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MELISSA

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Biomass Harvester

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Draft	0	30/01/98	Preliminary Version
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I. INTRODUCTION

The general concept of MELISSA includes the use of the biomass generated in the two photosynthetic reactors, *Spirulina* in compartment IV and *Rhodospirilum* in compartment II, as food supply. Previous studies have shown that both microorganisms can be used as supplement of the food diet in rats. On the other hand, cell concentration in the output of these bioreactors is low, in the order of 0.5-3 g/l, and any further use of them would require to increase substantially this concentration. This is the main objective of the module that has been denominated as Biomass Harvester : the harvesting of the cells produced in the photobioreactors for its further use, with an increase of cell density in the output of this equipment. In consequence, it is important to define from the beginning of this task what is the final target regarding cell concentration, or, in other words, what percentage of the water present in the liquid output of the bioreactor should be eliminated. The suggested range in the workpackage was from 75 to 90 % water volume reduction or recovery. It is clear that if the final use of the cell as food additive requires a lower percentage of water (for example, they are required completely dried, or freeze-dried), then an additional step will need to be incorporated for the elaboration of the final product. However, this final step is not addressed in this proposal, because it can not be anticipated at the present moment, and it is not considered an objective for the biomass harvester as such.

The definition of the biomass harvester unit has been proposed in two parts. In the first part, a review and trade-off of the different hardware available for this purpose have been carried out. This part considers that the operation can be conducted in two consecutive steps. In a first step a significant recovery of the water content in working conditions not too drastic for the equipment (for example regarding clogging, pressure drops, etc.) In the second step an ultimate reduction of the biomass remaining in the clarified liquid obtained, should simultaneously assure a good recovery for the liquid phase and its possible reuse.

Another point that has been considered in the equipment selection is what operation mode is expected : batch or continuous mode. This point should be addressed regarding the normal output flow-rates that can be anticipated in the reactors operation (0.5-3.0 l/h for compartment IV will be the highest values), and checking this values with the commercially available continuous operating units and its efficiency. As a concept, continuous operation is desirable, and in consequence the equipment has been selected to assure that it is technically feasible for this particular case. As a result of this trade-off, some concepts were selected and tested for evaluation in the second part of this workpackage. Efficiency in terms of water and solids recovery were evaluated as well as operational problems for different feed flow rates and cell concentrations.

II. PART I

TRADE-OFF AMONG THE DIFFERENT HARVESTING EQUIPMENT

II.1. PRELIMINARY CONSIDERATIONS

The traditional methods of separating cells from culture broth have been conventional sedimentation, centrifugation and filtration. If cells are highly hydrated have a low specific gravity and tend to be rather glutinous in character. Thus, methods of solid/liquid separation based on sedimentation are generally problematic and inefficient.

Normally, processing solids until a very low percentage of humidity involves several solid-liquid separation steps plus thermal or freeze drying of the end products. Rotary vacuum-drum filters or dryers and washing-dewatering centrifuges are often used as dewatering equipment. A dryer with a given size, however, can evaporate only a certain amount of water at a given retention time. In order to increase the dryer throughput without sacrificing end-product dryness, centrifuges have traditionally been used to reduce the moisture level in the feed.

A centrifuge with a given separation force achieves a certain hydrostatic pressure based on the cake layer's thickness. The hydrostatic pressure increases as the cake layer thickens, which adversely affects the permeability of the cake. Therefore, achieving the lowest possible cake moisture content in a centrifuge is always a compromise between maximising hydrostatic forces and minimising cake thickness.

An alternative method is the use of cross-flow or tangential filtration on membranes for the separation of cells and/or product from the culture broth. The suspension of cells is fed continuously, under pressure, through a filtration module. If batch operation is desired, the retentate is recirculated through the module, and the permeate (filtrate) is continuously removed. In principle, as both cells and permeate are continually removed from within the module, there is no accumulation of either within the filtration system, but having a substantial increase in concentration of solids in the retentate stream. Sludges containing 50-60% (wet weight/volume) suspended solids can be achieved.

For cell concentration, the user has a choice of microfiltration (MF) or ultrafiltration (UF) membranes. The former allows retention of cells and colloids with passage of macromolecules into the permeate stream. The latter permits concentration of macromolecules with the cells while allowing passage of smaller molecules into the filtration stream.

In general, both techniques (MF and UF) have had basic problems for their application to the harvesting of large volumes of cells, like the relatively delicate nature of the membranes, low fluxes, and decreasing of flux with operation time due to phenomena such as concentration polarisation and fouling of the membranes. Recent developments in polymer chemistry and module construction have spawned a generation of both MF and UF membranes of high chemical and physical stability combined with high fluxes. The application of cross-flow filtration or tangential flow filtration instead of classical Y-flow can overcome some of the problems inherent in the concentration of cells in culture broth.

As a result of these advantages, one can predict the eventual replacement of centrifuges and continuous dead-end filters (e.g., rotary vacuum) for cell harvesting by cross-flow or tangential-flow filters. Most of these applications appear to be proprietary and specific for every case, since there is little if any documentation in the literature ; thus the application of the technique and design of an adequate system must still depend on membrane manufacturers' usually sketchy data and user trials. The diversity of membrane types and configurations can and does make the rigorous testing and evaluation of systems a time-consuming, laborious task but necessary.

II.2. EQUIPMENT SELECTION

In order to make the equipment selection one can use some practical guidelines to carry out optimal solutions to the solid-liquid separation problems. Some of these guidelines can be found in the open literature (Ernst et al., 1991, Hanisch, 1986, Belter et al.,1988), which include different schemes and several of them use a series of questions aimed at avoiding unappropriate equipment. The factors that must be taken into account are related to the solid or slurry itself and the process, including others like capital and operating cost as well as equipment size and volume.

In reference to the solid the parameters that are important to make a decision are the sedimentation velocity, solids concentration, liquid vapour pressure, flow rate and environmental hazard. If the sedimentation velocity is low and the solids concentration are moderate, as in the present case (<0.02 cm/s and (0.1-4. %) respectively), the methods based on gravity sedimentation are discarded. If the solids concentration achievable are not low membrane process can present some operational problems like premature fouling and polarisation concentration. Due to the low liquid vapour pressure, a method based on vacuum like vacuum filters is not feasible. When the flow rate are low the requirements of automation decrease being more suitable a discontinuous procedure.

To properly define the process is necessary to clearly state the objective of the separation. Clarification of the liquid is the objective when the purest possible liquid is desired. This eliminates equipment that does not generally produce clean liquid (sedimentation). This objective also assumes a low to medium solids concentration. With

high solids concentration slurries and medium to high volumes, two devices should be considered, one to remove the bulk of the solids, the other to clarify the liquid.

In the system under study, because of the nature of solids recovery that it is wanted, the addition of flocculants, coagulants or any chemical to enhance separation is not possible to prevent chemical contamination. In this sense, membrane processes are the best trial, as considered as clean technologies.

Finally the choice of continuous or batch device usually depends on the nature of the upstream and downstream process. If the upstream and downstream process is continuous, a continuous separation device reduces the hold-up and storage of slurry and solids to keep those processes going. On the other hand, a batch unit upstream can feed a batch separation with little or no immediate hold-up. In addition, certain devices, such as those using precoat filter aids, are highly inconvenienced by unplanned shutdowns like those caused by power outages.

In the MELISSA loop the processes are mainly in continuous mode. Thus, the equipment selected have to be capable to operate in continuous mode, but due to specific characteristics or requirements of the separation, batch mode should be considered as well at least as a concept in a qualitative way. These specific characteristics or requirements are for instance : contamination prevention, flow-rate variations, low process dynamics, the possibility of consider the implementation of surge or holding tanks to dampen oscillations, etc. In general, when the performance of a separation system in continuous mode has been checked, the operation in discontinuous or semi-continuous mode are not very problematic, but considering transient phenomena involved.

Taking into account all these considerations and restrictions, the equipment selected to be tested are : Membrane processes and centrifuge systems.

Among all the different possibilities of membranes to be used, the selection has been made in such a way that problems related to membrane fouling and concentration polarisation are minimised. First, a **tangential microfiltration** has been proposed, and second, a **cross-flow microfiltration** by means of a **spiral filter**.

The centrifuge to be tested is a **disk stack centrifuge** that has been shown as a good alternative because does not have drastic restrictions to be used in the system under study, as would occur with sedimentation systems, standard filters, etc. Moreover, it is an equipment that permits to handle large amounts of volumes and flow-rates with a high recovery of liquid and relatively high cell concentration.

In Table 1 several treatment options are listed covering briefly their advantages and disadvantages. The techniques are ordered from those more suitable for processing liquids with low concentration of solids to liquid sludges. The final form of the solid obtained is also indicated.

Technique	Technical description and advantages	Disadvantages	Final form
Microfiltration	• membrane process for particles between 0.1 μ m - 1.0 μ m	• prone to membrane fouling /degradation • concentration polarisation	Sludge
Evaporation	• heating to concentrate solids • useful if solids can be recovered	• high capital and energy costs • Concentration of salts within the solid	Wet solids
Flotation	• air bubbles dispersed into agitated suspension with hydrophobic particles collected at surface	• may require wetting, frothing and deflotation agents	Sludge
Filtration	• simple to operate • can have low capital and running costs • wide range of vacuum, rotary, pressure and belt devices	• filter media may "blind" • precoat may be need • high energy costs for vacuum systems • back washing may add to costs	Filter cake
Centrifuges	• continuous conical bowl • enclosed • high throughput • high concentration • not prone to clogging • polymer dosing may allow up to 45 % solids	• high energy maintenance costs • noisy • may require prior screening and de-gritting	Sludge cake and concentrate may need further treatment
Sedimentation	• simple gravity settling of treated sludges prior to final conditioning	• high capital cost and space • labour intensive • sensitive to distribution and flow patterns	Thickened sludges and supernatant
Hydro-cyclones	• centrifugal separators • simple • good for coarser sludges	• need careful design • need consistent flow rate	Sludge and concentrate may need further treatment
Dryers	• thermal separation of liquids from solids • large choice of equipment • significant volume reduction	• high energy costs if cheap waste fuel is not used • risk of air pollution in convective drying systems	Dry solids

Table 1. Treatment options with their advantages and disadvantages

II.3. DESCRIPTION OF THE EQUIPMENT SELECTED

II .3.1. Spiral Filter.

The spiral filter module supplied by *Bioengineering AG* is suitable to be used for micro-and ultrafiltrations. The secondary flow pattern, induced by the spiral plate, results in a higher efficiency of the filtration performance. Any filter material sterilisable and suitable for the process can be used. Technical data of the cross-flow membrane module are presented as follows.

Technical data

Membrane surface (gross)	147 cm^2
Membrane surface net (useful)	105.7 cm^2
Channel length (1 plate)	1.7 m
Volume spiral channel	35.7 ml
Membrane pore size	0.45 µm (Millipore MF- HAWP 142 50)
Filter diameter	142 mm

Cross-flow over the filtration surface continually resuspends cells that are deposited on the membrane during the course of the filtration. This is directly analogous to the tangential flow removal of the soluble gel layer polarised on UF membranes. The limitation to throughput (flux) is the accumulation of solutes or particles at the membrane surface. This concentration polarisation is a consequence of the stagnant boundary layer adjacent to the membrane. Obviously, good fluid management techniques designed to minimise the boundary layer, such as the presented in the spiral filter module, will result in greater fluxes and more efficient operation.

When a relatively high final concentration of cells is wanted the recommended operation is in batch mode with retentate recirculation to the feed tank. However, this kind of operation becomes in a lower permeate flux than the continuous operation that follows a simple scheme, that is to say, simple feed input and double product output for the permeate and retentate respectively. The reason for this lower permeate flux is due to the application of low permeate/retentate flux ratios in the batch mode in order to try to reduce fouling and concentration polarisation while increasing the cell density vs. time.

In any case, all the membrane systems are expected to be problematic when moderate or high cell density is wanted to be processed because of early cell accumulation in the membrane system.

Taking into account all these considerations the operation proposed to be tested is to use a simple scheme to perform the harvesting in continuous mode. In this way, the expected permeate flux should not be very low and so, the recovery of liquid medium in terms of system productivity satisfactory.

II .3.2. *Minitan*^{TM} Tangential Filtration.

The general aim of this kind of filtration system is similar than for the spiral filter, that is to say, to minimise fouling and concentration polarisation, in order to maintain good properties in respect to permeate flux and separation efficiency.

The *Minitan*^{TM} filtration system from *Millipore* is an equipment that allows tangential flux over ultrafiltration and microfiltration membranes. The exclusive design of the filtration plates produces a retentate flux that keeps an effect of "cleaning" over the membrane surface. With the aid of a peristaltic pump the feed to be processed (liquid/solid) is pumped from a non-pressurised ' vessel (or system). As stated in the Spiral filter section, if a high concentration of cells is wanted a normal way of operation is to recirculate retentate stream to the feeding system (vessel), but obviously producing a low rate of liquid recovery.

With this harvesting system the operation mode to be tested, as well as for the spiral filter, will be the continuous scheme to achieve a reasonable recovery of the liquid medium in terms of permeate flux. Technical data is presented as follows

Technical data

Membrane surface net	60 cm^2/plate
Number of plates	4
Dead volume spiral channel	<50 ml
Membrane pore size	0.45 μm (Millipore HVLP OMP 04 - Durapore)

II .3.3. Disc Stack Centrifuge.

The solid concentrate produced by centrifugation differs from the produced by standard Y-flow filtration (Simple input-simple output/discontinuous mode). At best centrifugation produces a paste ; often it yields only a more concentrated suspension. Filtration produces a relatively dry cake, which is a major advantage. However, many biological feeds which can be centrifuged cannot be effectively filtered, so that centrifugation is often an attractive alternative.

The centrifuge selected is from *Westfalia Separator AG* and the type is a CSA 1-06-475. The system is steam sterilisable with flowing steam at a maximum pressure of 1.5 bar. Technical data is presented as follows

Technical data

Solids discharge time	0 s - 10000 s
Rotation speed	0 rpm - 10000 rpm
Feed flow	0 l/h - 50 l/h

These kind of centrifuges are probably the most common type for bioseparations. The stacked conical discs allow a large sedimentation area to be contained in a relatively compact volume. Feed usually enters at the top and clarified liquid flows out an annular slit near the feed. Solids are either removed intermittently or continuously, out of orifices on the side of the centrifuge.

The solids discharge frequency, feed flow and rotation velocity have to be fixed in such a conditions to have a good compromise between flow treatment capacity and separation efficiency. In this way, the selection of the operation conditions has to be experimentally made according to the feed cell concentration, percentage of separation desired, particle size, viscosity, etc.

Intermittent solids ejection is the alternative to the continuous nozzle discharge. The nozzles are replaced by a number of large peripheral ports or by a continuous slot around the bowl, which are closed and opened by an externally controlled, hydraulic circuit. The solids ejecting type tends to be used with medium solids concentrations when neither continuous discharge nor batch operation would be as effective.

It is also useful for solids which might break or de-aggregate under the shear forces of nozzle discharge. Applications of this type of centrifuge include the clarification of various juices and food extracts, and the purification of marine fuels and similar liquids.

III. PART II

CHARACTERISATION OF THE SELECTED EQUIPMENT

As discussed in the equipment description section a simple scheme in continuous operation has been tested. The harvesting equipment was installed as depicted in figure 1, where the nomenclature for process variables and streams is indicated.

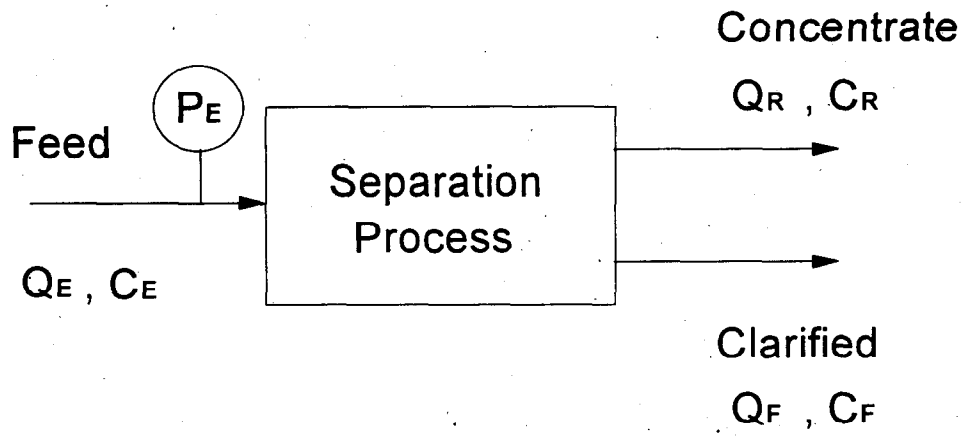

Figure 1. Flow-chart of the simple harvesting systems

During the harvesting tests the inlet pressure (P_E), the feed biomass (C_E), concentrated (C_R), and clarified stream concentrations (C_F) were measured, as well as the volumetric feed flow rate (Q_E), concentrated or retentate flow rate (Q_R) and clarified or filtrate flow rate (Q_F).

Three key parameters were estimated in order to evaluate performance of the separation process. They were water yield for the clarified stream (R_{H2O}), solids yield for the concentrated stream (R_{sol}) and rejection coefficient (R). R_{H2O} and R_{sol} attempts to the recovery of the liquid phase by the clarified flow and solid phase by the concentrated flow respectively, and R is related to the separation efficiency for the solid between feed and clarified.

- **Water yield :**

$R_{H2O} = P_F\ (1 - X_F) / P_E\ (1 - X_E)$ where X_F and X_E are the mass fraction of solids at the clarified and at the inlet section respectively. P_F and P_E are the mass flow rates of clarified and feed. It can be used an approximate relation as follows :

$$\mathbf{R_{H2O}\ (\%) = (Q_F / Q_E) * 100}$$

- **Solids yield :**

If there is no accumulation of solids in the separator, an overall mass balance can apply and the solids yield can therefore be determined from any two of the three material streams involved (Svarovsky, 1985).

