

System and Method for Filtration of Liquids

The present invention relates to a system and a method for the filtration of liquids.
5 More particularly it relates to a system and method for the filtration of liquids which may have high solids contents such as beer, wine, water and fruit juices, or biological streams such as from bioreactors containing polyclonal, monoclonal or other desired proteins or enzymes, according to attached claims 1 and 19.

10 Background of the Invention

Wines, beers, fruit juices, water and the protein containing streams from bioreactors and other such liquids need to be filtered to remove impurities such as sugar crystals from wine; or cell debris and other cellular components from the bioreactor stream, or yeast from
15 beer, or grape, other fruit skins and other debris found in raw and even partially purified liquids.

Traditionally, this has been done with loose diatomaceous earth that is added to the liquid and allowed to settle. More advanced technology has become the various lenticular or plate and frame products that are formed of a cellulosic fiber material and various fillers such
20 as diatomaceous earth and various charged polymers. These filters are normal flow devices, meaning that liquid is directed at them and the liquid flows through them to an outlet while impurities remain trapped in the pad(s). These filters are arranged in a housing which may contain one or more, generally several of these filters either in a frame in a plate and frame device or on a central rod that has a series of holes leading to the outlet within the rod in a
25 lenticular pad device. Liquid enters through an inlet generally at the bottom side of the housing and flows around and through the filter(s) to the openings in the rod and out the bottom of the housing through an outlet. The pad filters become easily clogged with impurities that limit their use in production runs. This often requires the use of two or more identical filter systems that are run sequentially during a filtration operation to ensure adequate capacity.

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More recently, users have begun to look at TFF (tangential flow filtration) devices for such filtration applications. The TFF systems utilize the tangential flow across the face of the

membrane to constantly sweep the membrane surface clean of materials that could block or plug the membrane leading to a decline in filter efficiency and life time. These devices can be made of flat or hollow fiber ceramic filters or flat, hollow fiber or spiral wound polymeric filters.

5 While helpful in increasing the life of the filter system, such TFF systems have drawbacks including cost both of the equipment and to run it as well as high hold-up volumes and potential injury/degradation to the liquid due to numerous recirculations through the pump(s) of the system.

10 TFF filter systems are more capital intensive than pad filters and require extensive specialized equipment including special filters, holders, pumps, retentate lines, etc. that are expensive to purchase. Additionally, the process using this type of filter is different and requires special training and dedicated capital equipment to do so. Moreover, the system uses 10 to 20 times the energy of a pad system for the pumping to create adequate recirculation of
15 the fluid to create and maintain the TFF flow. Likewise, due to the extensive plumbing used in such systems, there is a large holdup volume in the system after filtration is completed. The fluid that has not been filtered and is in the tank, retentate lines, pumps, etc. is discarded after the filtration process. Often this is measured in 10s of gallons of liquid that is lost and can amount up to 10% (depending of the hold up capacity of the system and the length and
20 number of repeat cycles of filtration) of the starting volume leading to lower overall yield of product. Lastly, many liquids are sensitive to shear and other similar forces imposed upon them in TFF devices and can degrade or injure the product especially wine.

 Ceramic filters work but have the additional disadvantage of being susceptible to
25 breakage under a variety of conditions which for the most part can't identified or quantified. An alternative to TFF ceramic filters is now a plastic or polymeric hollow fiber system with low or limited cross flow so as to reduce the number of cycles that the liquid is recirculated. While stating that the quality of the liquid is improved by reducing the recirculation, there are still the drawbacks of expense and large hold up volume. However and more importantly, the low
30 crossflow is accomplished by increasing the surface area of the membranes used, often by at least 2X that of a traditional TFF system, again increasing cost and holdup volume. Additionally, TFF polymeric membranes are relatively weak in strength and are susceptible to rupture if too

much pressure or shear is applied to them. Additionally, cleaning such filters is difficult, costly and time consuming making the cost of such filtration much more expensive

Besides, TFF is in general very difficult to apply to cold filtration such as may be used
5 with wine, beer, and fruit juice applications as higher viscosity of the liquid due to the lower temperature leads to lower flow rates and therefore bigger systems making them difficult to be economically viable. Another disadvantage in using polymeric TFF filters in cold wine or fruit juice applications which often include the filtration of crystals is that the polymeric membranes are not compatible with the "scratching" effect of the crystals of sugar in cold filtration causing
10 wear on the filters and the production of particles into the fluid.

