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New Trends in Microbial Beer Stabilization Using CFS NEO Membrane Technology

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Introduction

With modern innovations in membrane technology and system design, membrane based solutions are gaining more share in today's beer production process. In some applications, like hollow fiber replacement of kieselguhr filtration for beer clarification, membranes have become the standard, while other applications like cold filtration for replacement of thermal treatments are still at their infancy.

For cold "sterile" filtration, widespread membrane adoption has been slow due to perceptions of high cost and contamination risk. In recent years, however, with increasing consumer interest in a wider variety of beer types and flavors, membrane filtration for microbial security is increasing and even outperforms pasteurization in many areas. In Japan, Korea and China along with some top brands in the Americas and Europe, brewers are setting thermal treatment aside in favor of microbial stabilization with membranes. The marketing positioning obtained by producing non-pasteurized beer enables perception of fresher more natural product, in line with today's consumer trend, thus delivering strong competitive advantage to the brewer.

To support this trend, Pall has developed the CFS NEO technology and a new family of filter cartridges for cold microbiological stabilization of beer. Drawing on experience from over 250 membrane systems around the world, the goal for this new development was to reduce the capital investment and in parallel, reduce water and cleaner consumption for a total cost of ownership below flash pasteurization.

The Basics of Beer "Sterile" Filtration

Brewers use the term "sterile" in a way that implies a microbiologically stable product rather than a product completely free of all microorganisms. The terminology applies regardless of whether the stabilization is performed with thermal treatment or membrane filtration. The Codex Alimentarius Commission (WHO/FAO) CAC/RCP 40-1993 defines the term "commercial sterility" for low acid food as the absence of microorganisms capable of growing in beer at normal non-refrigerated conditions at which beer is likely to be held during manufacture, distribution and storage. Hence, the aim of sterile filtration is to remove spoilage organisms which could impact product quality post-distribution. The term "sterile" used in this paper is always meant as "commercial sterility".[1]

Cartridges used for beer sterile filtration

Membrane cartridges used for beer filtration have a single open end (SOE) design and are based on multiples of 10 inch modules, with 30 and 40 inches as the most common lengths.

The membrane itself is pleated around an inner core which is further supported by an outer cage. For beer filtration, membrane is constructed from polyethersulfone (PES) or nylon with additional support and drainage layers.

Beer membrane filters should have specific microbial claims, describing the reduction level of the microorganisms in the product under process relevant conditions. The pore size itself gives an indication of the microbial performance, but no specific information on the true safety level.

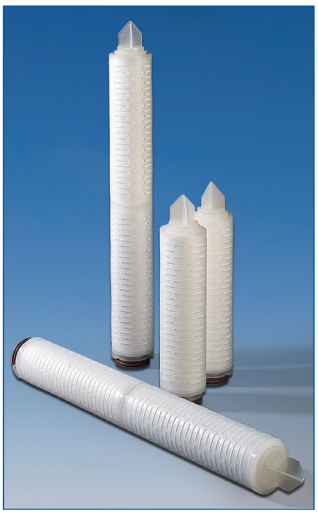


Figure 1: Selection of typical membrane cartridges used for beer final filtration

Pall has developed a specific product family of cartridge filters, the PARE family, designed for pasteurizer replacement in beer. The family consists of pre-filters and hydrophilic membrane filters for use in combination with the CFS NEO system.[2]

Pasteurizer replacement filter cartridges are suitable for exposure to repeated hot water sanitization and *in situ* steam sterilization cycles for longer service life in the CFS NEO system. The optimized support and drainage materials provide increased mechanical strength during operation, repeated hot water, chemical and steam sanitization and thus, high throughput for a low operating cost for the brewer.