$R_{sol} = (Q_E C_E - Q_F C_F) / Q_E C_E = 1 - (Q_F C_F / Q_E C_E)$ $\mathbf{R_{sol} = 1 - (Q_F C_F / Q_E C_E)}$

- **Rejection coefficient :**

$R = (C_E - C_F)/C_E = 1 - C_F/C_E$ $\mathbf{R = 1 - C_F/C_E}$

III.1. SPIRAL FILTER.

The harvesting equipment was installed as depicted in figure 1. Due to the fact that for this type of separation the cell concentration to be tested is relatively high (0.5 - 3.0 g/l) a simple configuration was performed to prevent fouling, concentration polarisation and low permeate flux rates. Hence, recirculation was not used in order to not increase the cell content in the feed and trying to work with a flow-rate as high as possible but not exceeding an inlet pressure of 1.5 Kg/cm^2.The spiral filter from *Bioengineering* was used with both cellulose filters (not defined pore size) and with microfiltration membranes of 0.45 μm (*Millipore* HAWP 142 50). The approximate volume treated was about 1.5 L of culture broth of *Spirulina Platensis* at different cell concentrations ranging from 0.5 to 2.5 g/l of dry weight. The system is not operating at standard conditions of flux until approximately 10 min. This is the reason why data are normally not shown until pseudo-stable values are reached.

During the first experiments carried out with cellulose filters, P_E increased slightly until a moderate value during the experiment, reaching a reasonable separation efficiency but decreasing significantly the filtrate/retentate ratio during the experiments and producing low water yields (R_{H20}). This effect is more important when the cell concentration is higher (2.2 g/l vs. 1.3 g/l) being at the end of the process around 20% of water yield. These range values are similar to the obtained for a tangential or cross-flow microfiltration with cell recirculation in batch mode. To explain the behaviour of the retentate concentration C_R there are at least two phenomena that must be pointed out. First, as a result of the accumulation of biomass in the membrane the mass balance for the biomass is not accomplished, and second, due to the increase of the retentate/filtrate ratio a wash-out phenomena is observed. The combination of these two effects results in a C_R increase. At the first stage the accumulation of biomass is predominant and as microfiltration proceeds the wash-out phenomenon becomes more and more important. Experimental results are shown in figure 2 and 3.

When microfiltration membranes (0.45 μm) were used pressure increased to 0.6 bars after 15 minutes as can be seen in figure 4. At the same time membranes became clogged and Q_F decrease until a very low value. After 35 minutes of operation, membranes became totally obstructed not allowing to continue the harvesting process.

As a conclusion, either the membranes clogged rapidly or the water yield was not satisfactory which invalidates the use of this device to operate in continuous microfiltration of *Spirulina platensis* cultures.

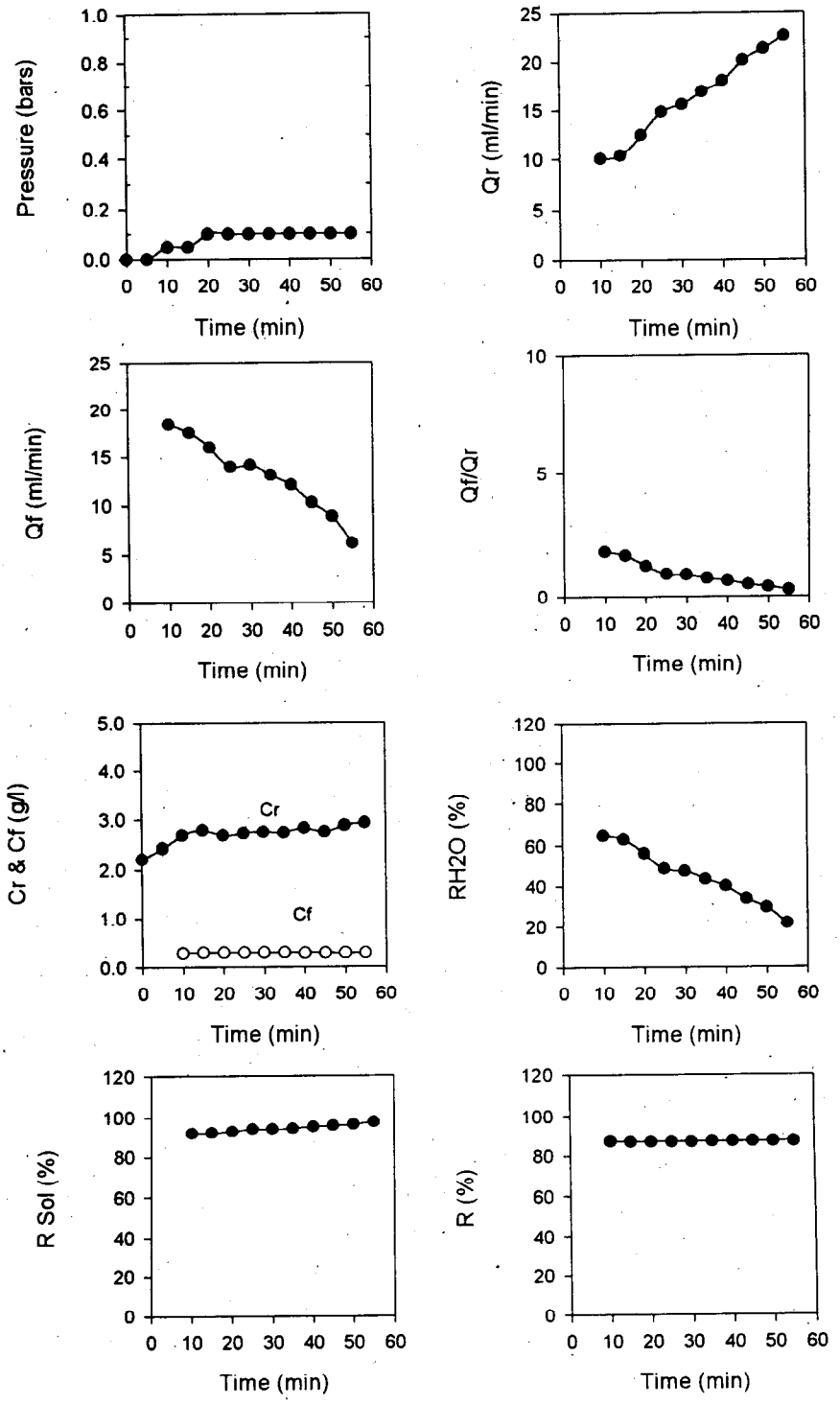

Figure 2. Spiral filter tests using cellulose filters. Cell concentration = 2.2 g/l

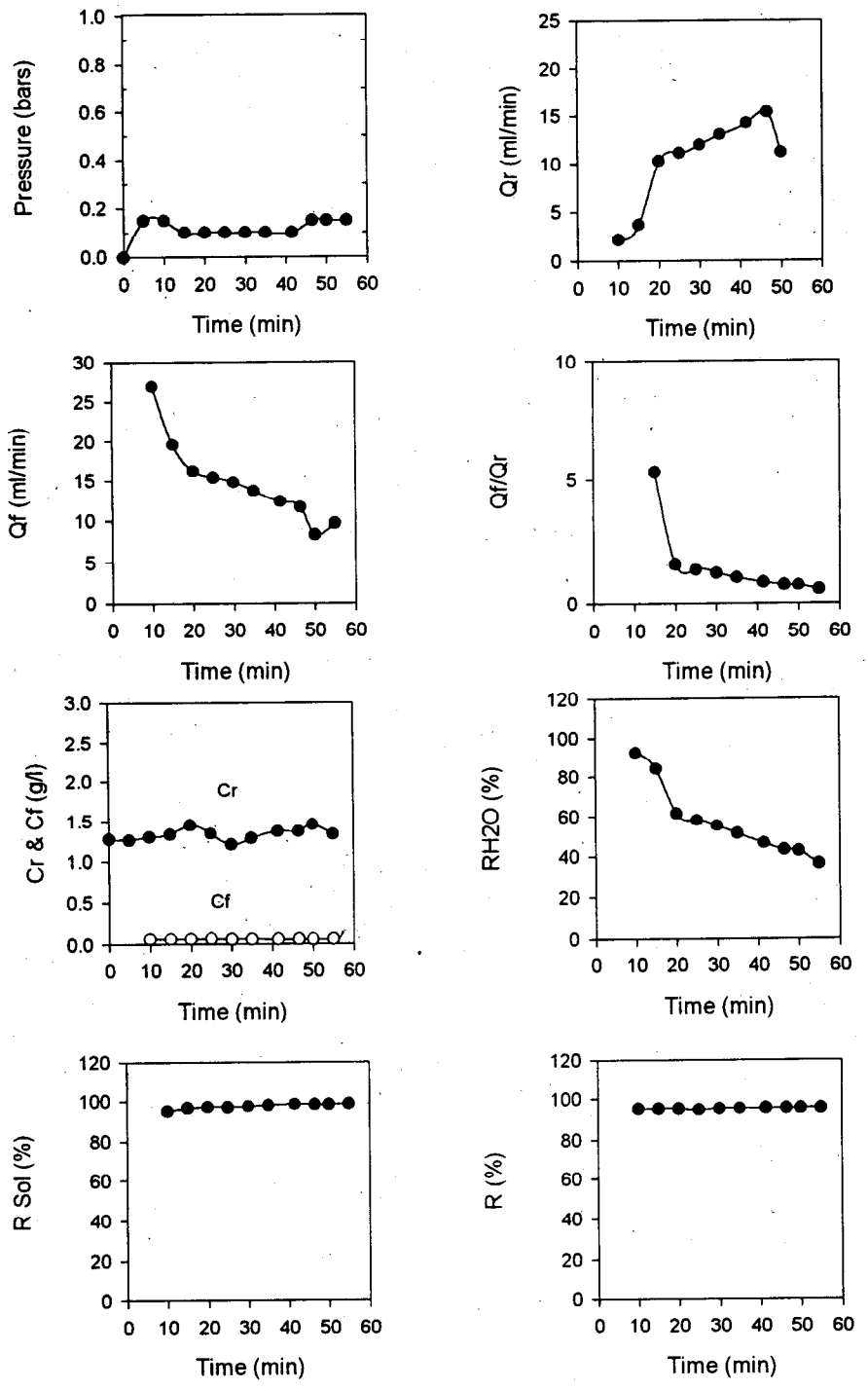

Figure 3. Spiral filter tests using cellulose filters. Cell concentration = 1.3 g/l

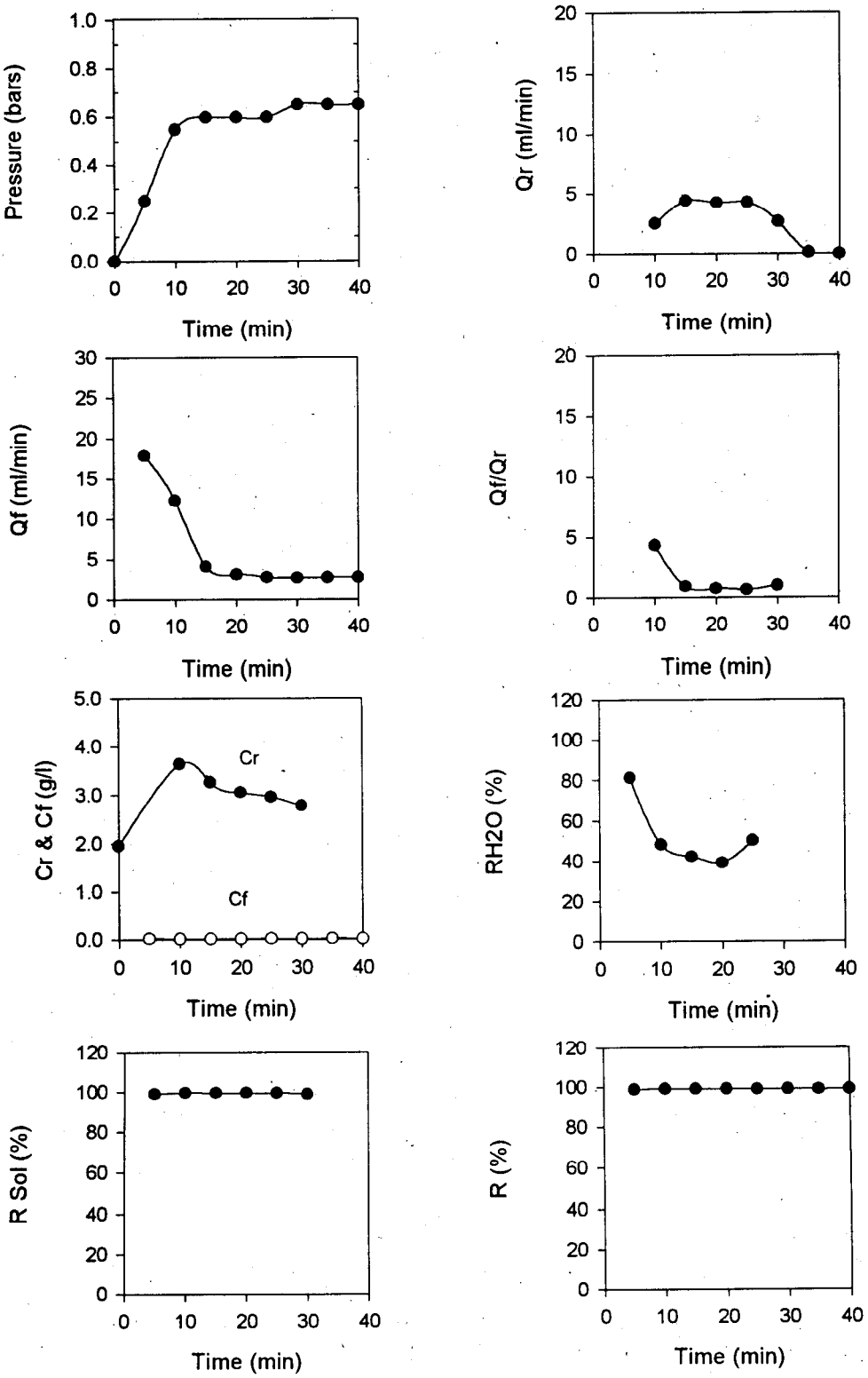

Figure 4. Spiral filter tests using 0.45 μm filters. Cell concentration = 1.95 g/l

III. 2. TANGENTIAL FILTRATION.

In order to conduct *Minitan*^{TM} tangential microfiltration four microfiltration plates with a pore size of 0.45 μm (*Millipore* HVLPOMP 04) were used. The filtration area obtained was 240 cm^2. Microfiltration was performed at constant pump speed allowing variations of pressure inlet. As a consequence variations of feed flow rate, Q_R and Q_F were observed. Three microfiltration tests were conducted for three different initial *Spirulina* cell concentrations, that is 1.0 g/l, 1.6 g/l and 3.6 g/l dry weight and an approximate treated volume of 1.5 L.

The results obtained for the three experiments are very similar as can be seen in figures 5, 6 and 7. The system is not operating in standard conditions of flux until approximately 10 min. This is the reason why data are normally not shown until pseudo-stable values are reached. P_E increased and reached a constant value of about 1 bar after 30 minutes of operation. As P_E increased, Q_R increased and Q_F decreased. One effect of increasing the Q_R and also the (Q_R/Q_F) is observed in the evolution of the retentate concentration C_R. This concentration C_R diminishes during the experiment, because the liquid of the feed is not being recovered satisfactorily. The filtrate concentration C_F does not vary significantly, because its values are governed for the rejection coefficient that is characteristic for the membrane and the solute in a fixed operating conditions. The experimental value of the rejection coefficient that represents the separation efficiency for the solid is also kept rather constant during all the tests.

On the other hand a reduction of R_{H2O} is produced as a function of time operation. After 40 minutes, this value was lower than 40 % for the lowest feed cell concentration and about 20% for the another higher cell concentration. Thus, filtration efficiency was strongly reduced in terms of liquid recovery. The estimated recuperation of solids by the retentate stream is rather total due to the low values of the filtrate concentration. However, if the recuperation of solids is calculated directly from the retentate concentration the problem of accumulation of biomass inside the membranes is clearly shown because of the mass balances are not accomplished until approximately 30 minutes of operation.

To summarise, the main problem of this membrane system is that due to the relatively high cell density of the feed to be processed a concentration polarisation phenomenon, fouling and finally clogging of the system appears. To avoid these phenomena an alternative might be the use of membranes with a higher pore size or make a pretreatment of *Spirulina* biomass before using *Minitan*^{TM} filter. Anyway, these two alternatives could not be totally satisfactory.

First, when using membranes with a higher pore size should produce an important flux of biomass (due to biomass size distribution and biomass fragments) through the membrane and as a consequence a decrease in separation efficiency and quality of the liquid recovered. Second, a pretreatment like coagulation or flocculation, is not indicated because it would change strongly the characteristics of the biomass to be used for food applications in the MELISSA loop.