US-A-2 423 172, US-A-3 155 613, US-A-4 973 404 and US-A-4 704 210 disclose common filter aid filtration processes with reconditioning the filter medium surface with filter aid material after regeneration by backflushing. The reconditioning is carried out by recirculation of
15 the filtrate to the fed side of the filter until the filtrate becomes clear. The backflushed filter cake material is emptied at the bottom of the filtering apparatus.

WO 2008/109928 A discloses a common filter aid filtration process wherein the fluid to be filtered is directed from a fluid inlet to barrier filters arranged between the fluid inlet and a
20 first fluid outlet, so as to promote a continuous erosion of the material built up on the barrier filters.

What is needed is a system for filtration of high solids systems that is simple to set up, run and is less expensive than the TFF systems to purchase and operate and which increase
25 yields with minimal filtration passes through the system to minimize degradation.

Summary of the Invention

The present invention relates to a system and a process of running the system that
30 allows for the long term filtration of product without loss of filtration capability due to clogging or fouling, in line with the attached claims. The system is a normal flow filtration system having one or more filter cartridges attached to an outlet of one or more housings in the system. The

filter cartridge(s) are contained within a bowl and depend preferably vertically from the outlet. Liquid enters the bowl of the housing and contacts the outer surfaces of the one or more cartridges. Impurities are trapped on or in the surface of the filter and the filtered liquid flows through the filter and through the outlet. One or more parameters such as flow rate,
5 transmembrane pressure drop and/or time are measured and when the desired parameter(s) are met, the filtration ceases. A backflushing occurs back through the filter cartridges so as to remove the trapped impurities on or in the filter surface. This backwashed material is directed to an outlet of the bowl that is connected to a drain. The system is then recirculated in a downstream manner to reestablish equilibrium and filtration is then restarted.

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Optionally, there may also be a lateral flushing of the outside of the cartridges through one or more ports formed in the sidewall of the bowl adjacent the outer surface(s) of the one or more cartridges. This may be done in lieu of but preferably in addition to the backflushing step and may occur either before or after the backflushing step but before the recirculation step.
15 Unfiltered liquid is directed against the outer surfaces of the cartridge(s) to dislodge any trapped impurities and to remove any impurities that may have settled in the bowl. The port(s) may be tangential to the vertical surface of the filter cartridge(s); preferably the port(s) are perpendicular to the outer vertical surface(s) of the cartridge(s).

20 Additionally, steps for the washing of the filter(s) with water and cleaning of the system can be conducted using the existing system design.

Moreover, a system with two or more housings may be used so that at least one is on line while the other(s) is being regenerated or cleaned.

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The system can be used in a process that is automatically operated (through a series of PIDs, a CPU, computer, computer network or other system that controls hardware and/or software).

30 The system also includes a process for the filtration of a liquid through one or more filter cartridge(s), backflushing of filter cartridge(s), optionally lateral flushing of the exterior of

the cartridge(s) through a port in the housing sidewall and a recirculation step. Optionally, water washing or CIP may also be accomplished in the present system.

In the Drawings

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Figure 1 shows a housing useful in a system according to the present invention in cross sectional view.

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Figure 2 shows a close up of a portion of the housing of Figure 1 according to the present invention in cross sectional view.

5 Figure 3 shows the flow path for filtration in a system according to the present invention in cross sectional view.

Figure 4 shows the flow path for backflushing in a system according to the present invention in cross sectional view.

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Figure 5 shows the flow path for recirculation in a system according to the present invention in cross sectional view.

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Figure 6 shows the flow path lateral flushing in a system according to the present invention in cross sectional view.

Figure 7 shows the flow path for water washing or cleaning in place (CIP) in the reverse direction in a system according to the present invention in cross sectional view.

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Figure 8 shows a system of the present invention using two such housings either in parallel or alternately.

