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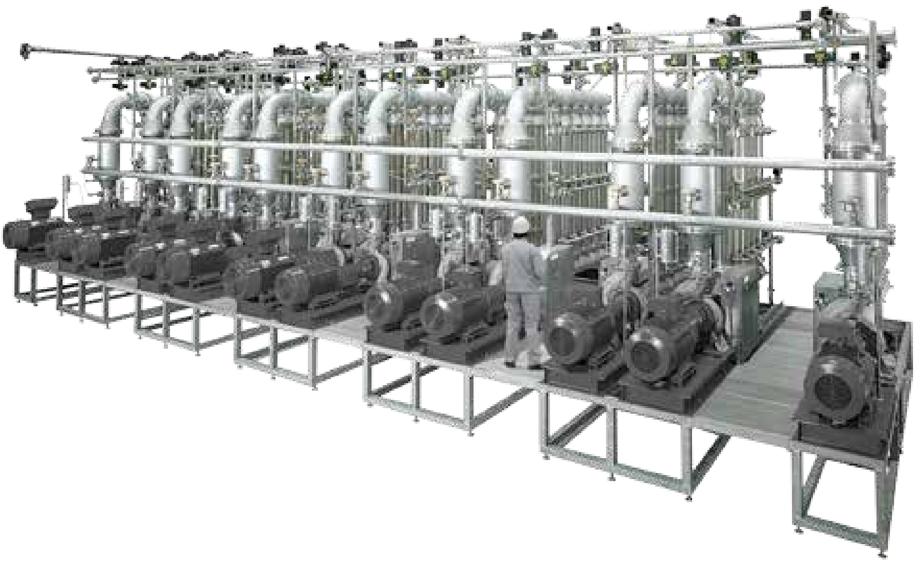
СИСТЕМЫ ПИВОВАРЕННЫЕ CLEARAMIC BEERFILTRATION Технические характеристики



1. Introduction

Sustainability is now a universal process criterion. The brewing industry too is intensively concerned with optimizing the consumption of natural resources and launching “green” products, which represent a high level of ecological responsibility. As well as changed legal constraints and image cultivation, cost concerns also play a substantial role here.

The procurement, handling and disposal of filter aids have become e. g. a cost factor that increasingly impairs the profitability of breweries. At the same time, the consumer also still expects a brilliantly clear product of consistent quality.

In this situation GEA **clearamic** BeerFiltration is the timely solution: as a wastefree beer filtration, this process works with absolutely no filter aids at the same time as ensuring genuine, unadulterated beer enjoyment.

The ceramic membranes form the centrepiece of this cross-flow filtration. The material is absolutely foodneutral and can be regenerated again at any time in the filtration system. The service life of the membrane is at least 10 years. The result: purest beer quality – brewed in a way that is sustainable and reduces costs.

The following report considers the technical-technological background and explains the basic principles and features of the filtration process.

2. Basic principles of beer filtration

Beer filtration must always be seen in conjunction with stabiliza-tion, as adequate turbidity and stability cannot be ensured with filtration only. Stabilization takes place before, during or after the actual filtration. Filtered beer becomes cloudy again shortly after filtration.

The reaction of the colloidal and genuinely dissolved substances – with the aid of m vement, light, temperature fluctuations and time – results in the formation of larger colloids. Initially, these form opal turbidity and might ultimately emerge as flakes.

This is slowed down by reducing or completely removing the reactants. Known stabilizing agents are polyvinylpolypyrrolidone (PVPP), silica gel and kieselsol as well as various enzymes and tannin outside of the purity law. Deep-bed, precoat and cross-flow filtration with membranes are used for filtering beverages. The first of these use filter aids such as cotton or cellulose fibers or kieselguhr and perlite as powder, the effectiveness of which is further improved with the addition of other substances such as silica gel or previously asbestos.

Generally, filter aids can produce pure separation, like a sieve; however, they can also work adsorptively and accumulate solids.

Essentially, the procedures used can be summarized in three groups:

2.1 Static deep-bed filtration

The cloudy product flows through a porous filter cake, which retains the solids. Depending on size and nature, these are deposited on the cake or in the pores of the cake. Ready-made filter layers with a thickness of approx. 10 mm are established, which consist of cellulose and kieselguhr.

Classic beer filtration – mass filtration – was carried out with cotton mass. Even though it was nearly waste- free it required large quantities of washing water, manpower and energy and was therefore superseded by kieselguhr filtration.