Testing of membrane filter cartridges

A membrane filter integrity test is used to test and document the ability of a filter to remove microorganisms in actual operation. Such an integrity test has to fulfil the following criteria:

- Quick, easy and reproducible procedure, with clearly defined criteria and documented test results
- Specific parameters for the filter material and cartridge in use
- No influence on the filter material, which provides a repeatable nondestructive test, usually carried out after each cleaning and sanitization
- Correlated to a bacterial challenge, giving a representative indication of that filter's capability to remove microorganisms in process

Integrity test measurement sensitivity is a direct function of the measured membrane surface area. To achieve a meaningful and repeatable result, a maximum number of one hundred 10 inch modules can be tested at once. With an increasing number of cartridges per test, the resolution limit is reached, the integrity test itself becomes less precise and does not allow a direct relation between test value and microbial effectiveness of the membrane.

To select the most suitable cartridge for the individual brewing process, the upstream filtration, the type of beer and the type and load of beer spoiling bacteria play a role.[3]

Pretreatment of beer

For beer "sterile" filtration, the upstream clarification process plays an important role, impacting the economics of the sterile filter process.

Crossflow membrane systems generally provide sufficient preclarification, so that no further fine filtration is required. Experiences with the Pall PROFi hollow fiber technology show optimal prefiltration resulting in maximum service life of the sterile filter cartridges.[4]

Kieselguhr filters combined with sheet based filtration also provide suitable prefiltration to membrane filters. Kieselguhr filtration alone, however, can result in short membrane service life due to colloidal or particle haze. Therefore, the use of depth filtration upstream of the membrane cartridges is recommended. The pasteurizer replacement cartridge family includes two types of pre-filters. One pre-filter is designed for high colloidal loads while the other is recommended for high particle loads which can come from kieselguhr bleeding downstream during filtration.

Membrane cartridge filter cleaning

The economics of membrane filtration depends very much on the applied rinsing and cleaning regime and frequency. The cleaning frequency is directly linked to the throughput and differential pressure. A hot water rinsing step should be applied after a fixed amount of filtered beer, even if no increase in differential pressure is noticeable. This fixed amount of filtered product depends on the preclarification technology and the filterability of the beer. Lager beers allow longer cycle times than dark and strong beers. The main factors impacting filterability are the various glucan fractions, protein levels, iodine values and haze levels.

For chemical cleaning, the use of standard caustic at concentrations of 0.5 -1% at 65 °C is most common. If water hardness is high, scaling might become an issue, in which case a conditioned caustic cleaner can be used at comparable concentration and temperature levels.

Significant extension of cartridge lifetime can be achieved by adding a regeneration step with enzymes. The most common and effective are cellulase type enzymes that hydrolyzes (1,4)-beta-D-glucosidic linkages in cellulose and other beta-D-glucans plus side activities of beta-glucanase.

In rare cases other enzymes might be selected for membrane recovery, depending on the blocking substances. This needs to be evaluated on a case by case in close co-work with the membrane supplier.

Applying enzymatic regeneration in combination with caustic cleaning and rinsing at the recommended frequency results in longer cartridge filter lifetime and lower filtration cost.

Membrane sizing

Proper membrane sizing has a major impact on cartridge lifetime. The installed filter area relates to the filter throughput in an exponential function. Doubling the filter area typically results in four times longer life. Therefore, the key criteria for economic beer sterile filtration are system sizing and rinsing. Ideal process conditions are as follows:

Low and gentle flux during beer filtration (0.5 to 1 hl/10" *h)

High and intensive flow during rinsing and cleaning (3 to 8 hl/10" *h)

Undersizing for beer filtration (> 1.5 hl/10" module *h) directly impacts cartridge life and the total cost of ownership (TCO). Any savings in CAPEX is quickly negated by higher OPEX during overall system operation. Additionally, insufficient flux during rinsing and cleaning results in partial membrane blockage.

Single filter housing installations are always a compromise between these two requirements. Accordingly the cluster technology has been developed to fulfil both criteria.