Detailed Description

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By "port(s)" it is meant that one or more ports exist or can be used. By "filter cartridge(s)" it is meant that one or more cartridges can exist or be used.

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Figure 1 shows a filter housing 2 according to the present invention. It is formed of two major components, a head 4 and a bowl 6. The head contains an inlet 8 and an outlet 10. The bowl 6 has a drain 12 formed at or near its lowermost point 14.

The bowl 6 may have a frustoconical bottom 16 as shown or it may have a rounded, a tapered or even a flat bottom if desired. Preferably, it is a frustoconical, rounded or tapered shape. By having such a shape adjacent and/or at its lowermost point 14, the drain 12 can work more efficiently to remove debris and impurities from the housing 2 as will be described further in. Often these shapes allow for the concentration of the impurities so that minimal amounts of product are lost from the system when the impurities are removed from the housing.

As shown the one or more filter cartridges 18 are attached to the outlet 10 of the housing 2. The cartridge(s) 18 are arranged so that the cartridge(s) 18 hang vertically from the outlet 10 of the head 4 into the bowl 6. These cartridge(s) 18 are well known in design and have a closed end 19 which in this embodiment is farthest from the outlet 10 and an open outlet end 21 which is attached to the outlet 10 of the housing 2. The cartridge(s) 18 contain one or more layers of filter material which may be pleated porous plastic membrane, spun or wound fibers such as of plastic, glass and the like and/or non woven materials. If desired various support and protective layers such as an outer porous protective cage, an inner porous core and one or more layers of filter support materials such as porous non-woven scrims and the like.

Typical plastics for the filter material include but are not limited to polyolefins such as polyethylene and polypropylene, polyvinylidene fluoride (PVDF), polyvinyl alcohols, polyvinyl chlorides, polysulfones, polyarylsulfones, polyethersulfones, polyphenylsulfones, PTFE resins, PFA resins, polyesters, nylons, polyamides, polyimides, and celluloses and modified cellulosic materials such as cellulose acetate.

The pore size of the filter will vary depending upon the filter type chosen, the impurities to be filtered and the like. They may range from about 0.1 micron average pore size to 10 microns pore size. Typically, a 2.0, 1.0, 0.65, 0.45 or 0.22 micron pore size are used for membrane type filters depending on the application, the impurities to be removed, the amount of impurities present and the like. Preferably filter having a pore size between about 0.65 and 2.0 microns is used. Non-wovens and depth filters such as wound filters and the like are not

often rated by pore size but the extent that they are the same pore sizes as for membranes can be used.

The housing may also contain one or more additional port(s) 20 in the side of the housing 2 adjacent the filters 18 that is used in the cleaning process described further below. The port(s) are tangential to the substantially vertical surface of the filter cartridge(s) and may be at an angle Φ formed between the centerline (A-A) 23 of the cartridge(s) and the centerline (B-B) 25 of the port 20 as shown in Figure 2. Preferably the angle Φ is from about 15° to about 165°, more preferably from about 30° to about 150° or 45° to 135° and most preferably it is substantially perpendicular or about 90°. The port(s) 20 are in fluid communication with the source 26 of unfiltered fluid by a port conduit 21 which branches off of the conduit 28. This port conduit 21 is generally closed by a port valve (not shown) and only opened for a lateral flushing step explained below at Figure 6.

Figure 3 shows such a housing 2 and the system into which it is incorporated. A pump 22 is connected at its inlet 24 to a source of liquid 26 to be filtered. A conduit 28 connects the outlet 30 of the pump 22 to the inlet 8 of the housing 2. Liquid enters the bowl 6 and is drawn through the filter 18 and through the outlet 10. Drain 12 is connected to a waste line 32 and closed off from the waste line by a valve (not shown).