Static deep-bed filtration is nowadays used only rarely as the sole filtration. However, with layer filters, it is common and established as a safety filtration following another filtration.

2.2 Precoat filtration

The most common type is the filtration with kieselguhr as filter aid. Due to this many process steps have been adapted to the filtration.

The coarse kieselguhr (or perlite) is washed up on a supporting layer, e.g. coarse filter layer or metal sieve, and bridges the pores of the supporting layer. Another deposit of fine kieselguhr comes onto this first sedimentation that leads to a greater filtration intensity. Beer is now pumped onto the filter and clarified.

The active mechanisms here are both the sieve effect and adsorp-tion. A constant dosage of kieselguhr into the unfiltered beer prevents blocking of the cake surface by the solids. The filter cake grows over the duration of filtration and thus remains porous. With the addition of silica gel, proteins can be accumu-lated at the same time, which prevents a subsequent clouding reaction in the beer. With a variety of kieselguhr, other aids such as PVPP and various dosage quantities, a highly flexible and established system has been created. Time consuming is the treatment of the kieselguhr before and after filtration. The dis-posal of used kieselguhr is becoming increasingly difficult. Moreover, there is discussion of the transfer of substances from the kieselguhr into the beer.

From the present perspective, the resources can be considered unlimited. Kieselguhr filtration can withstand greater quantities of solids than e. g. mass filtration, yet preliminary clarification or young beer separators have become accepted everywhere since the introduction of CCTs (cylindro-conical tanks). The current processes for beer stabilization are entirely geared towards kieselguhr filtration and take place on its periphery.

2.3 Cross-flow filtration with membranes

By contrast with kieselguhr filtration, membrane filtration is largely a surface filtration.

Solids are retained on or in the pores of the membrane. With a flow over the membrane surface at right angles to the filtration direction, these solids are washed away again and held in suspension, so the membrane surface remains clear and therefore active. This cross-flow is achieved by high circulatory pumping capacities within the system, cf. fig. 1.

The membranes slowly become blocked due to the cross-flow then have to be chemically cleaned. This is
time-consuming as the membrane can also become
blocked at depth. Contamination that has settled here is difficult for cleaning agents to reach and can be removed only slowly and under aggressive conditions.

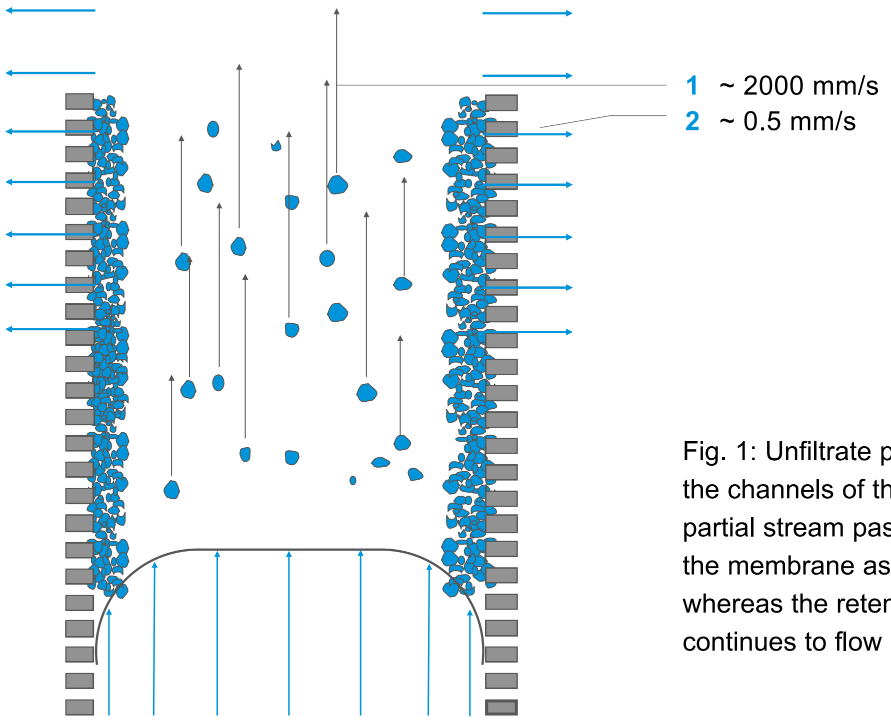


Fig. 1: Unfiltrate passes through the channels of the membrane: a partial stream passes through the membrane as filtrate (2) whereas the retentate (1) continues to flow

Polymer membranes are temperature resistant only to a limited extent and therefore destroyed by cleaning in the medium term. As they consist of organic material, they are not completely inert. There is always a need for membrane replacement which may even be required annually depending on the CIP (cleaning in place) intervals and operating hours. Ceramic membranes are more expensive to purchase but when optimally installed virtually indestructible.