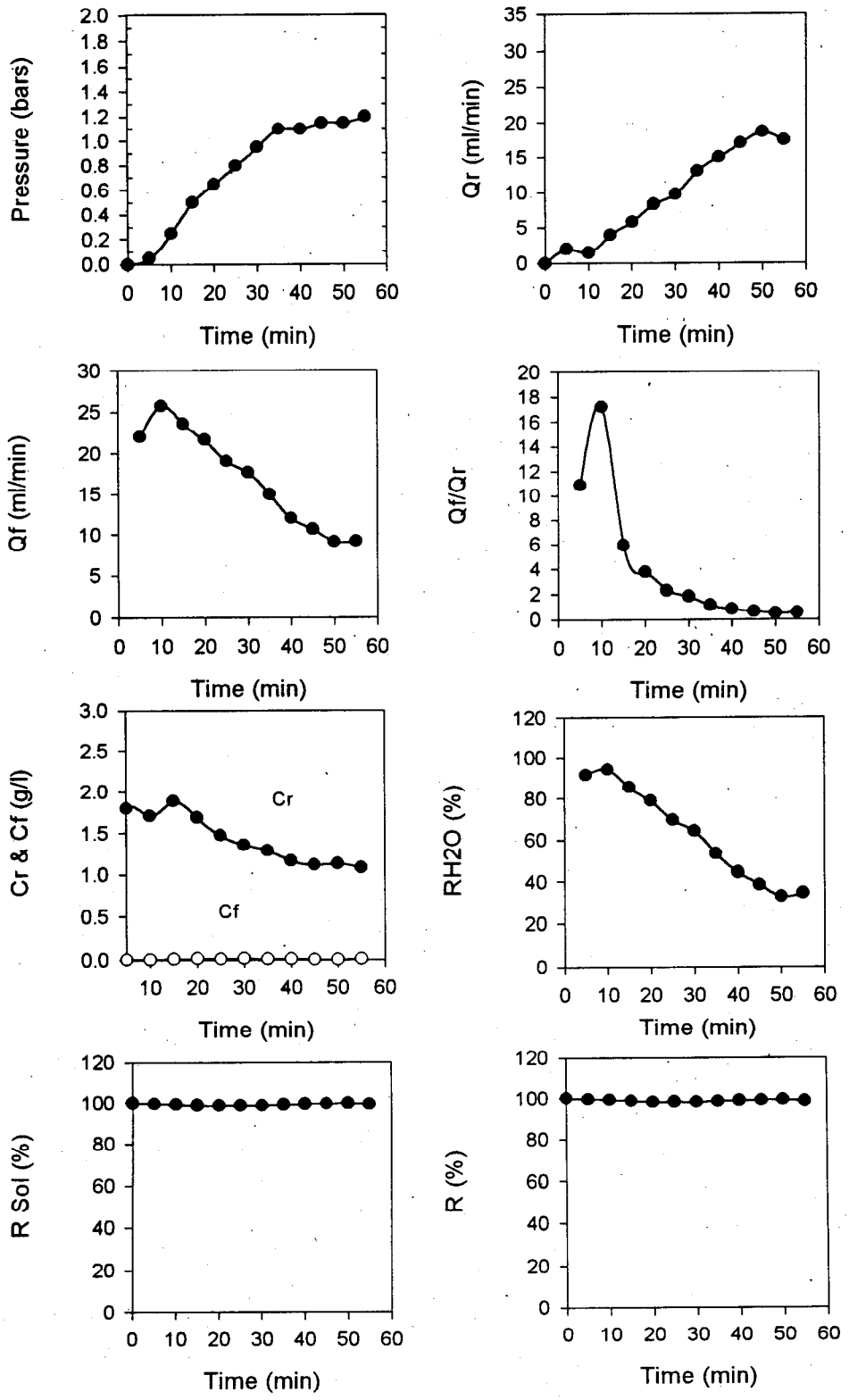

Figure 5. *Minitan*^{TM} tangential filtration tests . Cell concentration = 1.0 g/l

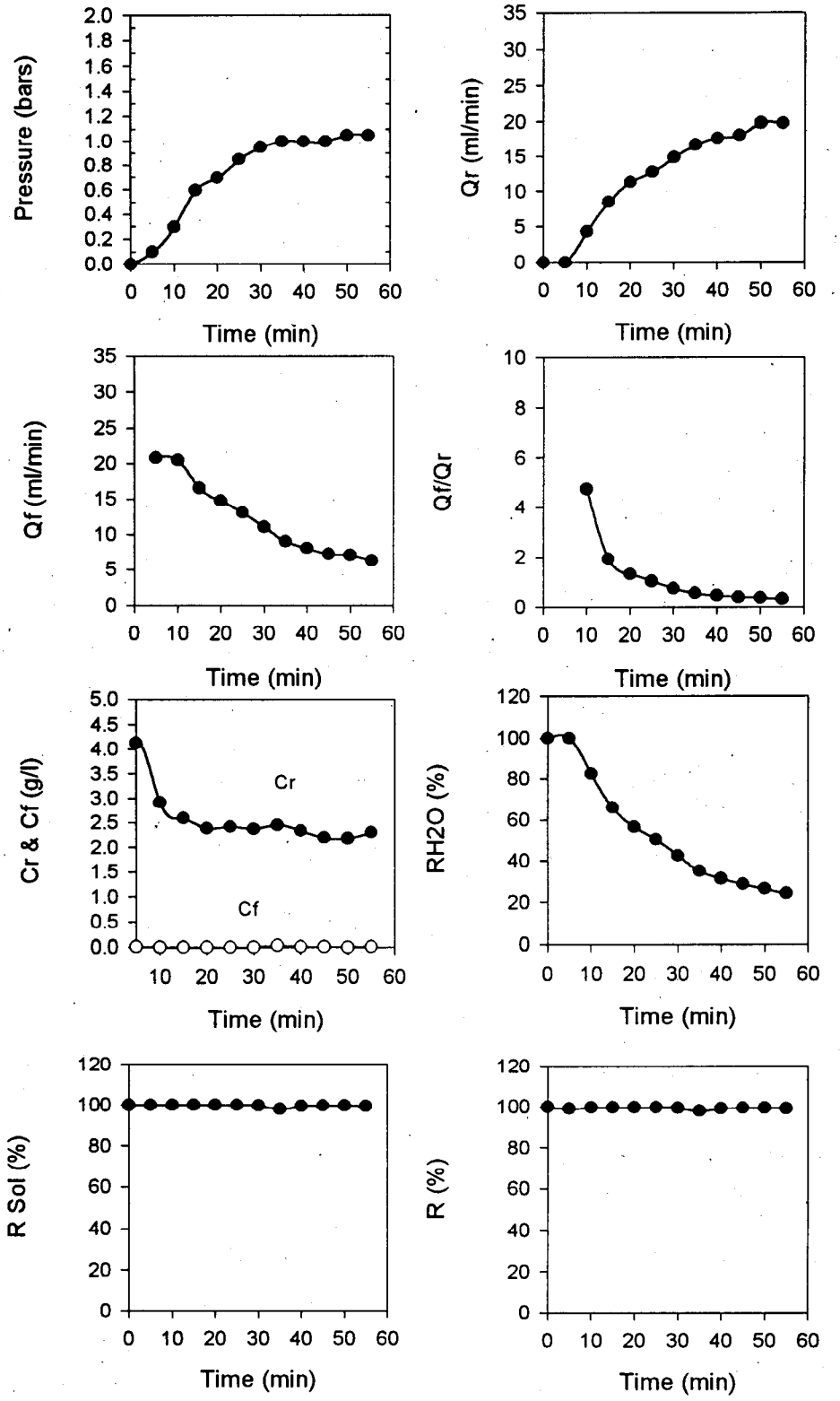

Figure 6. *Minitan*^{TM} tangential filtration tests . Cell concentration = 1.6 g/l

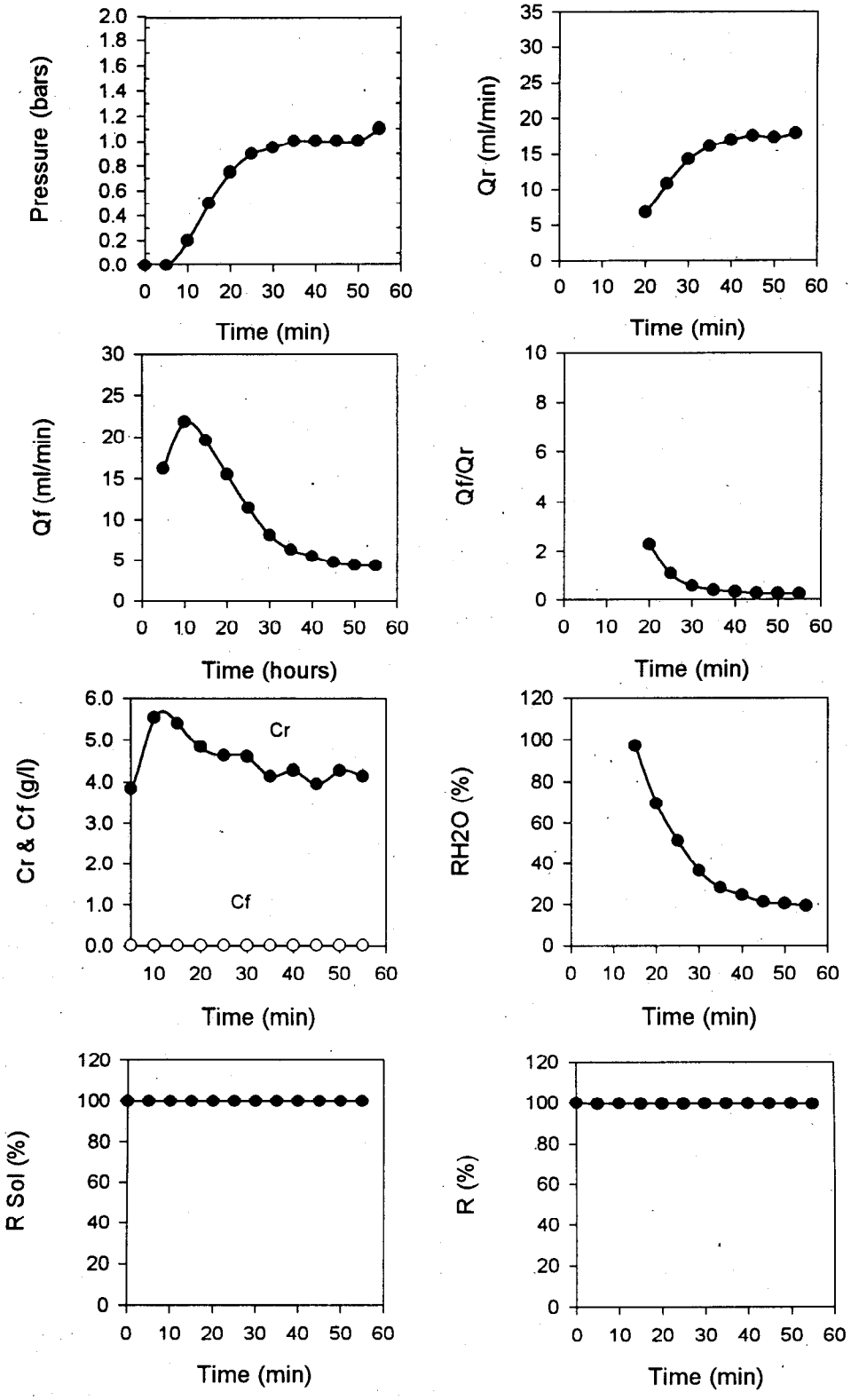

Figure 7. *Minitan*^{TM} tangential filtration tests . Cell concentration = 3.6 g/l

III. 3. DISC STACK CENTRIFUGE.

Continuous centrifugation was performed on cell suspension of *Spirulina platensis* with different cell concentrations. The approximate volume for each test was around 5L with 1.46 g/l and 2.83 g/l dry weight. In order to determine the optimal operating conditions, experiments were performed at various feed flow rates (Q_E) and rotation speed (rpm). In general, satisfactory results were obtained with this equipment. Water yield (R_{H2O}) , solids recovery (R_{sol}) and separation efficiency (R) were very high (>95 %) in all the experimental conditions. Although the water yield is very high, cell concentration at the concentrated stream is not higher than expected, due to the own characteristics of this continuous centrifuge. As stated in the equipment description section, this centrifuge works with periodical cake discharge in order to reject the separated solids. To carry out these discharges the centrifuge uses water supplied to the system, and so, the solids experiment a dilution while collected as concentrated stream.

Firstly, with a moderate cell concentration of 1.46 g/l, effects of the feed flow rate (1.0-4.0 l/h) and rotation speed (7000-10000 rpm) were studied. Results corresponding to this first set of experiments are presented in figure 8. The concentration of the clarified and concentrated streams, C_F was always lower than 5 % of C_E. C_R increased significantly when Q_E increased and was higher at maximum rpm (10000). Once it was shown that the rotation speed affects the overall efficiency of the system, high values of this variable were selected to perform posterior tests. In reference to the feed flow rate, is well-known that these kind of centrifuges have a minimal operation flow rate in order to work properly. In this sense, it was observed that when using flow rates below 2.0 l/h the overall performance of the centrifuge was not so satisfactory than for higher flow rates. These facts allow to define optimum conditions which are both high rotation speed and feed flow rate whenever possible. Thus, the flow rate obtained during continuous cultures in the bioreactors should be the limiting step if a continuous operation is desired.

Secondly, with a higher cell concentration of 2.83 g/l effects of feed flow rate and high rotation speed were studied. Results corresponding to this second set of experiments are presented in figure 9. The general behaviour is very similar than for lower cell concentrations. The overall performance of the centrifuge system is more satisfactory for high feed flow rate and rotation speed. However, in order to obtain a

good recovery of the solids and the liquid, the use of moderate operation conditions could be enough.

