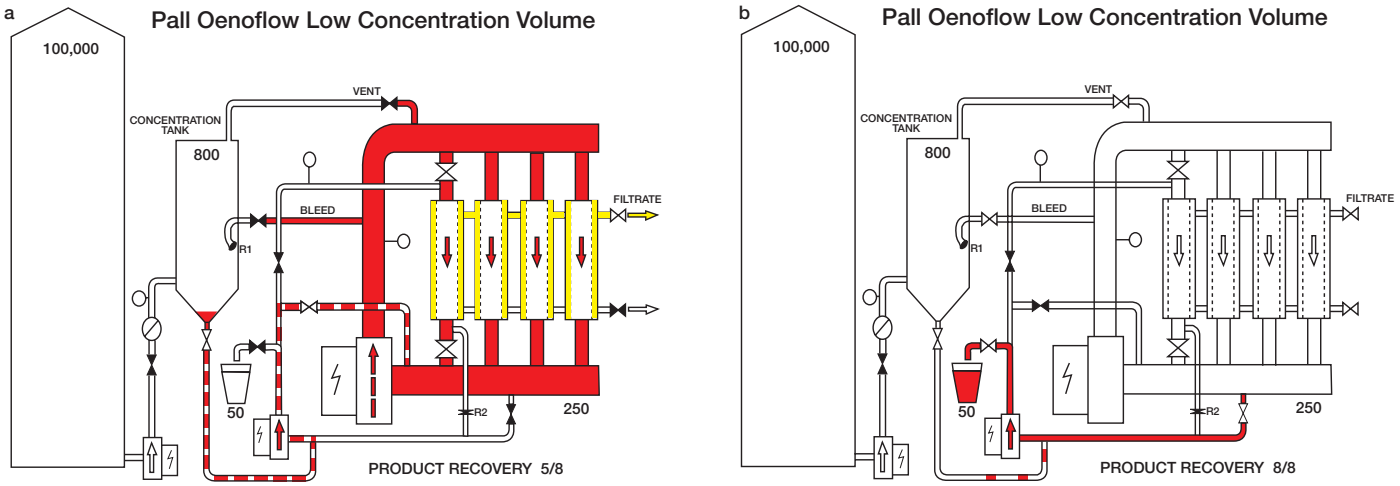

Fig. 2. Pall OenoFlow Low Concentration Volume system for maximising wine recovery. 2a: before final concentration (250L in system). 2b: after final concentration (50L residual volume)

- Is the supplier a filtration specialist, or a general equipment supplier?
- Is the supplier also the manufacturer, or only a re-seller?
- How many wine plants are operating successfully around the world and in your region?
- Is technical support and service available locally, or will you be given a telephone number that starts with '00' when you have a problem?
- Your expensive machine is made up of numerous $100 components. Eventually some of these may wear or fail. Are these available locally, or will you have to wait six weeks for delivery?

Summary

In conclusion, winemakers considering the purchase of a wine crossflow microfiltration system, should ask suppliers the key questions to ensure they make an informed decision. The authors recommend winemakers invest in buying quality, because in the long-term, quality pays.

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