Durabilities of well over ten years are common in practice. Moreover, they are a completely inert and therefore food-com-patible medium.

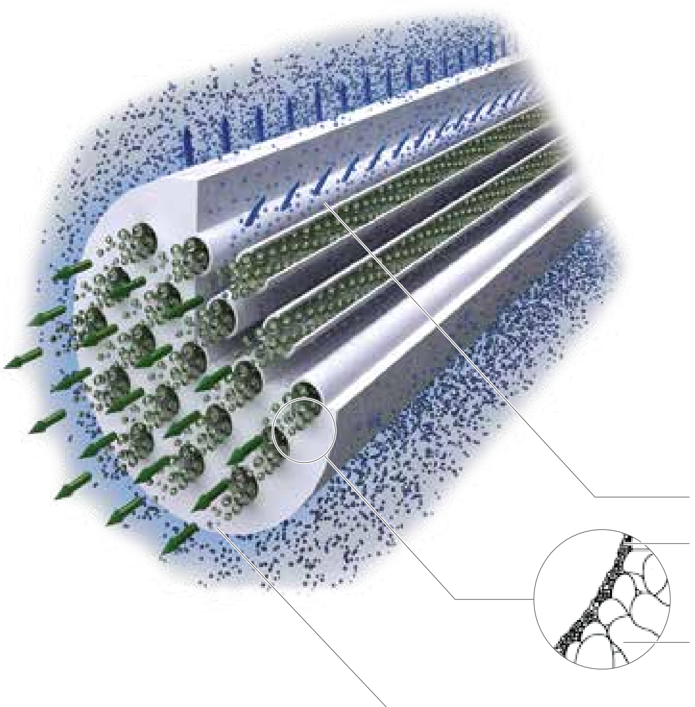


Fig. 2: With cross-flow, part of the volume passes through the membrane and is discharged as filtrate

2.3.1 Durable ceramic membranes

Advantages of ceramic membranes in cross-flow filtration:

- Completely inert material
- Free to choose the right pore size for an optimum filtration
- Operationally safe
- Long lifetime of more than 10 years
- High temperature range (135 °C), can be sterilized with steam
- High mechanical stability
- Very good cleanability
- Full pH range 0 – 14
- Standard cleaning agents: NaOH, HNO_3 and booster
- Cleaning times approx. 2.5 h
- Acid and base resistant, solvent resistant
- Can be regenerated
- No problems with back flushing
- Wear resistant
- Robust against pressure and temperature
- Constant flux rate of filtrate over the complete lifetime cycle
- Minimum operational costs
- Short installation and start-up times, due to pre-assembling

2.3.2 Manufacture and characteristics of ceramic membranes

Ceramic membranes are bodies that are sintered at a high temperature. Multi-channel elements are used for beverage filtration, cf. fig. 5.

The requirement for maximum mechanical and chemical stability with minimum flow resistance has been met by using a support with a macroporous structure made of pure aluminium oxide (α-Al_2O_3).

To manufacture the base body, aluminium oxide powder is initially mixed with water and an organic bonding agent. The resulting mass can then be extruded into the form desired. After careful drying, the water initially evaporates in the subsequent sintering process, whilst all the organic components including the bonding agent evaporates at approx. 600 °C.

The final sintering temperature is reached at approx. 1800 °C. Here the aluminium oxide crystals begin to fuse together and form the solid and stable base body of the membranes, cf. fig. 3. The porous base body that is now present has a pore size from 10 to 15 μm.

The membrane is washed into the channels of the element as a suspension with defined particles. The particles that stick to the wall of the base body are surface-dried and then sintered. With the sintering temperature, particle size in the suspension and number of processes, a defined membrane layer can be applied in a reproducible way, which is highly resistant both chemically and mechanically.

This multi-layered structure is comparable with the different sedimentations of kieselguhr filtration. The filtrate and its solids define the required pore size. However, valuable elements of the filtrate must not be separated. Its viscosity – often correlating with solid concentration – defines the channel width: the more viscous the product, the wider the channel.

Ceramic membranes are standard applications in yeast beer recovery and increasingly used for fruit juice filtration.