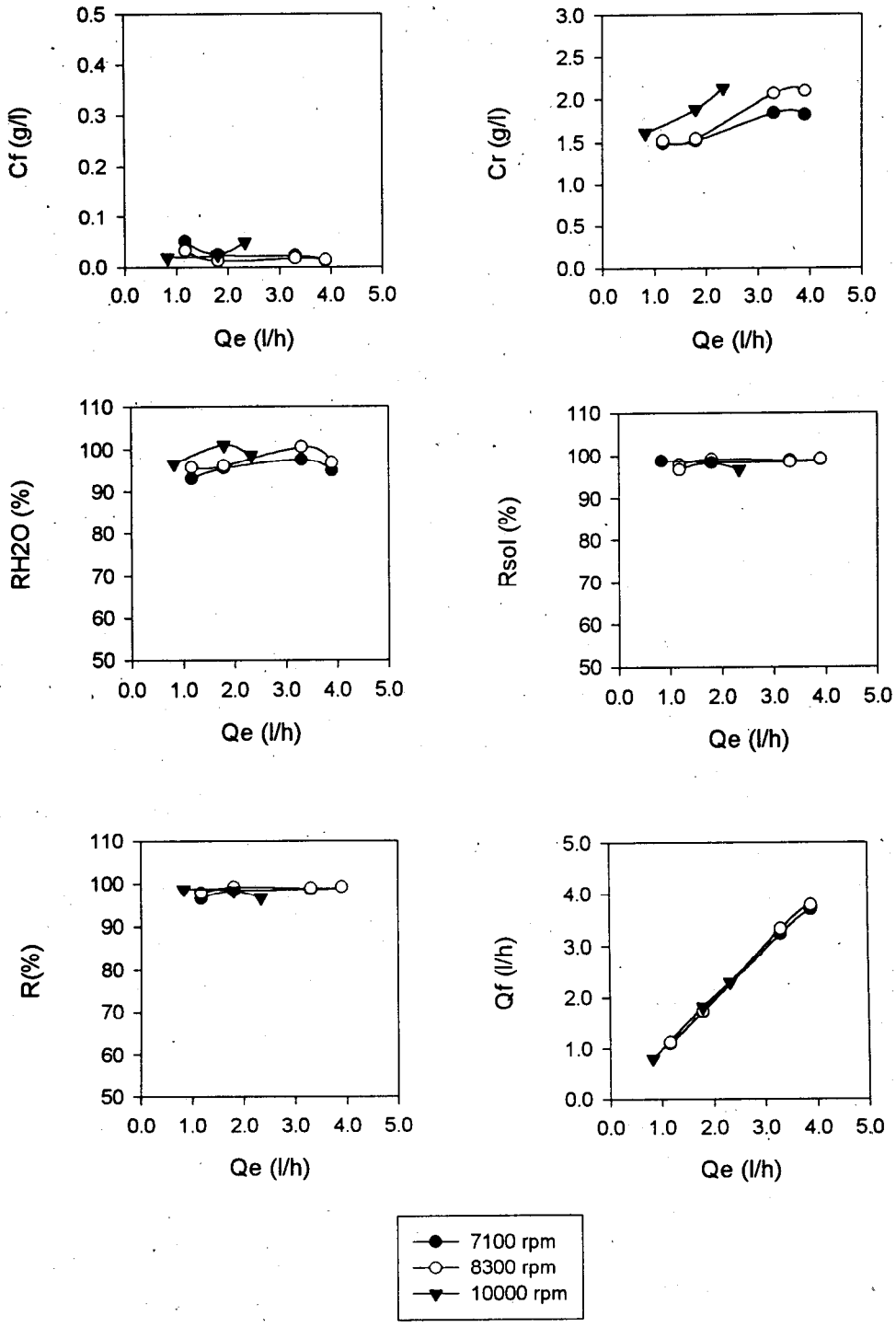

Figure 8. Disc stack centrifuge tests . Cell concentration = 1.46 g/l

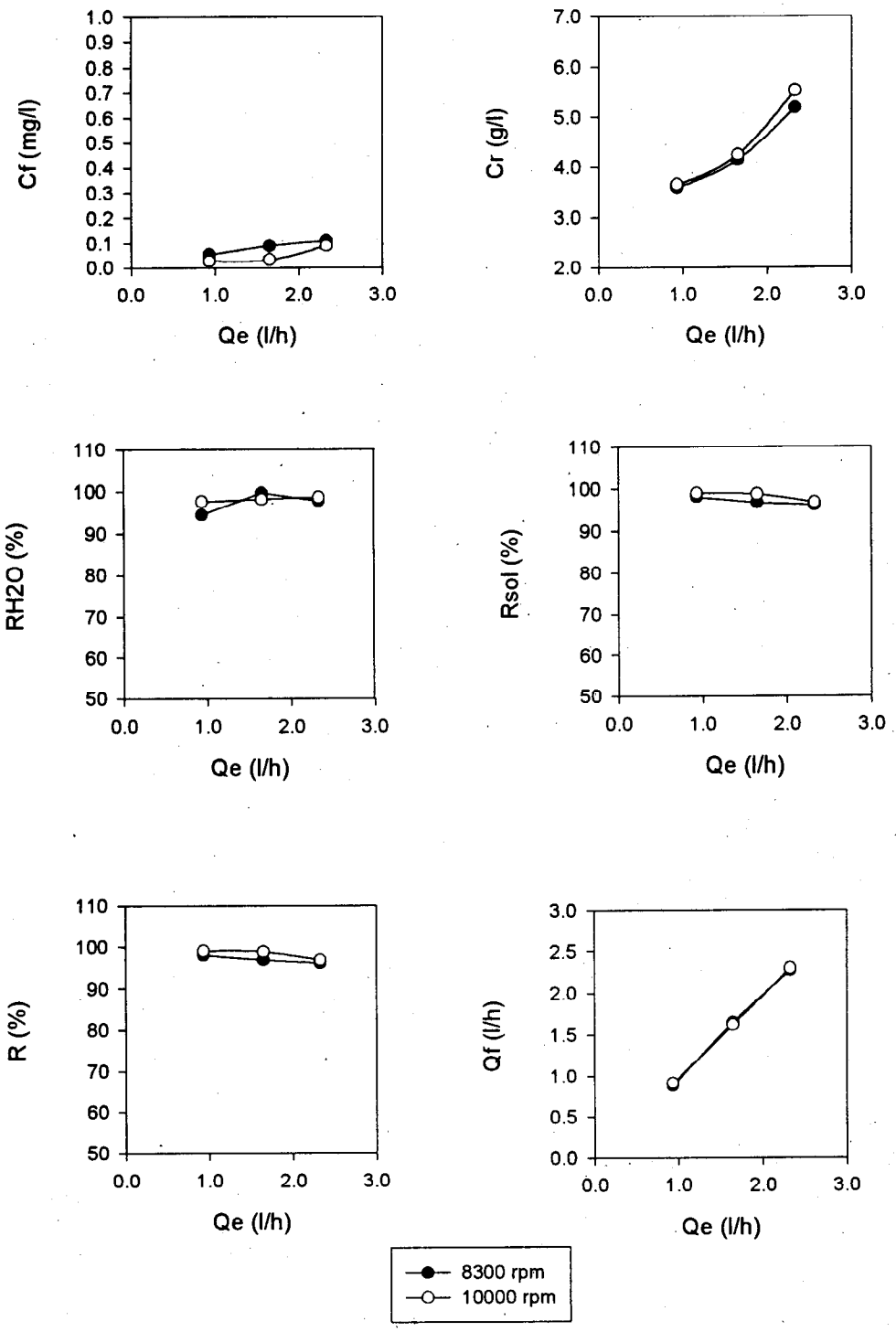

Figure 9. Disc stack centrifuge tests . Cell concentration = 2.83 g/l.

IV. PART III

DEFINITION AND CHARACTERISATION OF THE BIOMASS HARVESTER

IV.1 FINAL CONFIGURATION OF THE BIOMASS HARVESTER

Once studies on the selected equipment were completed the definition and characterisation of the biomass harvesting scheme was carried-out. Taking into account the previous results the final configuration proposed is a system composed of two separation units. In this way, the first step highly recovers the water by the clarified stream in terms of water yield and the second step has an ultimate clarification function for the liquid stream. The global configuration is shown in figure 10, with the nomenclature for each stream and its corresponding cell concentration.

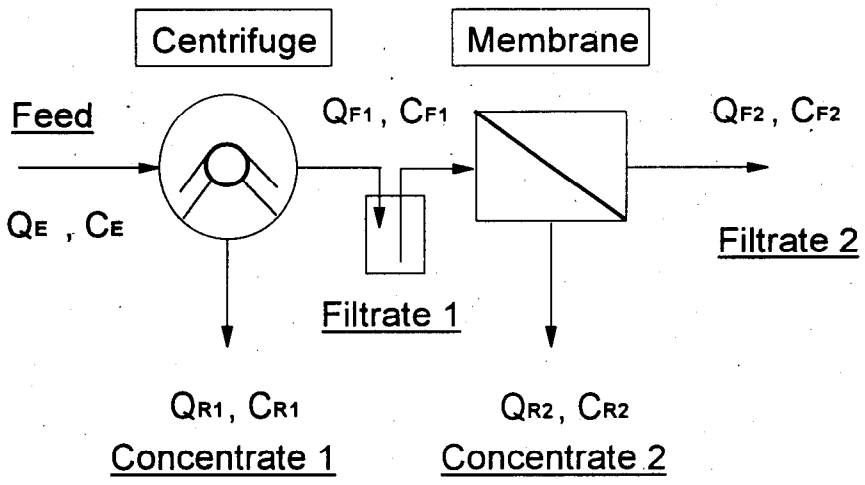

Figure 10. Scheme of global harvesting system

The first separation unit is a disc stack centrifuge working at moderate flow-rates (1.0 - 4.0 l/h) and high rotation speed (10000 rpm). The individual high performance of this equipment in terms of water yield, solids yield and separation efficiency has been clearly shown by the tests described above.

The second separation unit is a tangential filtration with the *Minitan*^{TM} equipment that operates at high permeate/retentate ratio (around 5) in order to recover the liquid as much as possible and with a minimal cell concentration.

A final test using this configuration was conducted with approximately 4L of *Spirulina platensis* culture broth at 1.75 l/h of feed flow rate, with a cell concentration of 2.71 g/l and a rotation speed of 10000 rpm. Results of this final test are presented in

figure 11 for the centrifugation step, figure 12 for the microfiltration step and figure 13 for the global system.

At the centrifugation step the cell concentration of the clarified stream, its corresponding flow rate, and the key parameters water yield, solids yield and separation efficiency are shown in front of time operation. The water yield is kept always above 90% reaching at steady state, after approximately 60 min, a value close to 100 % being higher than 95 % of recovery. The cell concentration of the clarified stream is always lower than 0.1 g/l and the corresponding solids yield and separation efficiency higher than 95%. The concentration of the solids discharge (wet *Spirulina* cells) obtained in the centrifuge was estimated as 4.48 g/l as a mean value . It should be emphasised that the nature of this discharge is discontinuous with time, and cells are somewhat dilute by the discharge procedure, that uses liquid. This preparation would be the starting point of an additional step to reach the final *Spirulina* conditioning for its use as food supply.

As previously mentioned, the microfiltration step has as a major objective to decrease the cell concentration of the clarified liquid obtained from the centrifugation step. The cell concentration to be treated in this step is around 0.1 g/l. From a first estimation of the reduction of cell concentration an approximate value of 50 % was obtained. However, the cell concentration measured in the filtered stream was then higher than for the previous experiments performed with fresh *Spirulina* cells (thus, not previously centrifuged), and the solid retention was apparently lower. This contradictory result can be explained in terms of an interference in the analytical method used to evaluate cell concentration in the filtrate stream. Due to its low concentration, absorbance at 750 nm is used for the measurement of cell concentration. When *Spirulina* cells are centrifuged the liquid stream from the centrifuge has a slight yellow colour, very probably produced by the leakage of some intracellular pigments that are responsible of a certain absorbance measurement when the normal conditions of the test are used (basically, using water or culture medium as a blank in the spectrophotometer).

Taking into account these facts, new measurements were made and the cell concentration of the ultimate filtrate were neglectable (< 0.01 g/l) as can be seen in figure 12. After that, if solids yield and separation efficiency are calculated their values are close to 100% always higher than 90% as when prior centrifugation is not used.

Finally, the yields and separation efficiency of the overall system are presented in figure 13. The water yield is between 75%-80% value that accomplish the requirements of the biomass harvester as established in the introduction (75% -90%). The solids yield and separation efficiency is higher than 95%. As summing up, the biomass harvester operating conditions, characteristics and their possibilities in terms of yields and efficiency are presented as follows.

Centrifugation step

Equipment :	Disc stack centrifuge from *Westfalia Separator AG*
Operating conditions :	10000 rpm, feed flow rate (> 2 l/h)
Water yield :	>95 %
Solids yield :	>95 %
Separation efficiency	>95 %

Microfiltration step

Equipment :	*Minitan*^{TM} tangential microfiltration (0.45 µm)
Operating conditions :	(filtrate/retentate)> 4, feed flow rate (> 2 l/h)..
Water yield :	>80 %
Solids yield :	>95%
Separation efficiency	>95%

Global system

Water yield :	75 - 80 %
Solids yield :	>95%
Separation efficiency	>95%

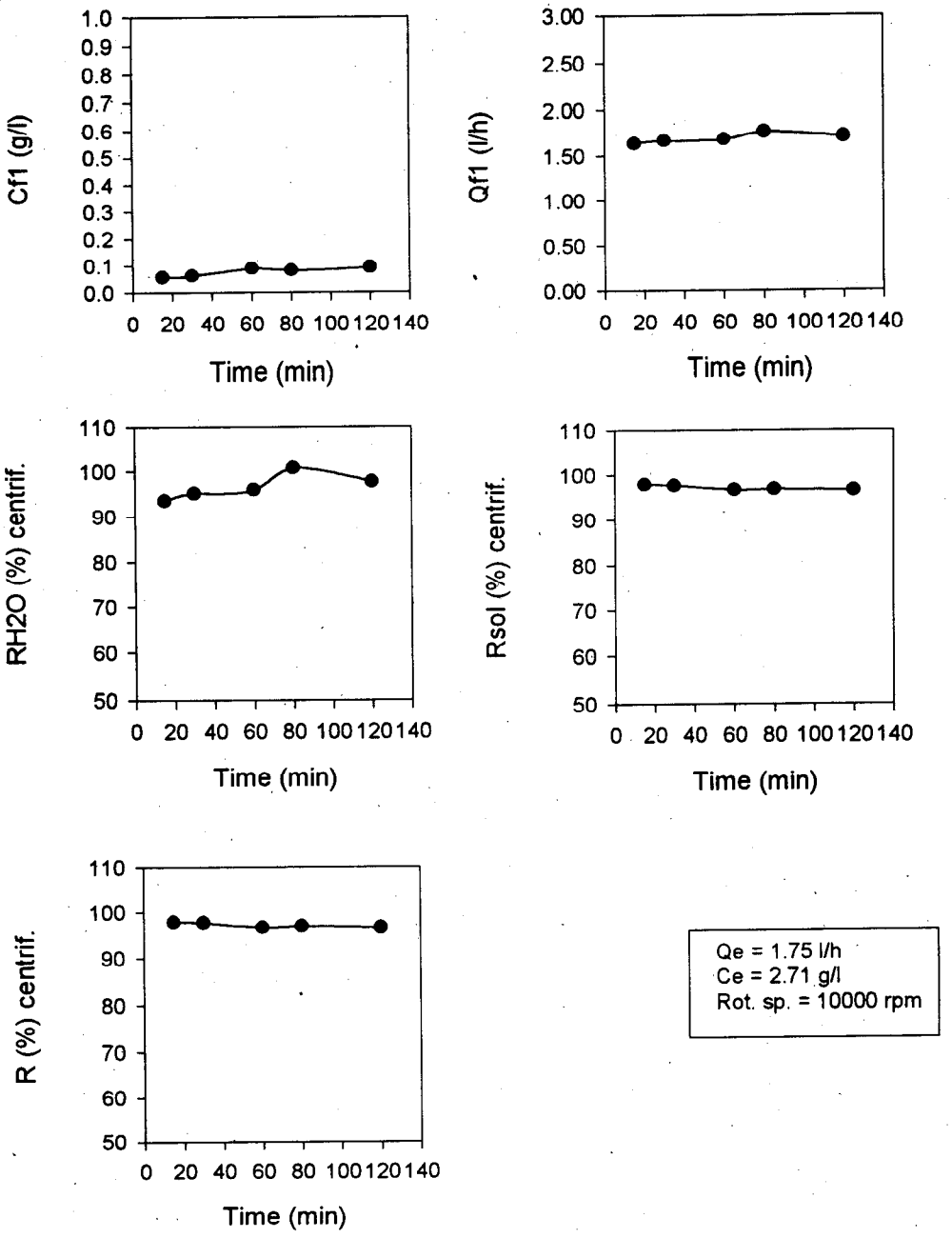

Figure 11. Biomass Harvester final tests . Centrifugation step.

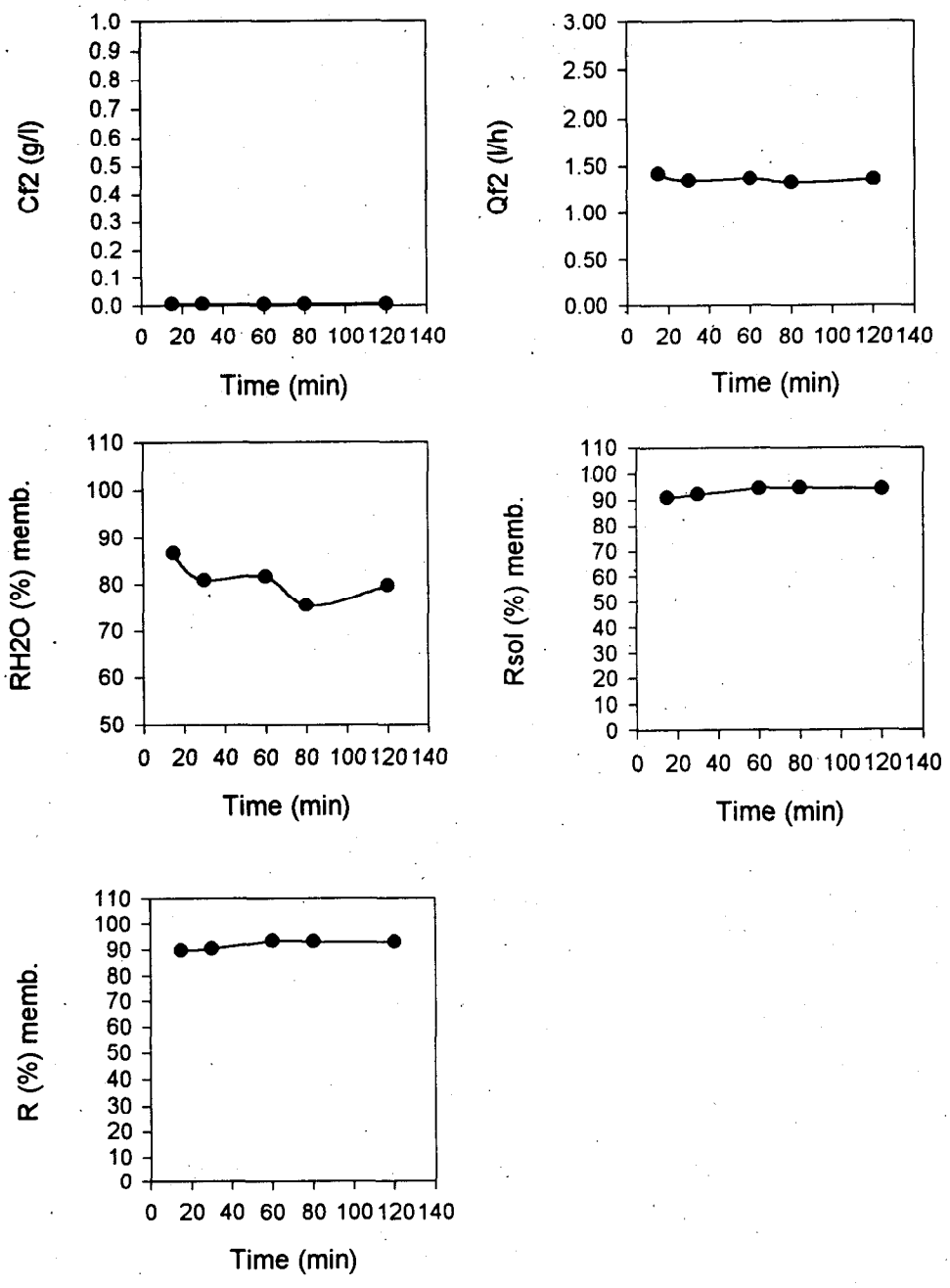

Figure 12. Biomass Harvester final tests . Microfiltration step.

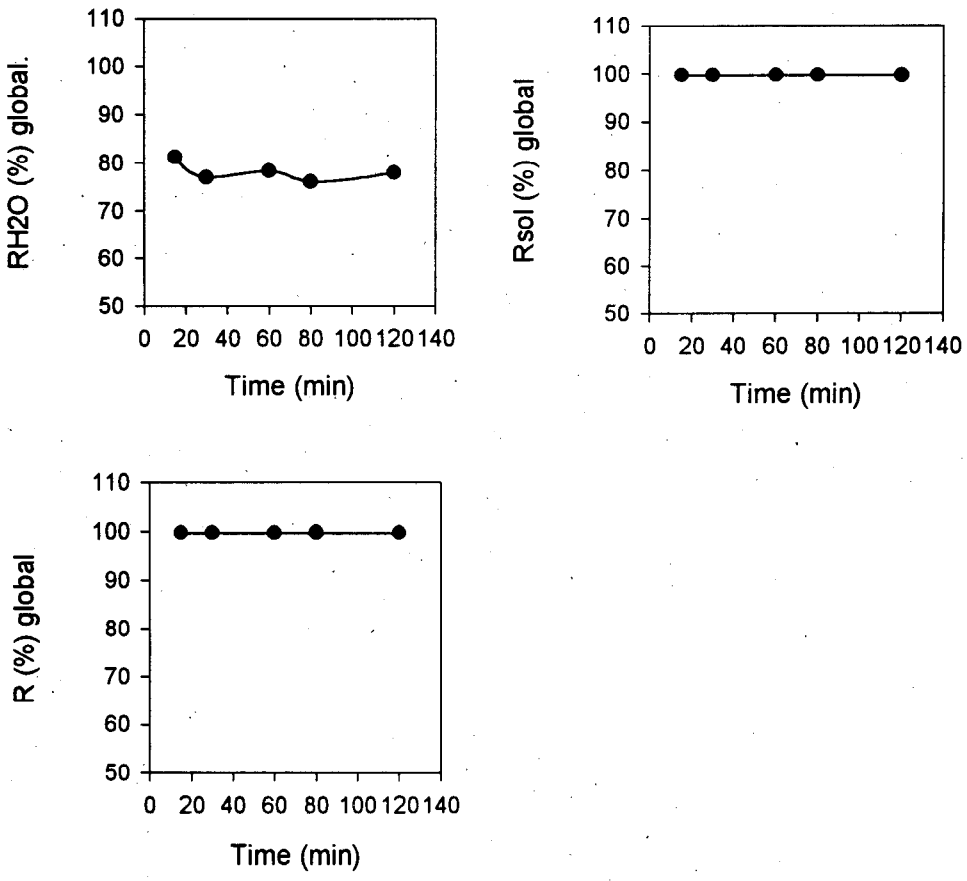

Figure 13. Biomass Harvester final tests . Global system.