Installation

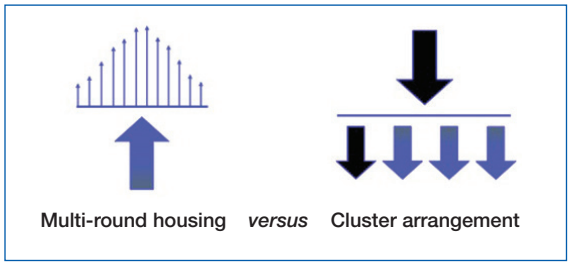
The main advantage of cold sterile filtration is the direct installation of the filter upstream of the filling line without a buffer tank. Membranes with a stable matrix maintain their separation characteristics at varying flow rates and pressure including start/stop situations. During filtration, the CFS NEO behaves like a piece of pipe. This provides maximum microbial safety, combined with minimum beer losses and true flexibility in terms of brand changes and start/stop operation.

Eliminating the buffer tank upstream of the filling equipment avoids a critical recontamination point, minimizes beer losses at production start and at brand changes and reduces expensive CO_2 consumption.

System design

In 1980s the very first installations for beer final membrane filtration were based on big multi-round filter housings connected to an existing CIP unit, installed downstream of the kieselguhr and sheet filters. During the last decade, system designs have improved followed by increasing interest in beer sterile filtration. The system designs became more application and process specific. In 1993, the first cluster filter system was introduced to the brewing industry, overcoming the disadvantages of big multi-round housing installations with many cartridges in one set up.

Figure 2:



With the cluster technology, the number of cartridges used for filtration are split into arrangements of small groups of 7 filter cartridges (the cluster) which operate together during beer filtration but fully isolated during cleaning, regeneration and testing.[5]

Features and Benefits of the Cluster Arrangement

- Each cluster of filters can be individually integrity tested hence 'failures' can be more easily identified
- Less risk from sensitivity errors in the testing
- Clusters can be isolated from main beer flow to allow uninterrupted production in the unlikely event of integrity failure
- More consistent and thorough cleaning / flushing efficiency by treating clusters independently
- Reduced water consumption when compared to operation without clusters
- Quick and simple filter changes (*e.g.* one cluster versus seven cartridges, 14 clusters versus 98 cartridges)
- Specific control of flushing and cleaning leads to optimum filter life and hence the lowest possible filter costs

The original cluster design was based on a large vessel incorporating all cartridges split into clusters, each with 7x40 inch cartridges, which were opened and closed by individual valves. With this design flow rates between 50 to 600 hl/h can be accommodated.

Figure 3: Original cluster technology and cartridge arrangement for a 400 hl/h system

To further optimize the cluster technology, in the new CFS NEO system, the big vessel was replaced by small cluster housings, arranged in parallel on a skid and controlled by individual outlet valves. This new design improves the ratio between membrane area and system volume by 25 to 35%, resulting in lower consumption of water and cleaner, but also optimized beer losses compared to standard multi-round vessel or big cluster vessel designs.

By applying a modular design, the sizing is highly flexible and covers a range from 50 to 600 hl/h.

The new CFS NEO systems are comprised of the following:

- **Filter modules with cluster housings to hold the filter cartridges**
- **Connection module for beer and CIP inlet and outlet**
- **Membrane cleaning module (CIP) with all relevant components to rinse, clean and regenerate the system, independent from the periphery in parallel to line cleaning**
- **Integrity test function**
- **Control panel with user friendly HMI**

The system design and arrangement fulfils relevant regulations and directives including hygienic design.

The system is completely preassembled for plug and play operation directly upstream the filling equipment.

Fully automated operation is simple and typically controlled by the filling machine operator. The control system can be standalone with defined interfaces or integrated into existing brewery control concepts.

The CFS NEO system is available with and without prefiltration and for batch or continuous operation. Batch operation requires a stop for cleaning after a set filtration time (max. 45 hours), while continuous design allows 24/7 processes.