Optionally a first sensor 36 is located at the inlet 8 and a second sensor 38 is located at the outlet 10. The two sensors 36, 38 in combination can measure the transmembrane pressure in the one or more filter cartridges 18 or the flow rate of the system as will be described below. The sensors may be pressure sensors when determining transmembrane pressure differential or flow meters when determining flow rates. Any pressure sensor may be used, be it dial or analog or digital read out. The pressure sensor may be "dumb" requiring the operator to monitor the gauge or read out to determine if a desired parameter has been met (as will be explained below) or it may be intelligent and provide a signal to the system when the parameter is reached. Likewise any flow sensor may be used, such as a paddle wheel flow sensor that determines flow by counting the revolutions of the wheel or propeller in the sensor. It may be a dial or analog or digital read out. The sensor may be "dumb" requiring the operator

to monitor the gauge or read out to determine if the desired parameter (flow rate) has been met (as will be explained below) or it may be intelligent and provide a signal to the system when the parameter is reached.

5 Filtrate (liquid that has passed through the filter layer(s) of the cartridge(s) 18) exits the housing 2 through outlet 10 to conduit 40 and through valve 44 to a next step or storage tank 42. Also shown is valve 46 in conduit 48 that selectively allows filtrate to flow to backflushing tank 50 for storage and use as described below. Valve 46 is normally closed off allowing filtrate to flow through valve 44.

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 In operation, liquid to be clarified or filtered is supplied from the source 26 such as a vat, tank or bin to the pump inlet 24. The pump 22 moves the liquid through conduit 28 to the inlet 8 of the housing 2. The liquid enters the bowl 6 outside of the filter cartridge(s) 18 and passes through the filter layer(s) of the cartridge(s) 18 to the outlet 10 of the housing 2. Then
15 through conduit 40 and valve 44 to a downstream component such as a next step or storage tank 42.

 Impurities either are kept in the bowl 6 or become trapped in the filter layer(s) of the cartridge(s) 18. After a while the filtration rate will decline and/or the transmembrane pressure
20 differential will increase above the accepted parameter and the filter cartridge(s) 18 will need to be backflushed. When this backflushing is to occur can be determined by a variety of parameters, including but limited to time, transmembrane pressure and flow rates.

 As to the use of a time parameter, one can simply apply a timer to the controls for the
25 pump 22 and/or valves into and out of the housing 2 if any. At a predetermined schedule, the pump 22 is shut off and filtrate is pulled from tank 50 through pump 52 and conduit 54 and valve 56 which is opened and back through the filter(s) 18 to dislodge any impurities that are adjacent or embedded in the filter(s) 18. The impurities then settle out toward the lowermost portion 14 of the bowl 6. Valve 58 is also closed at this time. The backflushed liquid is then
30 preferably sent to drain so that all clogging material is removed from the system. This step and its flow path are shown in Figure 4.

The period of backflushing does not need to be long. It merely needs to provide a pulse of backflow and pressure sufficient to clean the filter cartridge(s) 18 to a degree sufficient to allow further filtration to proceed. In a preferred embodiment, the period of time for backflushing is from about 2 to 20 seconds, more preferably from about 5 to 10 seconds.

The pressure of the backflushing can be about the same as the filtration pressure differential (generally around 1 bar over the actual downstream pressure). If desired additional pressure may be applied to the backflushing operation.

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Then the pump 22 is turned back on and the remaining fluid from the backflushing step above in Figure 4 is moved through conduit 28 into the housing 2 and out through conduit 40 as in the filtration step of Figure 3. Valves 44 and 46 are closed and valve 60 is opened to allow the liquid to recirculate back to the inlet 24 of the pump 22. Optionally and preferably, new unfiltered liquid is also drawn into the system at the same time from source 26. This recirculation need only occur for a short period of time so that the liquid is reequilibrated and/or any filtration cake that is needed for filtration to occur is formed. Valve 60 is then closed and valve 44 is reopened and filtration resumes. Additionally, at some point during the filtration process, valve 46 is opened and valve 44 is closed to allow tank 50 to refill for the next flushing cycle.

The period of recirculation does not need to be long. It merely needs to provide a filtration cake if needed for filtration and/or equalize all the liquid within the system before filtration can begin again. In a preferred embodiment, the period of time for recirculation is from about 20 seconds to 60 seconds, more preferably from about 20 to 40 seconds and most preferably about 30 seconds.