Fig. 5: The ceramic multi-channel element

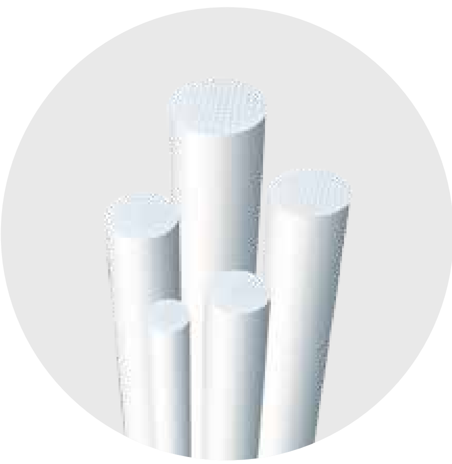


Fig. 6: Module housing made of stainless steel protect the ceramic elements

The oldest systems for yeast beer recovery have been in use for over 20 years with the first set of membranes. Because of their extreme durability, ceramic membranes can be cleaned very hot and chemically aggressively, whereby initial installation condition can be achieved over and over again. Furthermore, expensive enzymatic cleaners can be compensated for with high caustic at high temperatures.

Sodium hypochlorite or peroxide is used as the oxidative component for cleaning. The usual, cost- effective media of the brewery are therefore used.

Integration of the ceramic elements into modules

The ceramic elements are integrated into non-nesting stainless steel modules, cf. fig. 6. The module housings ensure reliable sealing of the filter elements. It is important here to compensate for the mechanical tensions between filter elements and module housing and to avoid direct contact between metal and ceramic.

Because of this specific requirement, GEA has expressly developed a specially moulded seal, which meets all the hygiene requirements as well as ensuring maximum durability.

The module’s primary functions include:
- Holding the working pressure
- Ensuring flow channelling of permeate and retentate
- Allowing a controlled flow across the membrane, cf. fig. 7

The high-end construction of the membrane in the usual GEA standard reliably connects the components with a 100 % seal. The rules of hygienic design which are of utter importance when flow speeds are low as specified here are particularly observed. The good drainability of the module, which allows considerable time savings, and guarantees optimum cleaning is also remarkable.

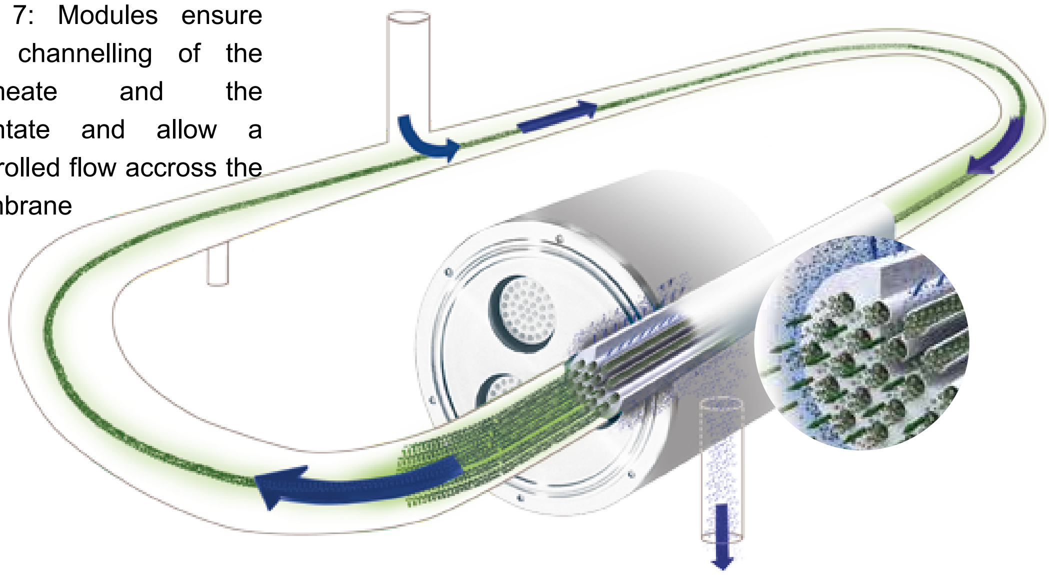


Fig. 7: Modules ensure flow channelling of the permeate and the retentate and allow a controlled flow accross the membrane

3. ystem layout for beer filtration with cross-flow filtration

One or more modules are combined into a filtration loop. The loop pump performs the circulation, the feed pump provides the filtration pressure. The filtrate is discharged from the modules via a flow or pressure control – cf. fig. 8. The loop is typically supplied with unfiltrate in three ways:

1. The unfiltrate is fed to the loop via a feed pump and only filtrate runs out of the loop. Solids therefore quickly become concentrated in the loop, so this variant is practical only for products with a low solid content.