IV.2 ADDITIONAL CONSIDERATIONS AND REMARKS

The evaluation of the hardware selected to carry out the operation of the biomass harvester have included a number of relevant features : minimum and maximum capacity, pressure required, biomass concentration attained, clogging of membranes, liquid and solid percentage recuperation (yield) and separation efficiency, among others. However, it is also important to take into account variables such as the EPS accumulation in *Spirulina* or PHB in *Rhodospirilum* cultures that can affect the performance of the harvester system.

In principle, from the three concepts selected to make the harvesting tests, the ones related to membrane processes, that is to say, spiral filtration and tangential filtration are expected to be more affected from additional or "extra" clogging phenomena due to their physical principle of functioning. When increasing the EPS content on the biomass, a variation of the physical properties such as density, viscosity-rheological properties of the culture broth- and size and composition of the biomass (includying percentage of water) may become in an increasing risk of fouling, concentration polarisation and even clogging of the membranes. Then, if the EPS content in *Spirulina* is very important, the concepts based on membranes (microfiltration) can hardly be suitable candidates even for a first or preliminary selection. These facts support the final configuration of the biomass harvester, that release the membrane systems for a second step of liquid recovery and biomass removal, when the biomass concentration is neglectable to consider the possibility of having problems with EPS accumulation in the cells.

The centrifugation of the cells may, obviously, also be affected for the presence of an important content of EPS in *Spirulina* cells, but not being the consequences so drastic than for the membrane systems. Maybe, there would be a loss of separation efficiency, and water and solids yield, but in the major part of cases this effect could be solved by favouring the separation conditions, for instance increasing the feed flow-rate. As stated in the results concerning to the centrifugation step, the higher the flow-rate, the higher the efficiency and yields are attained. If necessary, the global harvester system can operate in a semi-continuous mode, that is, with repeated operating cycles using a reservoir tank to provide enough volume to be fed to the centrifuge at higher flow-rates, and thus, to obtain high efficiencies and yields. In this way, the total volume treated per unit of time remain the same without significant loss of neither efficiency nor yield.

From the tests carried out in the compartment IV, the normal output flow-rates that can be anticipated in the operation of the 75 litre reactor range from about 0.5 l/h to 3.0 l/h. Then, when the output flow-rate of the reactor would be at the lower range the overall performance of the global harvesting system may slightly decrease. However, neither the water and solid yield nor the separation efficiency for the centrifugation step would be, in any case lower than 90 %. The second step of the harvesting system, the membrane filtration, are not supposed to be much affected by the flow-rate, and so, the overall yields and efficiency will be kept within satisfactory values. Anyway, if necessary, a reservoir tank can be used to increase the feed flow-rate to the harvesting system in order to obtain a higher performance of the system without changing the treated volume per unit of time, as described above.

Furthermore, this alternative of using reservoir tanks has to be considered when being necessary to process or harvest biomass from different compartments and reactors *(Spirulina* and *Rhodospirilum* cells). The alternative of working in semi-continuous mode with operating cycles is better than the possibility to work with the same number of harvester systems than effluent streams to be processed. It has many advantages, among others: investment cost, operational cost, maintenance, performance, robustness, versatility, place to be occupied, etc. Obviously, it is necessary to predict discharge and cleaning cycles, dead times, and start-up of the systems in such operation conditions. Further studies had to be done in order to investigate and optimise these operating cycles, as well as definitely confirm their applicability.

In reference to additional treatments of the cells prior to any final preparation of the biomass for food applications, it will be investigated in a next phase. Firstly, taking into account that a lower percentage of water will be required (for example, if they are required completely dried, freeze-dried, etc..) and so, that an additional step will be necessary to the elaboration of the final product. This final step is not considered an objective for the biomass harvester as such, and has not been included in this technical note.

In this way, in the next tests to be carried out the problem of biomass conservation and preparation for crew compartment will be investigated. This work will cover the study of the following aspects: washing operation (procedure, quality, pH, chemical contaminants,...) ; additional specific treatment (utilisation of fresh biomass, freeze dried, pasteurised or other methods proposed studying the effect of these treatments on the biomass quality) ; operational mode, and harvester feeding strategy (batch, continuous, manual, automatic, mixing with any other type of biomass and complements) and conservation procedure (possible treatments, microbial contamination preservation, sensors, duration, volume).

Although, something can be anticipated from the cell washing operation because a good alternative may be the washing of the cells prior to any harvesting procedure. Before the cell recovery, cell washing by cross-flow filtration is one way to change the liquid, or solvent, suspending the cells. The pH or ionic strength can be changed or a particular component can be separated from the bulk cell suspension. Cell washing is thus an alternative to dialysis and centrifugation. In this cell washing mode, the cells are retained by a membrane filter (microfiltration), and fresh wash solution is added to the cell suspension at the same rate filtrate is removed. Therefore the suspension volume remains constant. With time, the old cell-suspension medium is replaced by fresh solvent. Due to the certain possibility of membrane clogging when a high cell concentration is used, it is not advisable to do this kind of cell washing after the harvesting procedure has been completed. The cell concentration attained is higher than the initial, and so, the risk of membrane clogging is very much higher.

The use of a centrifugation system is also an alternative of cell washing that can be done as centrifugation cycles, recovering the cells and suspending them with fresh wash solution. This procedure can be repeated several times until the desired quality has been obtained. This alternative has an important disadvantage, that is the risk of cell disruption and leakage of some intracellular compounds, favoured by the repeated centrifugation at high rotation speed.

Both systems the membrane filtration and centrifugation can operate in axenic conditions. Only it is necessary to perform additional cleaning and sterilisation cycles prior to operate the corresponding equipment. The requirement of strict axenic conditions may depend on the posterior additional treatments to be done (freeze-drying, pasteurisation, spray-drying, etc..), operation times, dead times, additives, chemicals added, etc..

The integrity and viability of the cells is higher for the membrane processes than for the centrifugation ones. However, for the type of cells and centrifuge it can be estimated that the cell disruption, for a single centrifugation cycle, is always lower than 5-10% of the total amount of cells treated.

Once the harvesting of *Spirulina* cells has been defined satisfactorily with high values of efficiency and yields, it is necessary to make some considerations about the possibility to use the same biomass harvester for *Rhodospirilum*. The general discussion of this aspect can be afford taking into account the two subsystems present in the biomass harvester, the centrifugation step and the tangential filtration step.

First, it can be considered that the efficiency of the centrifugation step is directly dependent on the sedimentation velocity of the particle to be removed at fixed operation conditions. This sedimentation velocity depends on the solid density and the solid size (effective or mean diameter). In the case under study *Rhodospirilum* is smaller than *Spirulina*. However, the biomass density are also different, being higher for *Rhodospirilum* than for *Spirulina*. As a result, the sedimentation velocity for *Rhodospirilum* is higher than *Spirulina* and so, the efficiency in terms of solids removal and water recuperation is expected to be higher for the bacteria than for the algae. Following these considerations, the realisation of the corresponding tests for *Rhodospirilum* have not been considered as necessary in this phase. Nevertheless, in further studies, when enough biomass will be available, similar experiments can be carried out for *Rhodospirilum* than the ones presented for *Spirulina*. The presence of important quantities of PHB can decrease the efficiency of the centrifugation step, but this problem can be solved by increasing the feed flow-rate using semi-continuous operation mode, as in the case of *Spirulina*.

In reference to the tangential filtration step, due to the fact that *Rhodospirilum* has a lower diameter than *Spirulina*, it is expected that the problems concerning to clogging and fouling of the membranes will not be so important. Thus, it can be assured that for this second step, when the cell concentration is very low, the general performance of this equipment will be similar for both *Rhodospirilum* and *Spirulina*.

If the liquid recovered has an important amount of PHB or EPS is possible to have problems with concentration polarisation and even adsorption onto the membrane. If necessary, the solution proposed is to use diafiltration in order to minimise this effect. This technique is commonly used for spent fermentation broth. Undesirable soluble components may be removed when the final product is the cells, or residual product may be washed out when the desired product is in the broth (products, nutrients, salts,...) by using an eluent solvent (e.g., buffer). So, this technique can be used either as a cell washing prior to the harvesting procedure or even with recovered liquid after the centrifugation step, whenever a suitable membrane has been selected to reject PHB or EPS and neglectable quantities of biomass (selection of the membrane cut-off).

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VI. ANNEX 1. SELECTED EQUIPMENT

COMMERCIAL LEAFLETS

WESTFALIA SEPARATOR

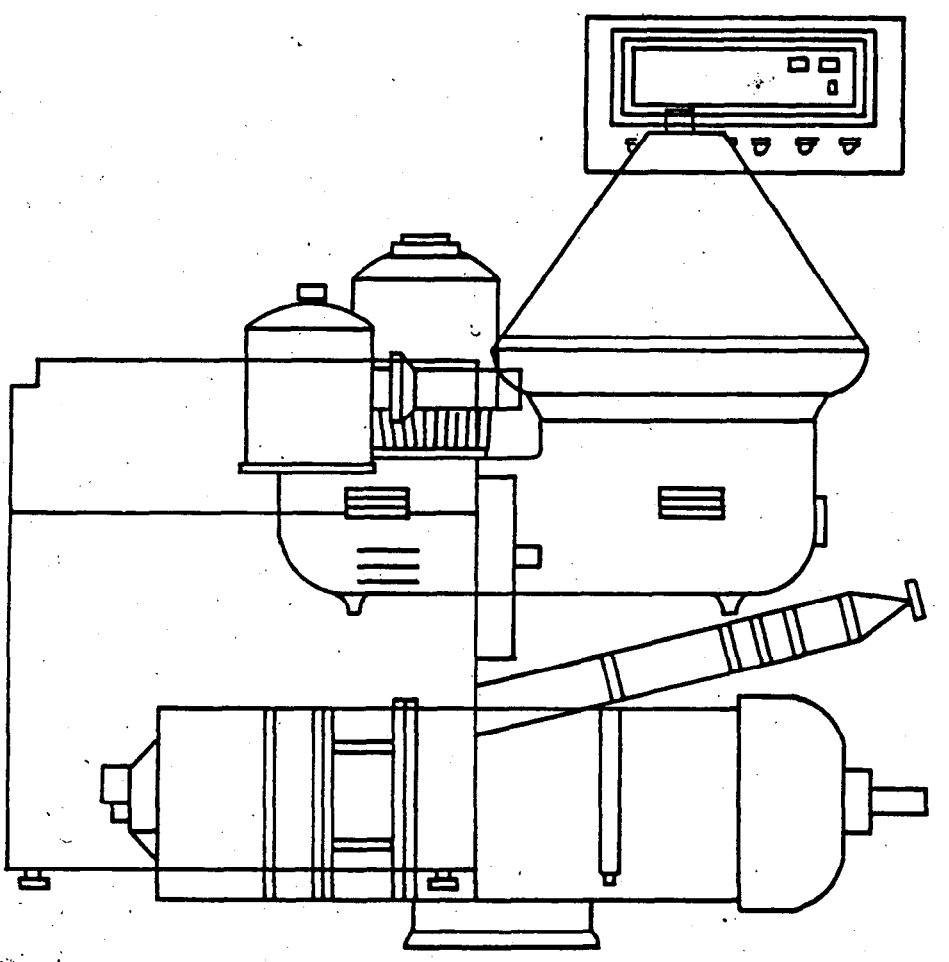
Manual de instrucciones y lista de piezas de recambio

No. 3139-9005-000

Edición 0287

Centrífuga clarificadora con tambor autodeslodante en ejecución esterilizable a vapor

Tipo CSA 1-06-475



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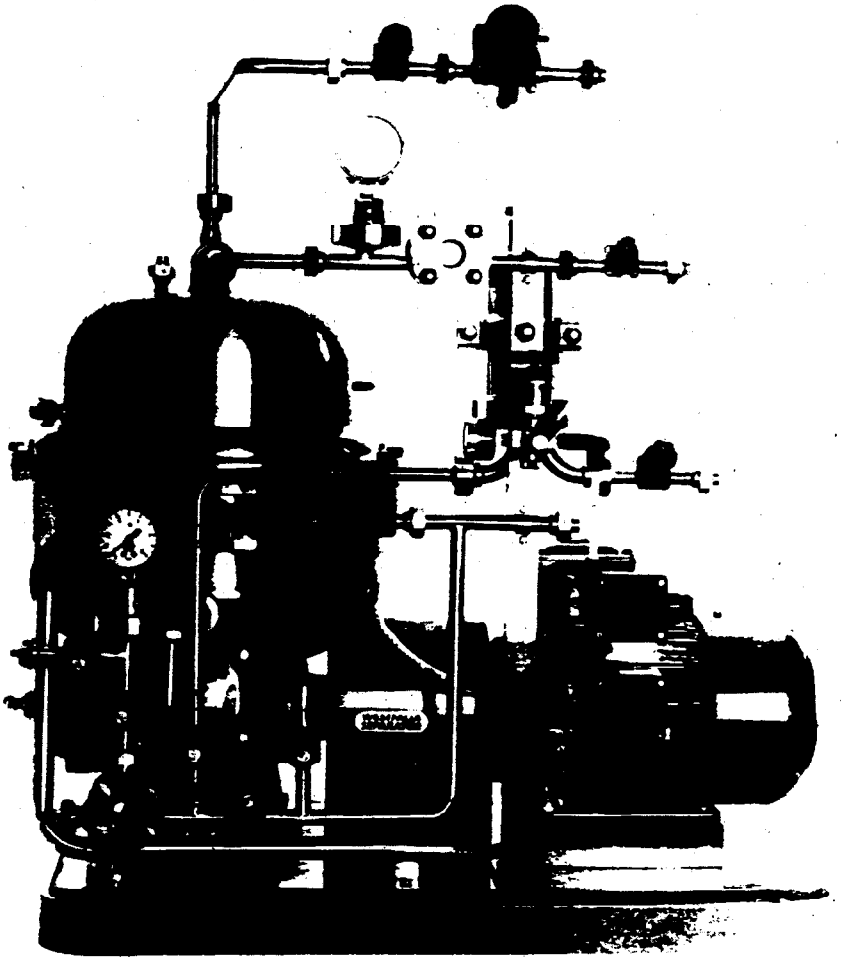
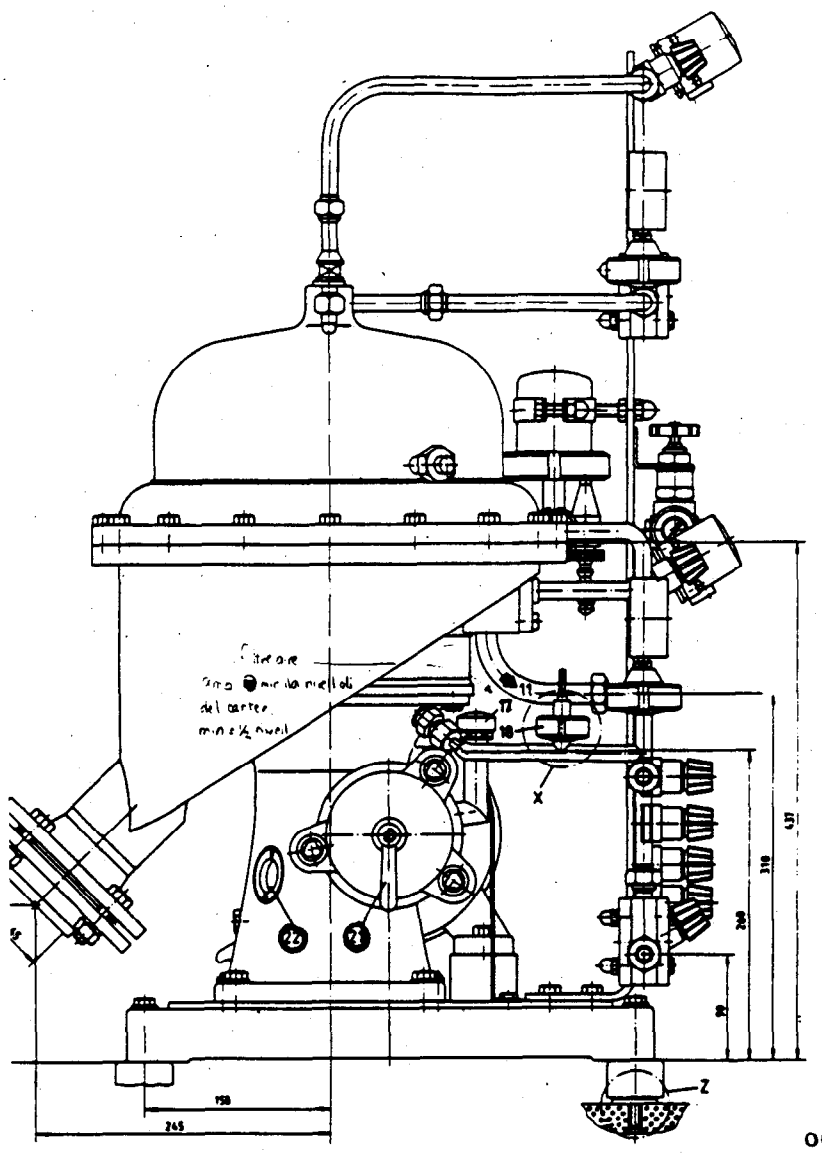
WESTFALIA SEPARATOR