Figure 4: CFS NEO 14 for 400 hl/h

Microbial safety

All Pall pasteurizer replacement cartridges used for beer filtration have microbial claims describing the microbial performance of filters in process. The claims are typically evaluated on a regular basis under defined conditions in beer, using beer spoiling bacteria, grown in beer specific growth media.[6]

Beer membrane cartridges should be qualified with the following types of microorganisms:

- *Lactobacillus brevis*
- *Lactobacillus lindneri*
- *Pediococcus damnosus*
- *Saccharomyces* type yeast strains
- *Serratia marcescens*

Qualitative statements with regards to *Megasphaera cerevisiae* and *Pectinatus spp* should also be available based on PCR measurement.

Compared to standard thermal treatment processes (flash or tunnel pasteurizer), membranes show a higher level in titer reduction corresponding with better microbial safety. At normal pasteurization level (15 – 25 PU), the microbial effectiveness of membranes is 103 to 104 log levels higher compared to thermal treatment – independent from flash or tunnel pasteurizer.[7, 8]

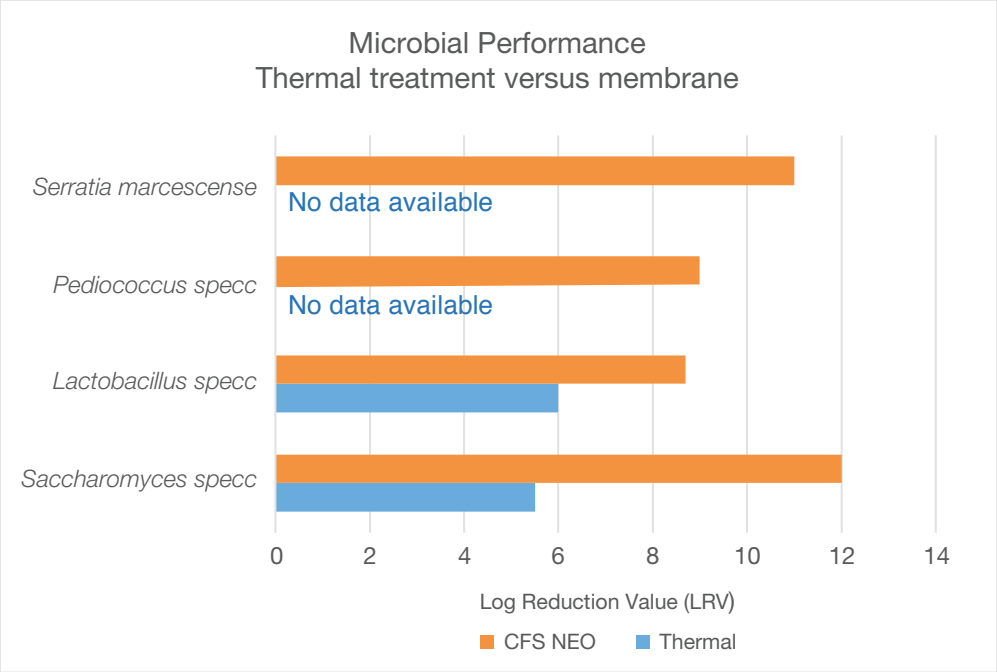


Table 1: Comparison microbial performance membrane versus thermal treatment

An additional advantage is that cells and spores are removed with membranes while thermal systems just inactivate the cells. Thus dead cells remain in the beer and limit the information of DNA based analytics such as polymerase chain reaction (PCR).

With the CFS NEO system, one significant difference to the multi-round housing design is the improved microbial safety resulting from the individual integrity test — cluster by cluster. Seven cartridges per integrity test results in a high sensitivity and reliability for the test.

Additionally, in the event of an integrity test failure result, the system isolates the specific cluster automatically and continues with the remaining cluster housings in full production. Up to 25% of the installed clusters can be shut down without impacting filtration safety or performance.

The identified cluster housing can be opened and the failed cartridge localized and replaced during next production stop.