2. For continuous concentration, filtering is conducted as de-scribed in 1 until a high concentration of solids occurs after a short time. This is then continuously discharged. The process runs until the membranes are exhausted. The disadvantage is the procedure with a constantly high solid concentration and therefore viscosity.

3. Unfiltrate is placed in a batch tank and fed into the loop. A partial flow is filtered off here. Another partial flow is fed back into the batch tank as a retentate. Due to the greater volume of the system compared with variant 1, the increase in concentration therefore takes place more slowly. Conse-quently, efficient filtering is possible forlonger with a low solid content – synonymous with low viscosity.

When the retentate flows through the filtration channels, a pressure loss occurs, the extent of which grows with the flow speed and viscosity of the medium and falls as the channel width increases. In addition to the aforementioned selection
"viscous = wide channel", a pressure gradient emerges over the channel, which results in an uneven flow through the membrane: the pressure difference to the filtrate is significantly higher on the input side than on the output side (cf. fig. 9). It is even possible for the input area to be filtered and for filtrate to flow back into the retentate in the output area. The filtration pressure is stated as the trans-membrane pressure (TMP), as there is no constant difference in pressure from filtrate to unfiltrate due to pressure loss in the channel. The TMP is therefore the averaged pressure on the side of the retentate less the filtrate pressure.

In addition to optimum adaptation of the channel width and flow the speed to the product, this is achieved by limiting the channel / element length. The channel length should be selected such that no backflow occurs. The length of the module is also calculated from the maximum element length. To effectively remove the covering layer on the surface of the membrane, the flow speed must be set sufficiently high. With the circulation power, the energy demand rises cubically. As such, a combination of cross-flow and back flushing momentum is frequently employed in the case of thin suspensions, e. g. pre-clarified beer. The cross-flow keeps the solid element in suspension, which is washed out of the membrane pores by means of periodical back flushing with filtrate. After back flushing, the TMP falls back to a lower value. Longer operational times can therefore be achieved. Back flushing can substantially reduce the cross-flow speed (from approx. 5 m/s to 2 m/s), which produces energy savings.

Due to shorter maturation times and thus higher solid contents, it is advisable to pre-clarify the beer in front of a filtration by a centrifuge.

These basic requirements and numerous trials produce an optimized system design:

- To create a large filtration surface, filtering is carried out with a narrow channel of approx. 1.5 mm
- The flow speed is around 2 m/s
- Periodic back-pulses are used. These pulses must be as sudden as possible in order to have equal impact on all pores
- The element length remains limited to 1200 mm in order to prevent backflow
- The optimum pore size is between 0.5 and 0.8 μm