The pressure of the recirculation should be about the same as the filtration pressure differential (generally around 1 bar over the actual downstream pressure). If desired additional pressure may be applied if desired (for example to generate a filtration cake).

Preferably, in one embodiment of the present invention where time is used as the parameter, one sets a schedule based upon the load of impurities in the stream, the filter cartridge(s) 18 selected and the volume of material to be filtered. Typically, it has been found
5 that a schedule set between every 10 to every 20 minutes is useful for most applications. For most the preferred time parameter is every 10 minutes. The same process of valve openings/closing and pump movements are used as described above to create the backflushing and recirculation steps.

10 The period of backflushing and the pressure used is the same as described above.

As to the use of a transmembrane pressure parameter, one can simply select a transmembrane pressure upper limit that corresponds to a certain level of clogging of the filters. One can use pressure sensors as sensors 36 and 38 to measure the upstream and
15 downstream pressures of the filter layer(s) and determine when the transmembrane pressure (the difference between the upstream or inlet pressure and the downstream or the outlet pressure) is too great. When that parameter is met or exceeded the same backflushing and recirculation steps occur.

20 Preferably, in one embodiment of the present invention where transmembrane pressure is used as the parameter, one sets a limit of from about 0.2 bar (20 KPa) to about 5.0 bar (500 KPa) depending upon the impurities in the stream, the filter(s) 18 selected and the volume of material to be filtered. Typically it is between about 0.2 bar (20 KPa) and 1 bar (100 KPa) difference (but again, the pressure differential chosen is dependant of the quality of
25 impurities, and therefore of the fluid to be filtered). For most applications, the preferred transmembrane pressure differential parameter is 0.2 bar (20 KPa).

As to the use of the flow rate parameter, one can simply select a sensor to measure flow rate such as flowmeter preferably on the downstream or outlet side of the system. A
30 reduced flow rate that equates to a certain level of clogging of the filter(s) is determined and when that reduced flow rate is reached the backflushing operation described above in relation to the transmembrane pressure differential or time system above is utilized.

Preferably, in one embodiment of the present invention where flow rate is used as the parameter, one sets a limit of from about 50% to about 80% of the initial flow rate depending upon the impurities in the stream, the filter cartridge(s) 18 selected and the volume of material to be filtered. Typically it has been found that a reduction in flow rate of between 20 and 40% from the initial flow rate is useful for most applications.

At some point in the process or as an alternative to the backflushing step (although the backflushing step of Figure 4 is preferred and this optional step is an additive step that may be used as desired either before or after the backflushing step), one may use a lateral flushing step by introducing liquid through port(s) 20 in the side of the housing 2 rather than through the inlet 8. Impurities are pushed off and out of the filter cartridge(s) 18 and then are discarded through the drain 12 in a manner described above. This optional step is shown in Figure 6. Fluid from source 26 flows into conduit 21 through one or more ports 20 and against the outer surface of the cartridges 18. From there, the fluid and any impurities removed from the cartridges are flowed out of the system to the drain 12.

The period of lateral flushing does not need to be long. It merely needs to provide a pulse of liquid at a pressure sufficient to clean the filter cartridge(s) 18 to a degree sufficient to allow further filtration to proceed. In a preferred embodiment, the period of time for lateral flushing is from about 2 to 20 seconds, more preferably from about 5 to 10 seconds.

Figure 7 shows a step for cleaning the system after use or flushing the system before use to remove any potential contaminants that may have entered the system during assembly. Water be it cold 70 or hot 72 or optionally steam instead of one or the other waters 70,72 is supplied by conduit 74 through tank 50 pump 52 and conduit 54 to conduit 40 and outlet 10 of the housing 2. Various valves such as 76 are closed to cause the water or steam to flow through the housing 2 and it can be returned to the tank 50 via conduit 80 for recirculation. After the desired time, the water or and/or steam is shut off and valve 78 is shut to close off the water return conduit 80 and the water/steam is drained through conduit 82 to a water/steam

drain. Optionally, the conduits used in this step may also be subjected to pressurized air to cause the water/steam to drain out more efficiently as is well known in the art.