Operation Costs

With the individual cluster housing design, consumption of water, cleaner and enzyme is reduced by 25 to 30% compared to the big vessel cluster systems and up to 45% compared to standard multi-round housing design concepts. With the CFS NEO design, the increase in flux during rinsing shortens the time from 20 to 30 min down to 30 to 60 sec per cluster housing.

The water and energy savings compared to thermal treatment installations is significant. Flash pasteurizers waste up to 75% more water and consume up to 80% more energy. Tunnel pasteurizers are even higher in consumption levels compared to the CFS NEO.[9]

With the introduction of the enzymatic regeneration, membrane lifetime can be increased by 3 to 5 times, resulting in a significant drop in filtration cost from 0.5 to 0.9 $/hl to 0.1 – 0.3 $/hl.

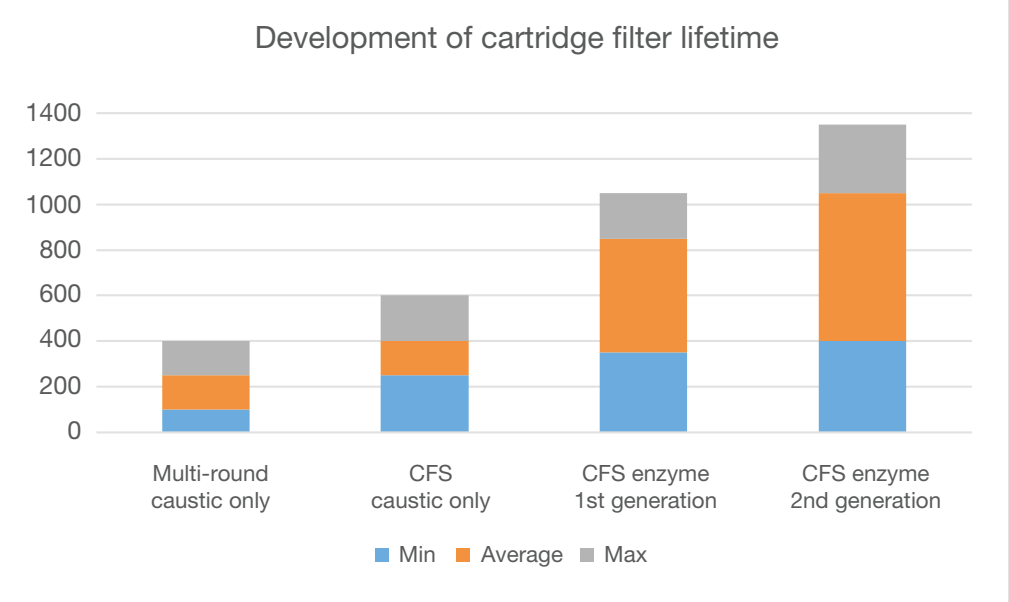


Table 2: Impacts from enzymatic cleaning

Labor is also reduced with the CFS NEO system. The system is fully automated and run by the filling machine operator, thus manpower cost including membrane replacement expenses are negligible.

Considering the aforementioned financial aspects, the CFS NEO system demonstrates significantly lower cost when compared to tunnel pasteurizers and at least equal but in most cases lower than flash pasteurizers.

Taste and quality

By eliminating exposure to high temperature, maintaining lower flux during beer filtration and utilizing a design with minimal oxygen pick up, the CFS NEO system does not impact beer freshness and taste stability.

Comparing endogenous anti oxidative potential (EAP) values as an index for oxidative flavor stability, cold filtered beers provide better values than thermally pasteurized beers directly after treatment. With cold filtration, taste remains unchanged long after bottling, while pasteurization can have a negative impact on beer freshness right after heat treatment.[10]

Summary

With the latest developments in beer sterile filtration, the CFS NEO system is setting new standards for replacing thermal treatment of product upstream of the filling line. In addition to higher microbial safety, the economics are favorable with cold sterile filtration using membranes. The positive impact on taste stability and customer satisfaction gives brewers the opportunity to strengthen their brand, improve shelf life stability and improve economics.

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