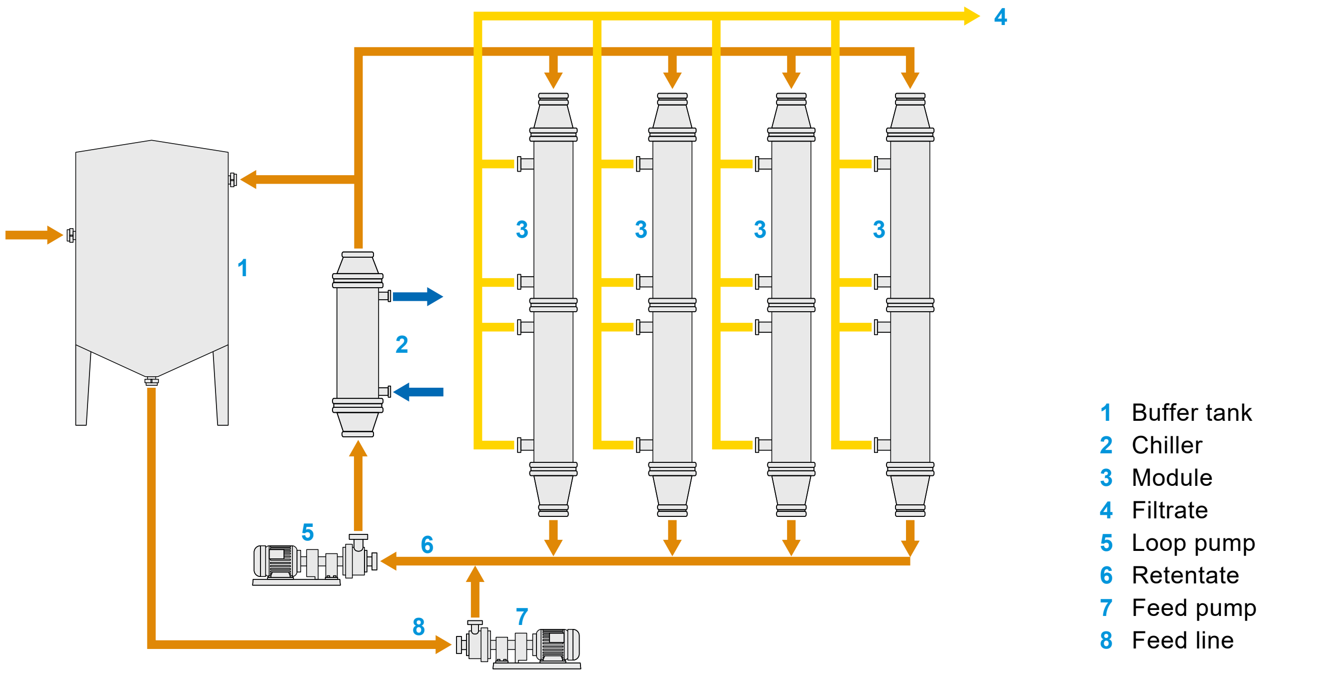


Fig. 8: Work sequence of cross-flow filtration

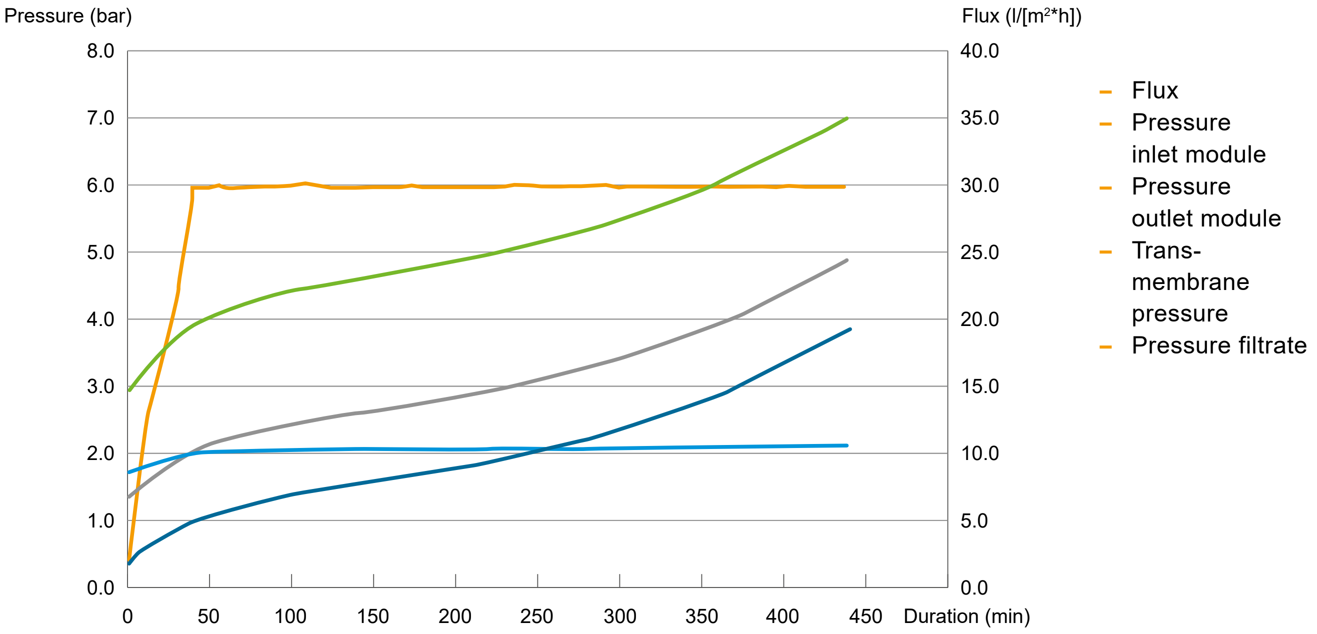


Fig. 9: Model filtration of a high gravity beer (> 17 °P)