Centrífuga clarificadora
con tambor autodeslodante en
ejecución esterilizable a vapor

Tipo CSA 1-06-475



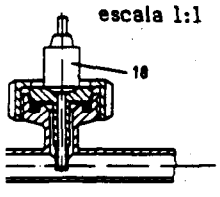


1 Alimentación de producto
2 Válvula de membrana con actuador neumático
3 Salida de producto
4 Válvula de presión constante
5 Mirilla
6 Filtro de aire esterilizado
7 Salida de agua de refrigeración del capó
8 Entrada de agua de refrigeración del capó
9 Entrada de agua de maniobra y agua de obturación
10 Válvula de membrana con actuador neumático
11 Salida agua de maniobra
12 Líquido de obturación para retén deslizante (entrada)
13 Líquido de obturación (salida)
14 Líquido de fugas
15 Conexiones para retén deslizante
16 Caja de bornes para motor
17 Filtro de aire (engranaje)
18 Controlador de caudal
19 Mirilla en la salida de líquido de obturación y agua de maniobra
20 Salida de líquido de obturación y agua de manibora
21 Freno
22 Mirilla de inspección de aceite
23 Salida de sólidos
24 Aireación y desaireación
25 Válvulas piloto para pos. 2 + 10
26 Caja de bornes para controlador de caudal, pos. 18

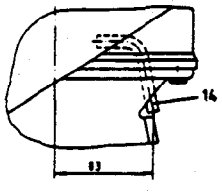
OL: • Controlar el estranqulament (Canviar cada 750h/6meses
• Si té aspecte cremós => conté H2O => s'ha de canviar
• Es pot purgar una mica

rotor sentit horari /màx: 10.000 rpm/ tarronge: 2 min

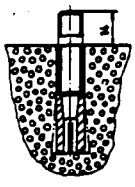
lle X
escala 1:1



Vista Y



Detalle Z
escala 1:1



Desviación admisible para las cotas sin especificación de tolerancias según D DIN 8570

5.1 Principio de funcionamiento del tambor

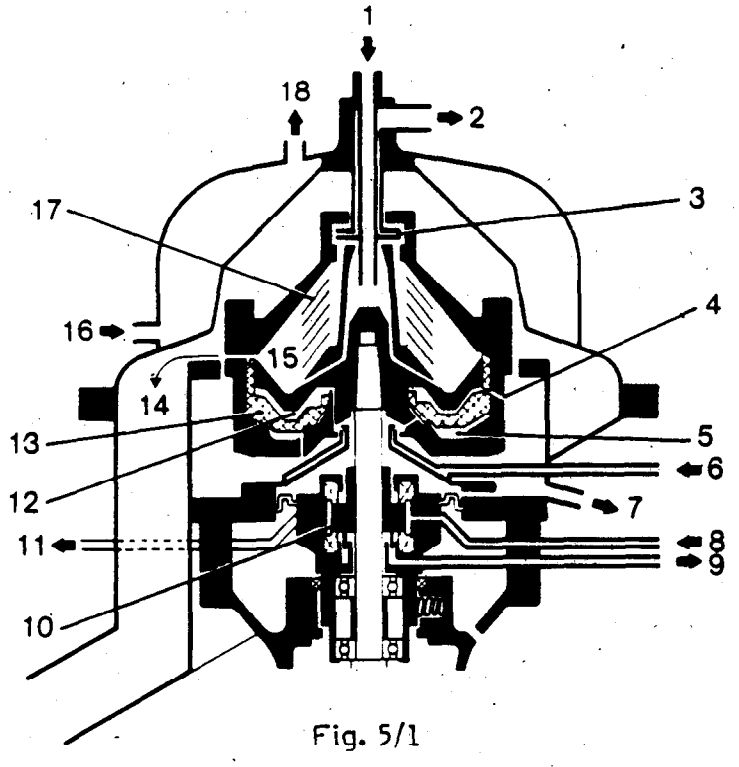


Fig. 5/1

1 Alimentación
2 Salida
3 Rodete
4 Orificio de salida
5 Cámara de cierre
6 Entrada agua de maniobra
7 Salida agua de maniobra
8 Entrada agua de obturación
9 Salida líquido de fuga
10 Retén deslizante
11 Salida agua de obturación
12 Cámara de apertura
13 Pistón deslizante
14 Rendija de expulsión de sólidos
15 Recinto de lodos
16 Entrada agua de refrigeración
17 Juego de platos
18 Salida agua de refrigeración

El producto a centrifugar entra en el tambor por la alimentación (1) y pasa al juego de platos (17), donde tiene lugar la clarificación. El líquido clarificado es vehiculado por el rodete (3) hacia la salida (2), a presión y sin espuma.

Los sólidos separados se acumulan en el recinto de lodos (15), siendo expulsados a intervalos periódicos a través de la rendija (14). Un programador de tiempos dirige los ciclos de descarga. El agua de maniobra se precisa únicamente durante las descargas.

La alimentación y la descarga del producto se efectúan mediante sistema de tuberías cerrado. Para observar el producto se ha incorporado una mirilla en la línea de salida. El caudal y la presión se ajustan mediante válvula de membrana y válvula de presión constante.

La distribución de vapor para las diversas fases de esterilización se realiza igualmente a través de válvulas de membrana.

5.2 Generalidades sobre las descargas del tambor

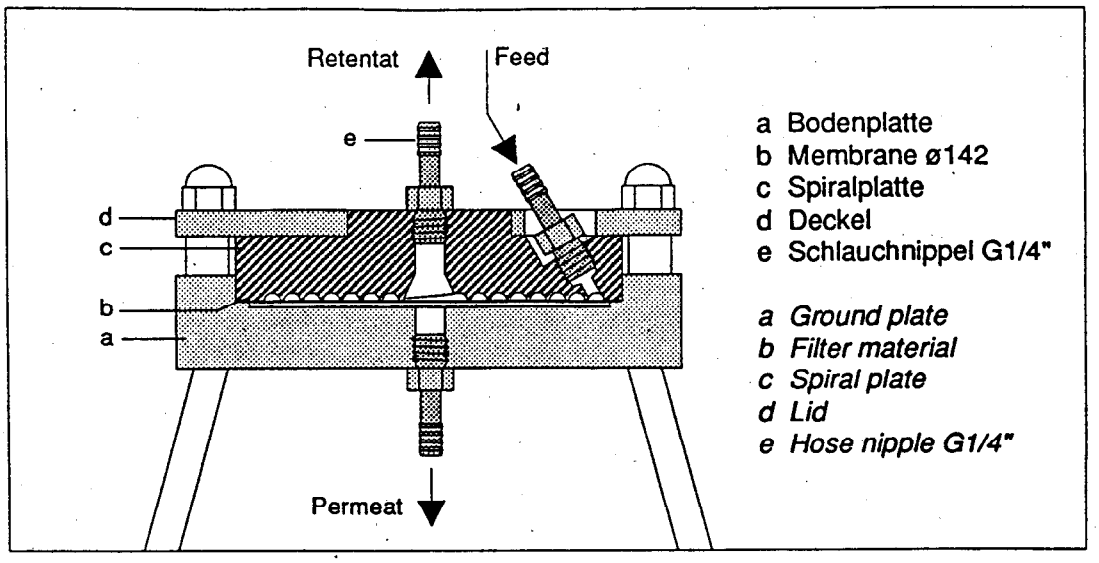
Intervalos de descarga

La duración de los intervalos en que ha de efectuarse la descarga del tambor depende del contenido en sólidos y del tipo de producto de alimentación. En cuanto sea posible, el recinto de lodos no debe llenarse por completo. Tan pronto como empiece a disminuir el grado de clarificación, deberá realizarse una descarga total o una parcial. En las descargas totales se expulsa todo el contenido del tambor, mientras que en las parciales sólo se evacúa parte del contenido del recinto de lodos. El comportamiento mecánico de los sólidos durante las descargas del tambor determina si ha de efectuarse una descarga parcial, una total o un programa combinado.

Antes de cada descarga total debe cerrarse la alimentación de producto a la centrífuga.

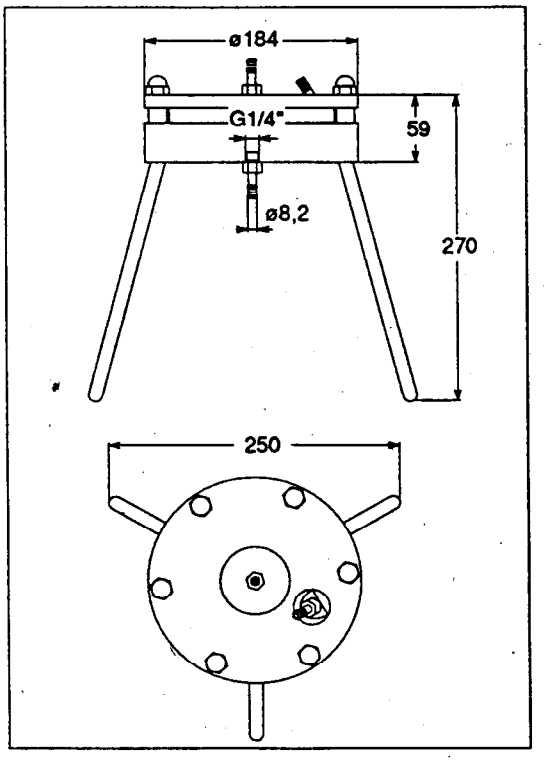
Spiralfiltrationsmodul
1-schichtig ø142

Crossflow Membrane Module
Mono layer ø142



Das Spiralfiltrationsmodul wird für die Mikro- und Ultrafiltration eingesetzt.
Die Sekundärströmung welche in der Spirale entsteht führt zur hohen Filtrationsleistung.
Jede handelsübliche Membrane ø142 kann verwendet werden.

The spiral filter module is used for micro - and ultra - filtrations. The secondary flow pattern, induced by the spiral plate, results in a hiher efficiency of the filtration performance. Any filter material sterilisable and suitable for your process can be used.



Technische Daten/*Technical data*	
Membranfläche brutto	
Membrane surface gross	147cm^2
Netto-Membranfläche (Nutzfläche)	
Membrane surface net (useful)	105,7cm^2
Hydraulischer ø Spiralkanal (4A/U)	
Hydraulic diameter spiral channel	4,2mm
Querschnittsfläche Spiralkanal	
Diameter surface area	20,2mm^2
Kanallänge (1 Membranplatte)	
Channel length (1 plate)	1,7m
Spiralkanalvolumen (holdup)	
Volume spiral channel	35,7ml

Art.No.	Werkstoff / *Material*
21455.1	PP
21455.2	1.4435
21455.3	Acrylglas PPM

0719-02

Spiralfilter ø142

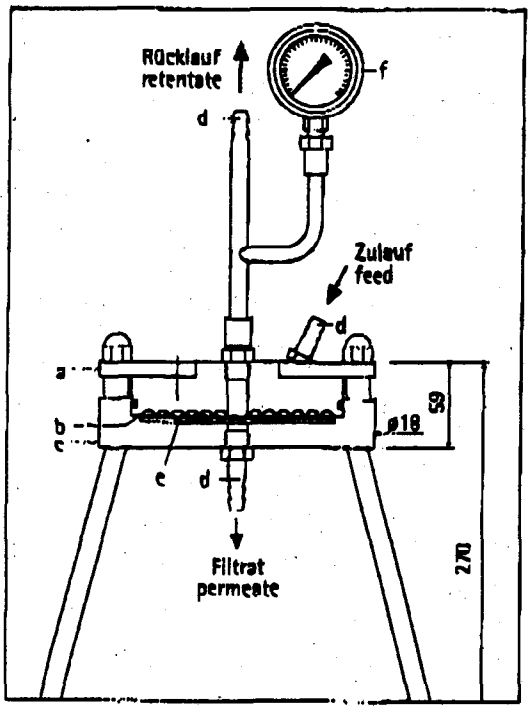
für Mikro- und Ultrafiltration

Das Spiralfiltrationsmodul wird für die Mikro- und Ultrafiltration eingesetzt.
Die Sekundärströmung welche in der Spirale entsteht führt zur hohen Filtrationsleistung.
Jede handelsübliche Membrane ø142 kann verwendet werden.

Spiral filter ø142

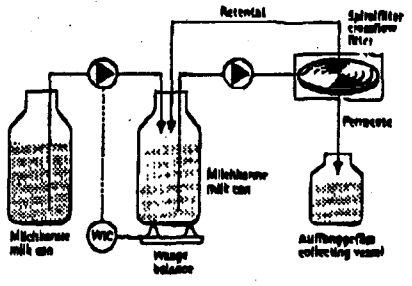
for micro- and ultra-filtration

The spiral filter module is used for micro - and ultra - filtrations. The secondary flow pattern, induced by the spiral plate, results in a higher efficiency of the filtration performance. Any filter material sterilisable and suitable for your process can be used.

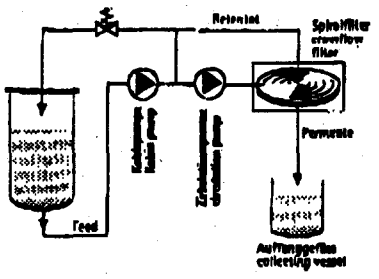


a Spiralplatte
b Membrane ø142
c Bodenplatte
d Schlauchnippel G1/4"
e Stützplatte

a spiral plate
b filter material
c ground plate
d hose nipple G1/4"
e support plate



Beispiel 1 / example 1



Beispiel 2 / example 2

Technische Daten	Technical data	
Brutto-Membranfläche	total membrane area	158,4cm2
Netto-Membranfläche (Nutzfläche)	effective membrane area	105,7cm2
Hydraulischer ø Spiralkanal (4A/U)	hydraulic diamter spiral channel	4,2mm
Querschnittfläche Spiralkanal	diameter surface area	20,2mm2
Kanallänge (1 Membranplatte)	channel length (1 plate)	1,78m
Spiralkanalvolumen (holdup)	volume spiral channel	35,7ml

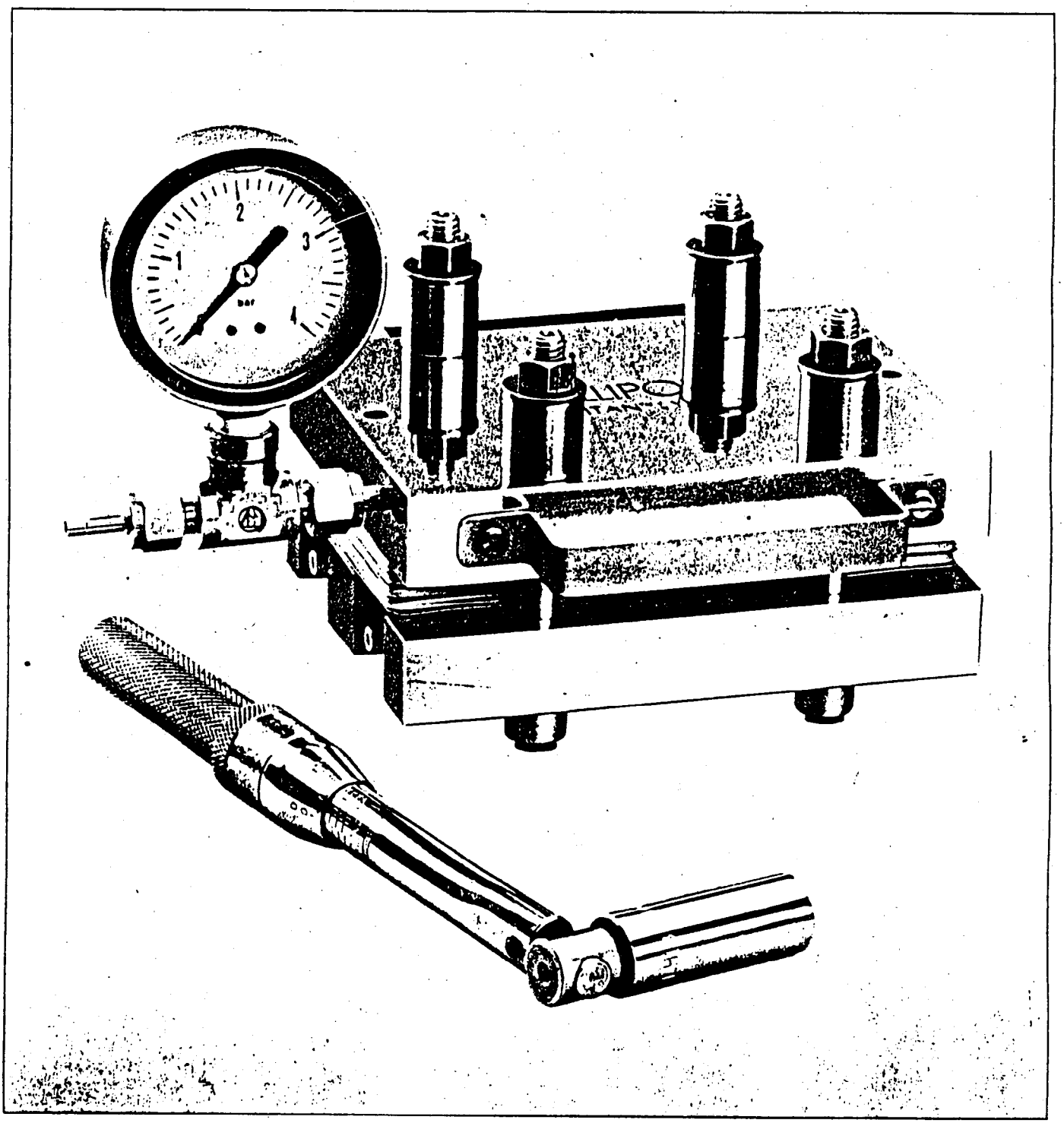
Bestellangaben	Details for ordering	Art.No.	Art.No.	Art.No.
Werkstoff Spiralplatte	material spiral plate	PP *	1.4435	Acrylgl.PPM *
Spiralfilter ø142	spiral filter ø142	21455.1	21455.2	21455.3

* nicht autoklavierbar/dampfsterilisierbar
not autoclavable/steam sterilisable

Minitan™

Sistema de ultrafiltración en acero inoxidable

Instrucciones de montaje, operación y mantenimiento



MILLIPORE

Contenido

Introducción

El sistema de ultrafiltración Minitan es un dispositivo de flujo tangencial que utiliza membranas de ultrafiltración y microporosas. Una bomba peristáltica impulsa el líquido a procesar desde un recipiente no presurizado, bombeándolo dentro de la célula a un caudal entre 100 y 1.000 ml/min.