Figure 8 shows a system having more than one or two or more housings 2A and B.
5 The operation of the system is similar to that explained in Figures 3-7 and would be obvious to one of ordinary skill in the art the only addition being a dedicated water/steam tank 100. This allows one to use one housing 2A while the other is being regenerated through the process described in Figures 4 and 5 and optionally 6 and/or 7. Alternatively, the two or more housing can be run in parallel at the same time if desired.

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Preferably the temperature of the process in any embodiment is kept at a range between about -6 °C and about 20°C (minus temperatures may be used for liquids that contain alcohol or salts that depress their freezing point or are formed of materials that have freezing points below 0°C). For many applications, such as wine filtration, fruit juice filtration, biological
15 filtration, the process takes place in chilled rooms and in chilled systems with temperatures ranging between about 4 °C and about 10 °C. In the case of filtration of wine for removing bitartrate crystals (cold stabilization of wines), the temperature of filtration is as a rule of thumb minus half of the alcohol content (otherwise the crystals would redissolve). This means for alcohol of 11% one would conduct the filtration at temperatures of about -4 °C or -5 °C

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The liquid can be prechilled before entering the system. The system may be insulated if desired but generally it is not needed as the time spent in the system is relatively low. Alternatively, the system may be run in a cooled or "cold" room to minimize any shift in temperature within the liquid while being processed. In some extraordinary situations, the
25 system can be affirmatively cooled by cold water circulation systems or chilling blankets as are well known in the art.

The filter is a normal flow polymeric filter such as a Polygard® CE filter available from Millipore Corporation of Billerica, Massachusetts which contain a glass fiber/diatomaceous
30 earth/polypropylene fiber blend of materials. However any normal flow filter that can withstand backflushing pressures on repeated cycles can be used in the present invention.

The system can be used in a process that may be manually operated (by a system operator manually operating the valves, pumps, etc) or automatically (through a series of PIDs, a CPU, computer, computer network or other system that controls hardware and/or software).

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EXAMPLE

A system according to that of Figure 8 which had a twin two 3 round 30" Polygard® CE filter cartridges (2- micron pore size) available from Millipore Corporation of Billerica, cartridges in parallel was used and incorporated a housing according to that of Figure 1 such
10 that the outlets of the cartridges were attached to the outlet of each housing via the housing round plate as is well known in the art so that liquid leaving the housing outlets first passed through the filter cartridges.

15 500 liters of unfiltered white wine with an alcohol content 12 % from a stainless steel tank was supplied to the inlet of the pump at a temperature of -2°C at an upstream pressure of 0.2 bar (20 KPa) as read by the upstream pressure monitor on the inlet to the housing. Filtrate passed through the outlet of the housing at a pressure of 0.2 bar (20 KPa).

20 Time was the parameter measured and this was done by a stop watch.

After 10 minutes, the pump was shut off manually and the backwashing step as taught in Figure 4 was run for 6 seconds at a pressure of 0.7 bar (70 KPa) as read on the pressure sensor of the outlet.

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The recirculation step as described in relation to Figure 5 was run at 0.7bar (70 KPa) measured at the upstream sensor on the inlet to the housing for 28 seconds to reequilibrate the systems and create the desired filter cake on the filter surface.

30 The above steps were run in sequence 6 times.

After 5 filtration and backflushing steps were completed a lateral washing step through the side port(s) of the housing was conducted for 6 seconds at a pressure of about 0.7 bar (70 KPa), followed by the recirculation step.

A control system formed of a standard TFF hollow fiber system (Ronfil hollow fiber system, sold by Domnick Hunter Ibérica) was run using the same wine and both systems had flow rates, turbidity of wine and clogging index (filterability index) measured.

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The Clogging Index is a filterability index is widely used in European wineries to gauge the filterability of a wine. Clogging index is the difference in time between how long it takes to filter from 200ml and 400 ml as compared to the time it takes to filter the first 200 ml on a continuous experiment at a given pressure and membrane.

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The method for calculating it is the following:

T_0 = initial time of 0 seconds.

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T_2 = time in seconds to filter the first 200 ml (from 0 ml to 200 ml) of wine through a 0.65 membrane at 2 Bar inlet pressure.