4. Use of ceramic membranes in cross-flow filtration

With appropriate preparation of the storage cellar beer, beer filtration with cross-flow filtration can be optimized in terms of production and cost:

- Adequate cold storage < 0 °C results in coarsening of the colloids, which then become easier to separate. This is particularly important for beers produced within the purity law, which are usually significantly less filterable than enzymated beers due to a lack of enzyme addition in the brewhouse
- Pre-stabilization with kieselsol, tannin or proteolytic enzymes

4.1 Work sequence of cross-flow filtration

Work sequence:

- The cleaned system is filled with de-aerated water, cooled to filtration temperature and emptied by means of CO_2 pressure
- Under counter-pressure, the system is filled with unfiltrate and vented
- The loop pump and temperature control are switched on and the filtrate side is vented, no prerun occurs
- When a predefined TMP is reached, the system either continues to operate with a falling flow, e. g. to drain a tank, or it is shutdown
- In the case of shutdown, the filtrate is removed from the modules and pipelines by means of CO_2 and completely extracted

4.2 Exploitation of the remaining retentate

The remaining retentate can be exploited in various ways:

- Buffering of the retentate in a separate buffer tank in order to then cut it off at the end of the next filtration run. This results in a further increase in retentate concentration per batch. However, this requires a low number of beer type changes.
- Exploitation in a retentate preparation, which can also absorb excess yeast for beer recovery
- Discharging the beer to the post-run tank with water in order to wash out the extract. The watery retentate is disposed of in the sewer or exploited in a biogas plant.

4.3 Cleaning sequence

During flushing, foam residues and the retentate are rinsed out and the system temperature is set to the range of the caustic solution temperature in the stack tank. The temperature should jump by no more than 20 K in the case of a change of medium and the temperature variation should not be higher than 10 K/min. For the caustic cleaning with booster a 2 % caustic soda solution at a temperature of at least 85 °C is used. The rinsing water accrued can be collected. It is then neutralized with acid, the system is rinsed, and the temperature is set. The cleaning takes around 2.5 h. Following the CIP, the pressure resistance of the elements can be checked with water under standardized conditions (temperature, flux, cross-flow) and the success of the cleaning can thus be determined.

4.4 Protecting against membrane breakage

Membrane breakage can be virtually eliminated with ceramic membranes and is drastic if it happens at all. This can be monitored using an in-line measurement of turbidity.

4.5 Modular block

The maximum size of a filtration loop or block is determined by the circulation pump, which becomes uneconomical from certain sizes in terms both of availability and of fittings. In the case of higher power, several blocks are then connected together. They can then be operated as a batch or continuous process.

5. Product result

Trials in various breweries in the side-flow to kieselguhr filtra-tion show only slight differences from this procedure. Better or equal turbidity values were achieved throughout. The other parameters of the beers were normal, as were the tastes. In tasting, some of the trial beers were described as a little more pure.

6. Costs

When considering costs, a fundamental difference of ceramic membranes compared with other systems must be taken into account: since the membranes are purchased with the system and last for the entire service life of the system this is pure investment activity.

With polymer membranes or kieselguhr filters, the costs of filter aids and the disposal of these can be found in the running costs, so the investment costs emerge as significantly lower.

The costs for polymer membranes specifically are a considerable factor in the OPEX (operational expenditure) and should always be taken into account. Accordingly, a filtration system must be planned for a high workload in order to make optimum use of the capital invested. The system design must allow easy expand-ability. Comparability of offers (polymer vs. ceramic) is not possible with the offer for the system alone.

The following design criteria have been taken as the basis:

1. . High g   vity beer (< 17 °P)
2. The caustic solution is considered replaced after three passes (mixing zones, resharpening).
3. Acid and booster are consumed in every pass.
4. . Rinsing   ater is accumulated:
   a. Interim rinsing water for pre-rinsing.
   b. Interim rinsing water for alkali pre-rinsing.
5. The overrun is replaced with water after each filtration. The diluted beer is collected in a tank and is dosed to the following filtration. The overrun is discarded below a defined gravity. This loss of extract is shown as beer loss.