El material concentrado regresa al recipiente original, y el filtrado se recoge en otro recipiente.

Pueden concentrarse y desalinizarse soluciones de proteínas o suspensiones de virus y células, en volúmenes iniciales de hasta 2 litros, en función del nivel de concentración deseado.

Un equipo completo se compone de una célula Minitan, una llave de ajuste, una bomba peristáltica con bajo nivel de cizallamiento y las placas filtrantes y separadores adecuados. El diseño exclusivo de las placas produce un flujo de retenido "en serie", que mantiene un efecto de barrido de alta velocidad sobre la superficie de los filtros, tanto si se utiliza una placa (60 cm^2) como diez placas (600 cm^2).

Portada: Célula Minitan y llave de ajuste.

Esquema completo de la célula Minitan (Figura 1)

Nº	Descripción	Cant.	Referencia
1	Célula Minitan, incluye arts. 2 a 9	1	XX42 00S MT
2	Soporte inferior	1	–
3	Espárragos	4	–
4	Soporte superior	1	–
5	Espaciadores	4	–
6	Arandelas	4	–
7	Tuercas	4	–
8	Manómetro 0-4 bar	1	FTPF 015 31

Nº	Descripción	Cant.	Referencia
9	Te, Swagelok-1/4" NPTF, acero inoxidable, incluye arts. 10 a 14	1	FTPF 015 32
10	Pieze en "Te"	1	–
11	Tuerca	1	–
12	Collarín	1	–
13	Virola	1	–
14	Adaptador Swagelok a tubo de 6 mm D.I.	1	FTPF 015 33

Célula Minitan en acero inoxidable

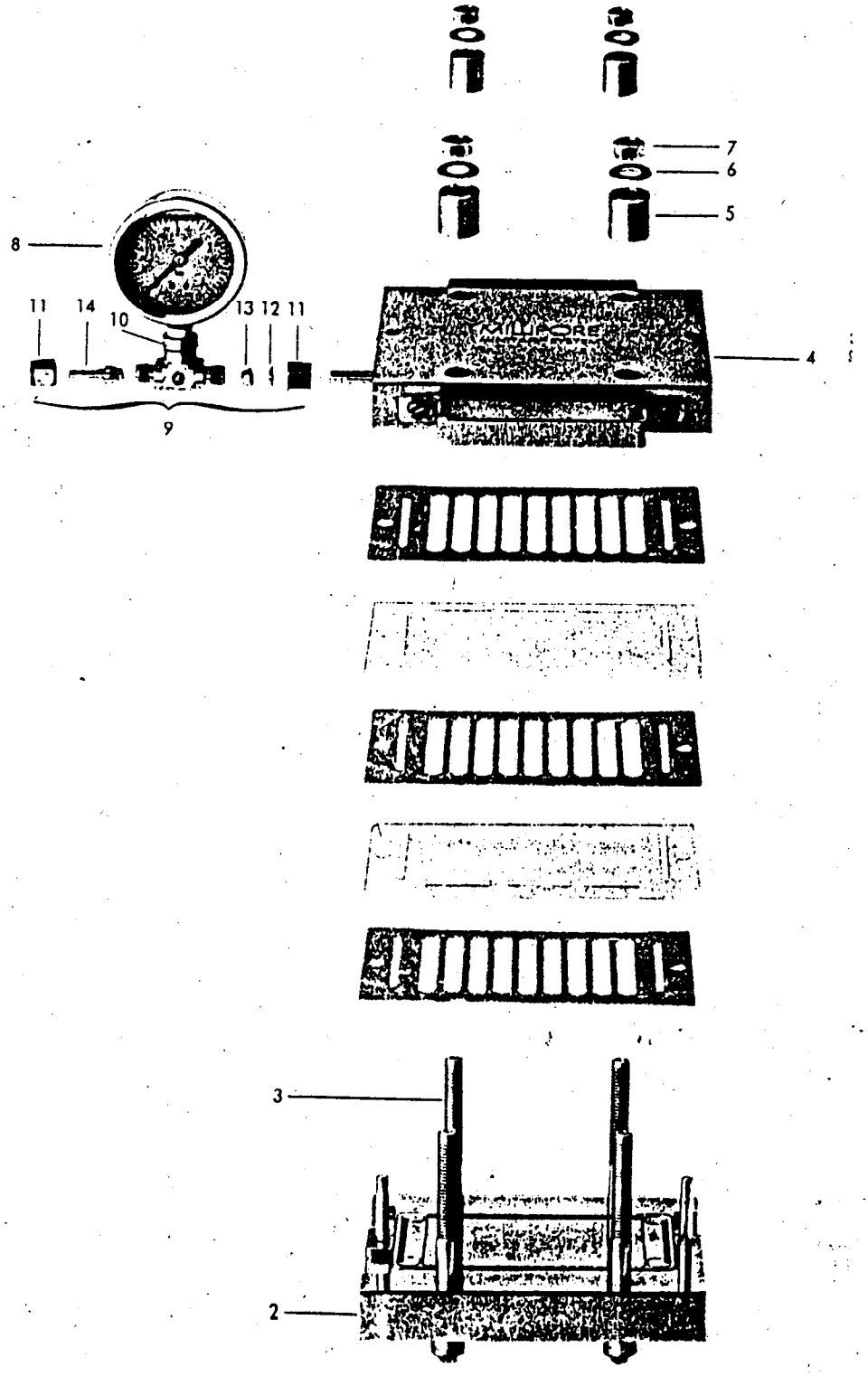


Fig. 1 Esquema completo de la célula Minitan.

Placas filtrantes : microporosas (MF) y de ultrafiltración (UF)

Una placa filtrante Minitan consta de dos láminas de membrana unidas a una estructura rígida de soporte. El diseño exclusivo del Minitan permite el apilamiento de entre 1 y 10 placas para adaptarse a diferentes exigencias en cuanto a caudal o volumen inicial.
Las placas se apilan en disposición alternativa para crear un caudal de retenido "en serie".
Este método de apilado de placas filtrantes permite el aumento de superficie sin comprometer la velocidad del flujo tangencial.
Nota : sólo pueden usarse simultáneamente placas filtrantes de un tipo.

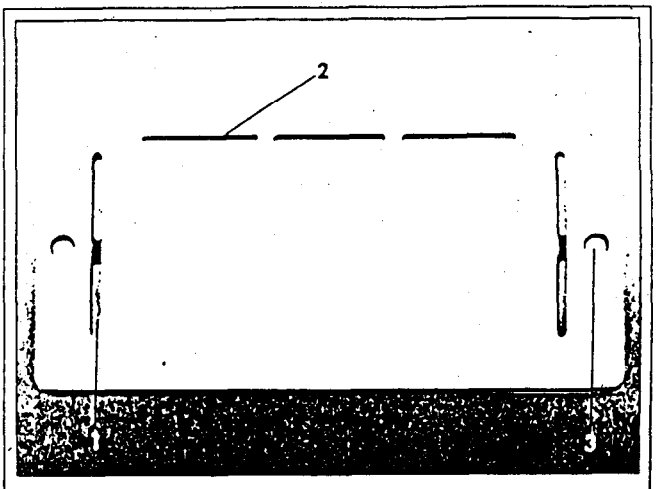


Fig. 2 Placas filtrantes Minitan.

1 Canales de filtrado (dos en cada placa)
2 Canales de retenido (tres en cada placa)
3 Orificios de centrado (dos en cada placa)

Guía de selección de placas

Membranas de ultrafiltración

Referencia y material	Retención nominal (PMNL)	Aplicaciones
PTGC OMP 04 Polisulfona	10.000	Concentración de proteínas, eliminación de pirógenos, desalinización de proteínas
PTTK OMP 04 Polisulfona	30.000	Clarificación de péptidos, concentración de proteínas de gran tamaño
PTHK OMP 04 Polisulfona	100.000	Clarificación de péptidos, concentración de virus y anticuerpos, recogida de células
PTMK OMP 04 Polisulfona	300.000	Purificación de virus, recogida de células

Membranas microporosas

Referencia y material	Tamaño de poro (µm)	Aplicaciones
VVLP OMP 04 Durapore®	0,1	Recogida y lavado de células, clarificación de soluciones de proteínas
GVLP OMP 04 Durapore	0,2	Recogida y lavado de células, clarificación de soluciones de proteínas
HVLP OMP 04 Durapore	0,45	Recogida y lavado de células, clarificación de soluciones de proteínas
DVLP OMP 04 Durapore	0,65	Recogida y lavado de células, clarificación de soluciones de proteínas

VII. ANNEX 2. FINAL CONFIGURATION COMMERCIAL LEAFLETS

WESTFALIA SEPARATOR

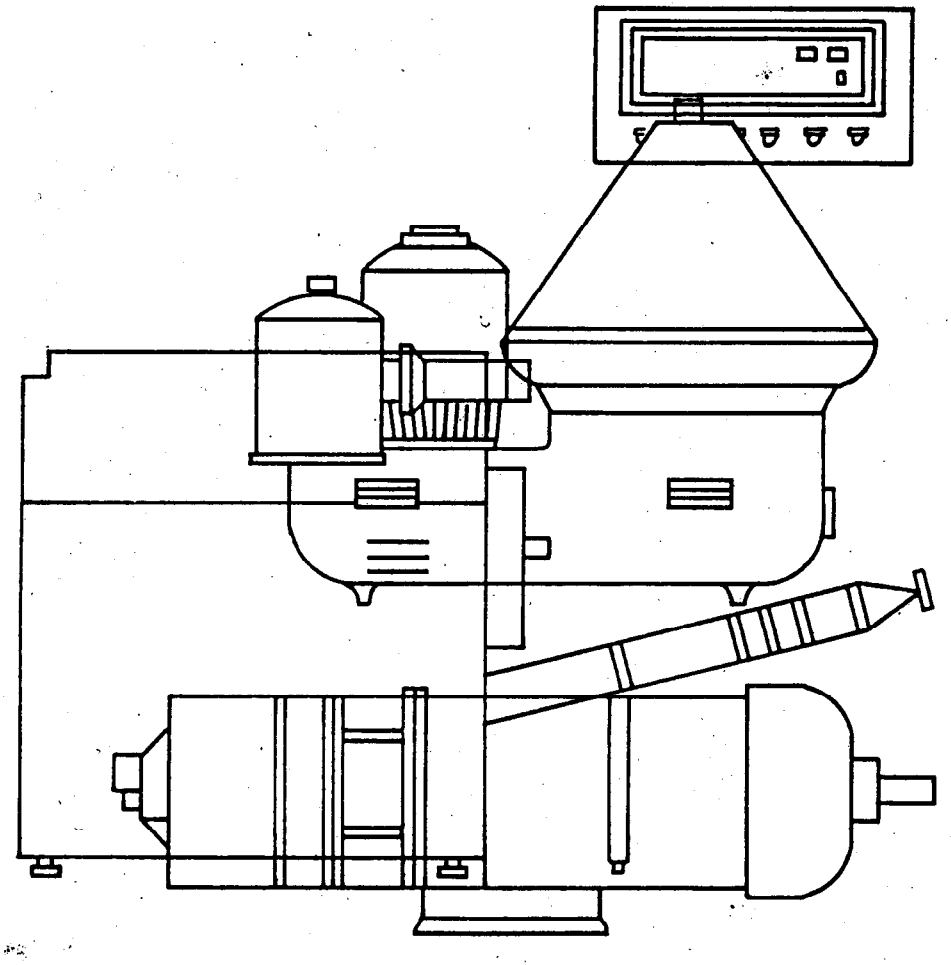
Manual de instrucciones y lista de piezas de recambio

No. 3139-9005-000

Edición 0287

Centrífuga clarificadora
con tambor autodesiodante en
ejecución esterilizable a vapor

Tipo CSA 1-06-475



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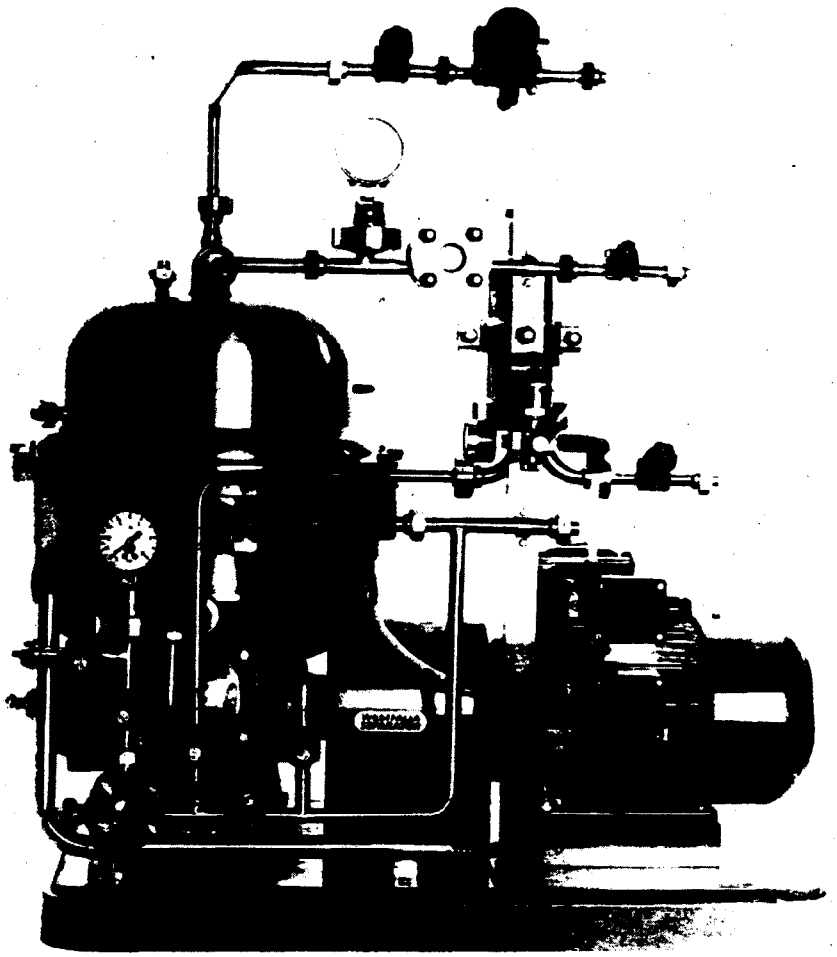
Printed in West Germany

WESTFALIA SEPARATOR

Centrífuga clarificadora
con tambor autodeslodante en
ejecución esterilizable a vapor

Tipo CSA 1-06-475



La centrífuga es una máquina especial de alta velocidad que funciona con seguridad absoluta siempre y cuando se sigan cuidadosamente las instrucciones de manejo y mantenimiento dadas en el presente manual.

Es preciso seguir exactamente las instrucciones para la puesta en marcha y parada de la máquina, así como para su mantenimiento y reparaciones.

La velocidad de rotación del tambor ha sido establecida de acuerdo con la densidad de los sólidos centrifugados y del líquido clarificado, entre otros factores.

El número de revoluciones del tambor y las densidades máximas admisibles se indican en la placa de características de la centrífuga.

Para el tratamiento de productos cuya densidad sea superior a la señalada en la placa de características, es preciso consultar a Westfalia Separator.