T_4 = time to filter the second 200 ml (from 200 ml to 400 ml) of wine through the same filter and at the same pressure.

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$$CI = (T_4 - T_2) - (T_2 - T_0) = T_4 - 2 \cdot (T_2)$$

Units are reported in seconds, but it is normally treated as an index with no units assigned.

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The wine filtered according to the control and the present invention had the following characteristics as set forth in Table 1:

Time(min)	Control Flow Rate (l/h)	Control Turbidity(NTU)	Control Clogging Index	Invention Flow Rate (l/h)	Invention Turbidity (NTU)	Invention Clogging Index
10	1200	<1	10	600	<1	11
20	900	<1	12	600	<1	14
30	650	<1	8	600	<1	12
40	450	<1	11	600	<1	14
50	150	<1	10	600	<1	13

The holdup and lost volume for backflushing and lateral backflushing for the present invention was 5 liters or 1% of the starting volume and the filtration occurred in 50 minutes.

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The holdup and lost volume for the control was 35 liters or 7% of the starting volume and the filtration required 66 minutes to complete.

As can be seen for the example the present invention significantly reduced the volume lost to hold up volume of the system and completed the filtration quicker and maintained a high, consistent flow rate through out the entire test.

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While the above example was with wine, this system can be used equally well with other liquids which need clarification such as beer, water, fruit juices, energy drinks that contain impurities such as fruit pulp or skin, solid impurities, clarification aids such as egg albumin or diatomaceous earth and the like. Likewise it is suitable for use with biological streams such as the output from a bioreactor which contains a protein of desire, such as a monoclonal antibody, along with other impurities including but not limited to clarification aids such as diatomaceous earth or flocculants, cell debris, host proteins and other undesirable cell elements and the like.

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CLAIMS

- 1) A method of normal flow filtration comprising
- 5 a. providing a source (26) of liquid to be filtered, a first conduit (28) connecting the source (26) to an inlet (8) of a filtration device, the filtration device comprising one or more housings (2) containing one or more filter cartridges (18), the one or more filter cartridges (18) being in fluid communication with a housing outlet (10) which is in fluid communication with a second conduit (40)
- 10 leading to a downstream component (42), the downstream component (42) being selectively closable by a normally open first valve (44), a selectively closable backflushing loop for the filtrate from tank (50) via a third conduit (54) back to the housing outlet (10) wherein the backflushing loop is normally closed off from the outlet (10) by a second valve (56), the inlet (8) and the
- 15 outlet (10) being located at an uppermost portion of the housing (2) and a drain (12) being located at a lowermost portion of the housing (2);
- b. supplying the liquid to be filtered through the first conduit (28) and into the inlet (8) of the housing (2);
- c. passing the liquid through the one or more filter cartridges (18) and into the
- 20 outlet (10) and into the second conduit (40) and past the first valve (44) to the downstream component (42);
- d. selecting a parameter selected from the group consisting of time, transmembrane pressure differential and flow rate reduction; and
- e. monitoring the selected parameter to determine when the parameter is
- 25 reached or exceeded;
- f. upon reaching or exceeding the selected parameter, closing the first valve (44), opening the drain (12) and opening the second valve (56) to direct filtrate from tank (50) via the third conduit (54) back through the outlet (10) and the one or more filter cartridges (18) into the housing (2) and out the drain
- 30 (12) for a period of time sufficient to backflush the filter cartridges (18);
- g. closing the second valve (56) and drain (12) and opening a third valve (60) and fourth conduit (62) between the first valve (44) and the first conduit (28)