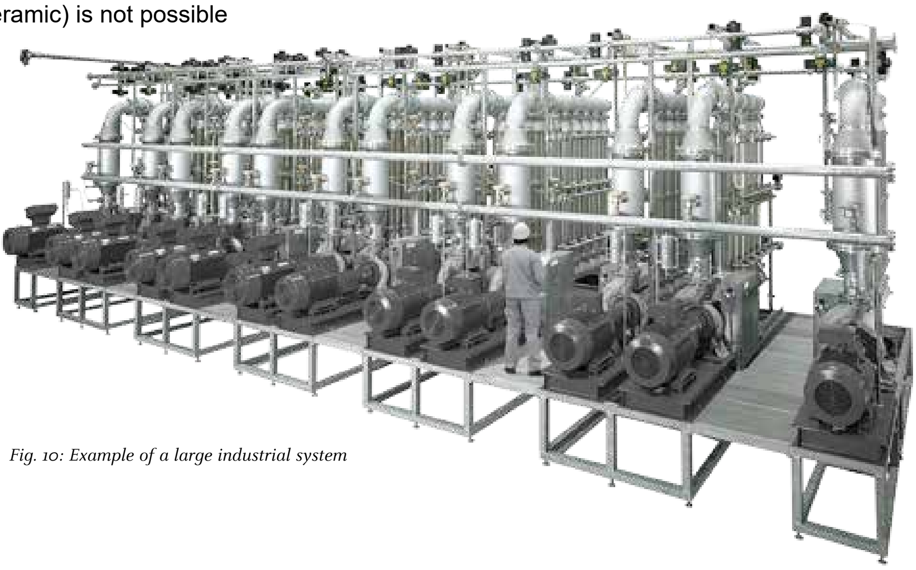


Fig. 10: Example of a large industrial system

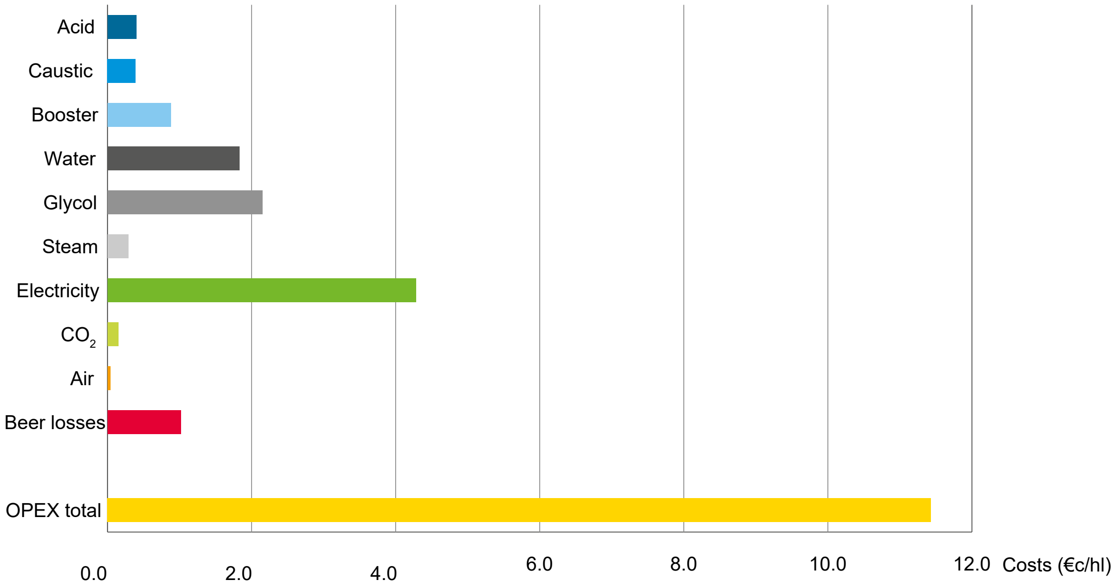


Fig. 11: **clearamic** BeerFiltration – example for filtration

costs

7. Summary

GEA **clearamic** BeerFiltration is the first waste-free beer filtra-tion process. Filter aids can be completely omitted. Sustainable and at the same time cost-cutting process management is thus supported at the critical point. In parallel with this, the process fulfils the consumer desire for crystal clear beer in permanently consistent quality. As the studies have shown, the beer quality remains consistently high with **clearamic** BeerFiltration.

With the use of ceramic membranes, beer filtration is carried out with greater process reliability, since in the case of proper integration, there is no risk of membrane breakage. Ceramic is food-neutral, so there is no risk of contamination. The service life of the ceramic membranes is at least 10 years. The staff costs are low. No expensive special cleaning agents are needed. In conclusion, the process is therefore economically superior to alternative products.

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