- for a desired period of time to recirculate the liquid remaining from step f. by pump (22), and
- h. closing third valve (60) and fourth conduit (62) and reopening the first valve (44) and reinitiating the supply of the liquid from the inlet (8) to the one or more filter cartridges (18) to reinitiate the filtration process.
- 5
- 2) The method of claim 1 further comprising step (i) wherein steps (b)-(h) are repeated at least one time.
- 3) The method of claim 1 further comprising step (i) wherein steps (b)-(h) are repeated N times wherein N is an integer from 1 to 100.
- 10 4) The method of claim 1 further comprising a first sensor (36) at the inlet (8) of the housing (2) and a second sensor (38) at the outlet (10) of the housing (2) for monitoring the selected parameters.
- 5) The method of claim 4 wherein the first and second sensors (36, 38) are pressure sensors for monitoring the transmembrane pressure differential parameter.
- 15 6) The method of claim 4 wherein the first and second sensors (36, 38) are flow rate sensors for monitoring the flow rate reduction parameter.
- 7) The method of claim 5 wherein the first and second pressure sensors are selected from analog and digital pressure gauges.
- 8) The method of claim 1 wherein the selected parameter is time and is measured by a timer.
- 20 9) The method of claim 1 wherein the valves are selected from the group consisting of manual valves, solenoid valves, hydraulically actuated and air actuated valves.
- 10) The method of claim 1 wherein the liquid is supplied cold.
- 11) The method of claim 1 wherein the liquid is supplied at a temperature of from between -4°C to 20°C.
- 25 12) The method of claim 1 wherein the filtration step (c) is from 10 to 20 minutes.
- 13) The method of claim 1 wherein the backflushing step (f) is from 2- 20 seconds.
- 14) The method of claim 1 wherein the recirculation step (g) is from 20 to 60 seconds in length.
- 30 15) The method of claim 1 further comprising a lateral flushing step (j) either before or after the backflushing step (f) by providing one or more ports (20) formed in the side of the housing (2) adjacent the one or more filter cartridges (18), the one or more ports

(20) being connected to a side of the housing (2) adjacent the one or more filter cartridges (18), the port(s) (20) being connected to the first conduit (28) by a port conduit (21) controlled by a port valve (23), for cleaning the filter cartridge(s) (18) to a degree sufficient to allow further filtration to proceed and the step (j) is from 2 seconds to 20 seconds.

5 16) The method of claim 1 wherein the one or more port(s) (20) are tangential to an outer vertical surface of the filter cartridge(s) (18).

17) The method of claim 1 wherein the one or more port(s) (20) are tangential to an outer vertical surface of the filter cartridge(s) (18) at an angle Φ formed between a vertical centerline of the cartridge(s) (18) and a centerline of the port(s) (20).

10 18) The method of claim 1 wherein the one or more port(s) (20) are tangential to an outer vertical surface of the filter cartridge(s) (18) at an angle Φ formed between a vertical centerline of the cartridge(s) (18) and a centerline of the port(s) (20) and the angle Φ is from 15° to 165°, more preferably from 30° to 150° or 45° to 135° and most preferably it is 90°.

15 19) A normal flow filtration system for the method of claim 1 comprising a source (26) of liquid to be filtered, a first conduit (28) connecting the source (26) to an inlet (8) of a filtration device, the filtration device comprising one or more housings (2) containing one or more filter cartridges (18), the one or more filter cartridges (18) being in fluid communication with a housing outlet (10) which is in fluid communication with a second conduit (40) leading to a downstream component (42), the downstream component (42) being selectively closable by a normally open first valve (44), a selectively closable backflushing loop for the filtrate from tank (50) via a third conduit (54) back to the housing outlet (10) wherein the backflushing loop is normally closed off from the outlet (10) by a second valve (56), the inlet (8) and the outlet (10) being located at an uppermost portion of the housing (2) and a drain (12) being located at a lowermost portion of the housing (2), a selectively closable recirculation loop comprising a third valve (60) and a fourth conduit (62) between the first valve (44) and the first conduit (28) to recirculate the liquid remaining from the backflushing loop by pump (22), and a system that controls hardware and/or software to carry out the method of claim 1.

- 20) A system according to claim 19 further comprising one or more ports (20) formed in the side of the housing (2) adjacent the one or more filter cartridges (18), the one or more ports (20) being connected to a side of the housing (2) adjacent the one or more filter cartridges (18), the port(s) (20) being connected to the first conduit (28) by a port conduit (21) controlled by a port valve (23) for cleaning the filter cartridge(s) (18) to a degree sufficient to allow further filtration to proceed.
- 5