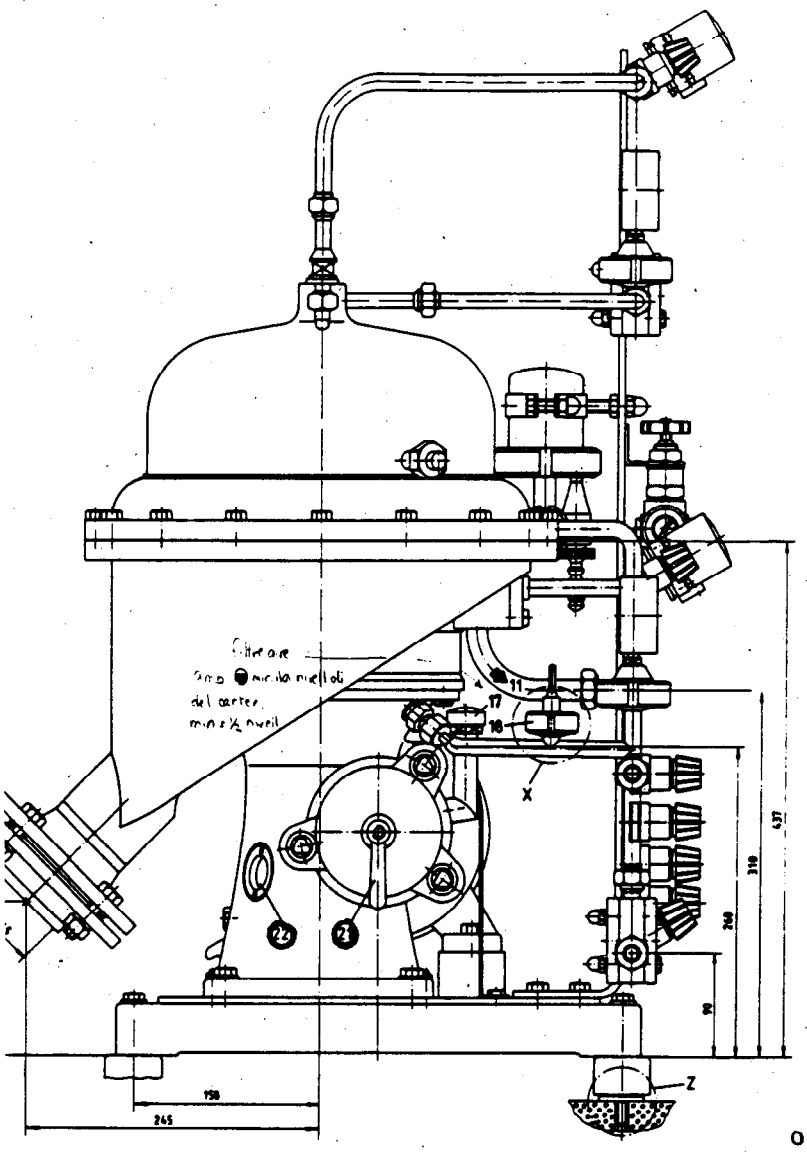
El contenido en sólidos del producto a centrifugar debe permanecer lo más constante posible.

Al montar las piezas del tambor deberá procederse siguiendo exactamente las instrucciones del presente manual, a fin de evitar desequilibrios inaceptables, ya que éstos pueden causar **graves daños.**

Los productos con propiedades corrosivas o erosivas pueden, especialmente cuando se trabaja a temperaturas elevadas, atacar el material del tambor incluso después de poco tiempo, circunstancia ésta que reduce la seguridad de servicio.
A fin de eliminar este riesgo deben revisarse todas las piezas del tambor, prestando particular atención a las roscas de la parte inferior del tambor y del anillo de cierre del tambor, así como a los tabiques comprendidos entre los orificios de salida de lodos de la parte inferior del tambor.

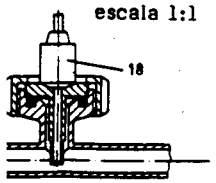
Recomendamos hacer revisar periódicamente la centrífuga por nuestros técnicos. Las inspecciones periódicas contribuyen a conservar la seguridad de servicio y evitan interrupciones en el mismo.

Cuando se precise una reparación del tambor, podemos alquilar al cliente un tambor mientras duren los trabajos de reparación.

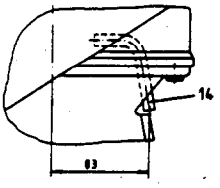


1 Alimentación de producto
2 Válvula de membrana con actuador neumático
3 Salida de producto
4 Válvula de presión constante
5 Mirilla
6 Filtro de aire esterilizado
7 Salida de agua de refrigeración del capó
8 Entrada de agua de refrigeración del capó
9 Entrada de agua de maniobra y agua de obturación
10 Válvula de membrana con actuador neumático
11 Salida agua de maniobra
12 Líquido de obturación para retén deslizante (entrada)
13 Líquido de obturación (salida)
14 Líquido de fugas
15 Conexiones para retén deslizante
16 Caja de bornes para motor
17 Filtro de aire (engranaje)
18 Controlador de caudal
19 Mirilla en la salida de líquido de obturación y agua de maniobra
20 Salida de líquido de obturación y agua de manibora
21 Freno
22 Mirilla de inspección de aceite
23 Salida de sólidos
24 Aireación y desaireación
25 Válvulas piloto para pos. 2 + 10
26 Caja de bornes para controlador de caudal, pos. 18

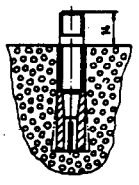
OL: * Controlar el estranglament (Canviar cada 750h/6mesos)
* Si té aspecte cremós => conté H2O => s'ha de canviar
Es pot purgar una mica



le X
escala 1:1



Vista Y



Detalle Z
escala 1:1

Motor sentit horari /màx - 10.000 rpm/ arrancada = 2 min

Desviación admisible para las cotas sin especificación de tolerancias según D DIN 8570

5.1 Principio de funcionamiento del tambor

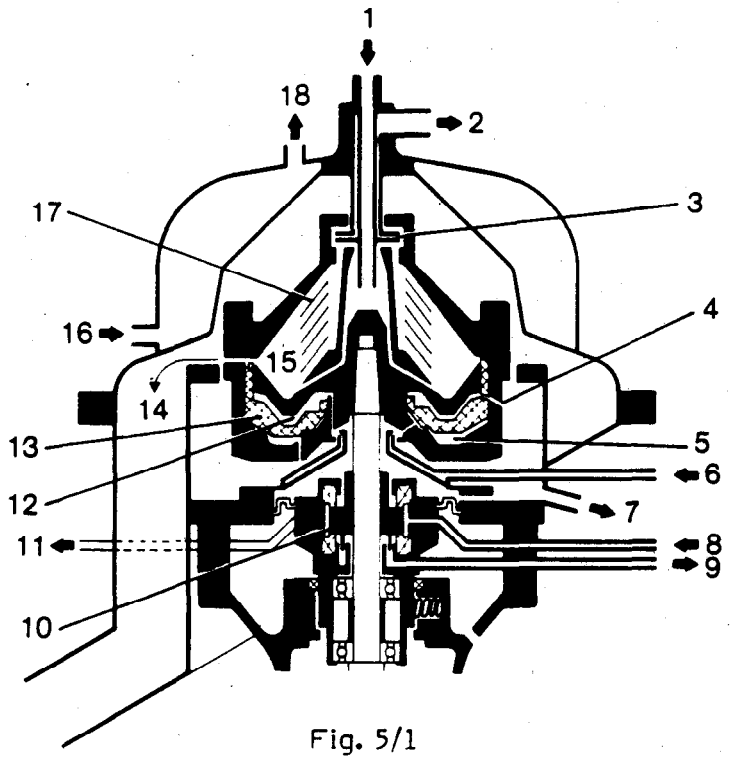


Fig. 5/1

1 Alimentación
2 Salida
3 Rodete
4 Orificio de salida
5 Cámara de cierre
6 Entrada agua de maniobra
7 Salida agua de maniobra
8 Entrada agua de obturación
9 Salida líquido de fuga
10 Retén deslizante
11 Salida agua de obturación
12 Cámara de apertura
13 Pistón deslizante
14 Rendija de expulsión de sólidos
15 Recinto de lodos
16 Entrada agua de refrigeración
17 Juego de platos
18 Salida agua de refrigeración

El producto a centrifugar entra en el tambor por la alimentación (1) y pasa al juego de platos (17), donde tiene lugar la clarificación. El líquido clarificado es vehiculado por el rodete (3) hacia la salida (2), a presión y sin espuma.

Los sólidos separados se acumulan en el recinto de lodos (15), siendo expulsados a intervalos periódicos a través de la rendija (14). Un programador de tiempos dirige los ciclos de descarga. El agua de maniobra se precisa únicamente durante las descargas.

La alimentación y la descarga del producto se efectúan mediante sistema de tuberías cerrado. Para observar el producto se ha incorporado una mirilla en la línea de salida. El caudal y la presión se ajustan mediante válvula de membrana y válvula de presión constante.

La distribución de vapor para las diversas fases de esterilización se realiza igualmente a través de válvulas de membrana.

5.2 Generalidades sobre las descargas del tambor

Intervalos de descarga

La duración de los intervalos en que ha de efectuarse la descarga del tambor depende del contenido en sólidos y del tipo de producto de alimentación. En cuanto sea posible, el recinto de lodos no debe llenarse por completo. Tan pronto como empiece a disminuir el grado de clarificación, deberá realizarse una descarga total o una parcial. En las descargas totales se expulsa todo el contenido del tambor, mientras que en las parciales sólo se evacúa parte del contenido del recinto de lodos. El comportamiento mecánico de los sólidos durante las descargas del tambor determina si ha de efectuarse una descarga parcial, una total o un programa combinado.

Antes de cada descarga total debe cerrarse la alimentación de producto a la centrífuga.

Desplazamiento

En todas las descargas totales se produce inevitablemente cierta pérdida de producto, la cual en muchos casos puede reducirse a un mínimo si se desplaza el líquido fuera del tambor antes de que comience la expulsión de lodos, utilizando agua o un líquido adecuado. Esta operación es importante tratándose de productos especialmente valiosos.

El caudal de alimentación del líquido de desplazamiento debe ser igual al utilizado para el producto.

La duración de la alimentación de líquido de desplazamiento se determinará por ensayo.

Enjuague

En aquellos casos en que no se puede expulsar completamente los sólidos y queden restos fuertemente adheridos a las paredes del recinto de lodos, bien sea porque los sólidos han permanecido mucho tiempo en el interior del tambor o bien a causa de su propia naturaleza, deberá reducirse el tiempo de centrifugación o deberá llevarse a cabo un enjuague con posterioridad a cada descarga total, llenando de líquido el tambor y volviendo a desenlodar.

Programación automática

La programación automática permite efectuar:

- descargas parciales
- descargas totales
- programa combinado de descargas parciales y totales
- desplazamiento de la fase líquida del tambor antes de una descarga total
- descargas de enjuague después de cada descarga total.

Para más detalles, ver el manual de instrucciones del programador de tiempos.

5.3 Modo de funcionamiento del sistema hidráulico del tambor

El agua de maniobra alimentada produce en el interior del tambor en rotación una elevada presión a causa de la fuerza centrífuga. Dicha presión se utiliza para accionar el pistón deslizante F (fig. 5/2), que puede desplazarse axialmente, cerrando y abriendo el tambor.

Los tiempos de apertura de la válvula de agua de maniobra son:

para una descarga parcial: 1,5 - 2 segundos

para una descarga total: 10 segundos

7.1 Limpieza química CIP

Es posible efectuar una limpieza química CIP de la centrífuga (CIP = cleaning-in-place).

El líquido de limpieza se bombea en circuito cerrado a través de la centrífuga y el circuito asociado.

El programa de limpieza química CIP debe incluir las siguientes etapas:

1. Lavado con lejía (p. ej. con hidróxido sódico NaOH al 2 % - hidróxido sódico sin cloruro)
2. Enjuague con agua
3. Lavado con ácido (neutralización con una disolución de HNO_3 del 0,5 %)
4. Enjuague con agua

Las etapas 1 - 4 finalizan siempre con una descarga total.

ATENCION: Emplear únicamente detergentes de probada eficacia.

Ejemplos:	Henkel	Lejía al 2% (P3 Super LA)
	Bayer	Lejía al 2% (Trosilin M alkalina)
		Solución ácida al 0,5% (Trosilin M ácida)

7.2 Limpieza manual del tambor

Por lo general no es necesario desarmar los tambores autodeslodantes para limpiarlos una vez terminada la centrifugación, a menos que así lo exija el tipo de producto centrifugado. La frecuencia con que debe limpiarse el tambor depende del producto y sólo puede determinarse en la práctica.

En los primeros meses después de haber puesto en servicio la centrífuga conviene desatornillar cada dos semanas aproximadamente los anillos de cierre y engrasar las roscas a fin de que los anillos no se agarroten.

Este espacio de tiempo puede prolongarse posteriormente de acuerdo con la experiencia adquirida. No obstante, se debe **desarmar el tambor por lo menos cada dos meses** para limpiar sus piezas interiores.

Al limpiar los platos y piezas del tambor

no deben emplearse raspadores ni cepillos metalicos.

Quitar las juntas de las piezas del tambor. Limpiar las juntas y las ranuras de alojamiento para evitar corrosiones en las ranuras. Sustituir inmediatamente las juntas dañadas o muy hinchadas.

Los pequeños conductos de la parte inferior del tambor previstos para el entrada y salida del agua de maniobra (fig. 10), deben limpiarse con especial cuidado a fin de que las descargas se desarrollen sin dificultad.

Engrasar las superficies de guía y las roscas de las piezas del tambor una vez que estén secas (ver 2.2). Untar con aceite el cono del eje vertical y el interior del cubo del tambor, y **limpiarlos y secarlos** con un trapo.

Montar de nuevo las piezas del tambor inmediatamente se termine la limpieza.

- Admisión de aire esterilizado a través de la alimentación de producto (3) con una sobrepresión p máx. = 1,5 bar.

- Cerrar la válvula de membrana (11).

Si la centrífuga **no** se pone bajo aire esterilizado al concluir la esterilización, abrir la válvula de membrana (11).

6.5.3 Enfriamiento con aire esterilizado

En la fase de enfriamiento se envía aire esterilizado a la centrífuga.
De esta forma:

- se evita la formación de depresión
- se mantiene la sobrepresión por el intercambio de la fase de vapor mediante aire esterilizado, evitándose la penetración de bacterias ajenas.

3ª Fase

— **aire esterilizado**

— **agua esterilizada**

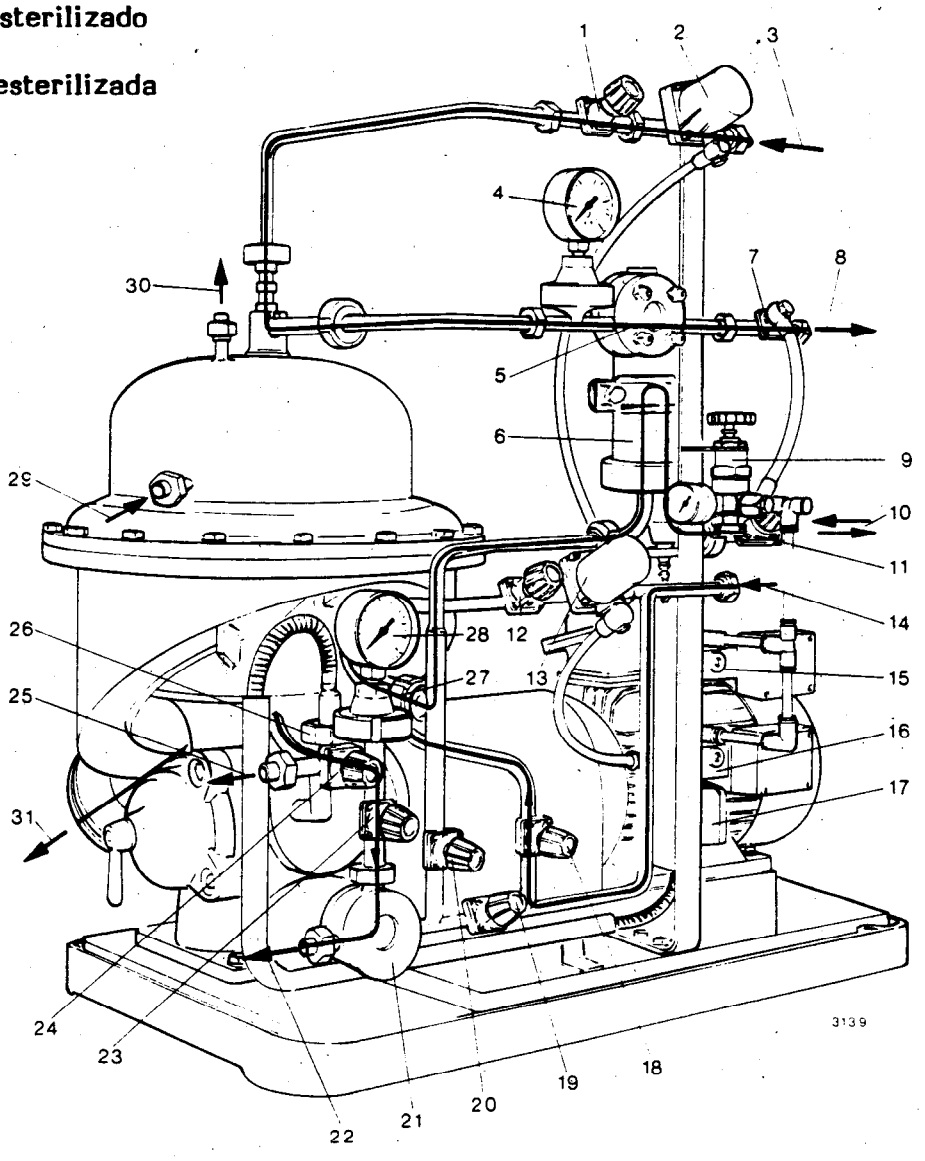


Fig. 6/9

- Al finalizar la segunda fase, enviar agua esterilizada al retén de anillos deslizantes.
  Estrangular la válvula de membrana (24) y ajustar una presión p = 1 - 1,5 bar.
  Observar el manómetro (28).
  Cerrar la válvula de membrana (23).

2. **Admisión de vapor por la entrada de agua de maniobra y agua de obturación (14)**

- Abrir la válvula de membrana (12).
- Abrir la válvula de membrana (13) de la manera descrita en el punto 1.
- Abrir las válvulas de membrana (19, 20).

La cámara de obturación del retén de anillos deslizantes deberá mantenerse bajo presión durante la segunda fase, a fin de garantizar la hermeticidad del retén de anillos deslizantes.

- Las válvulas de membrana (18, 23) permanecen abiertas.
- Cerrar la válvula de membrana (24).

Para la esterilización del filtro de aireación y desaireación (6):

- Abrir ligeramente la válvula de membrana (11), para obtener una mínima salida de vapor.
- Purgar periódicamente el condensado por el grifo de purga de agua del filtro de aireación y desaireación.

6.5.2 Esterilización de la centrífuga

2ª Fase

— Vapor

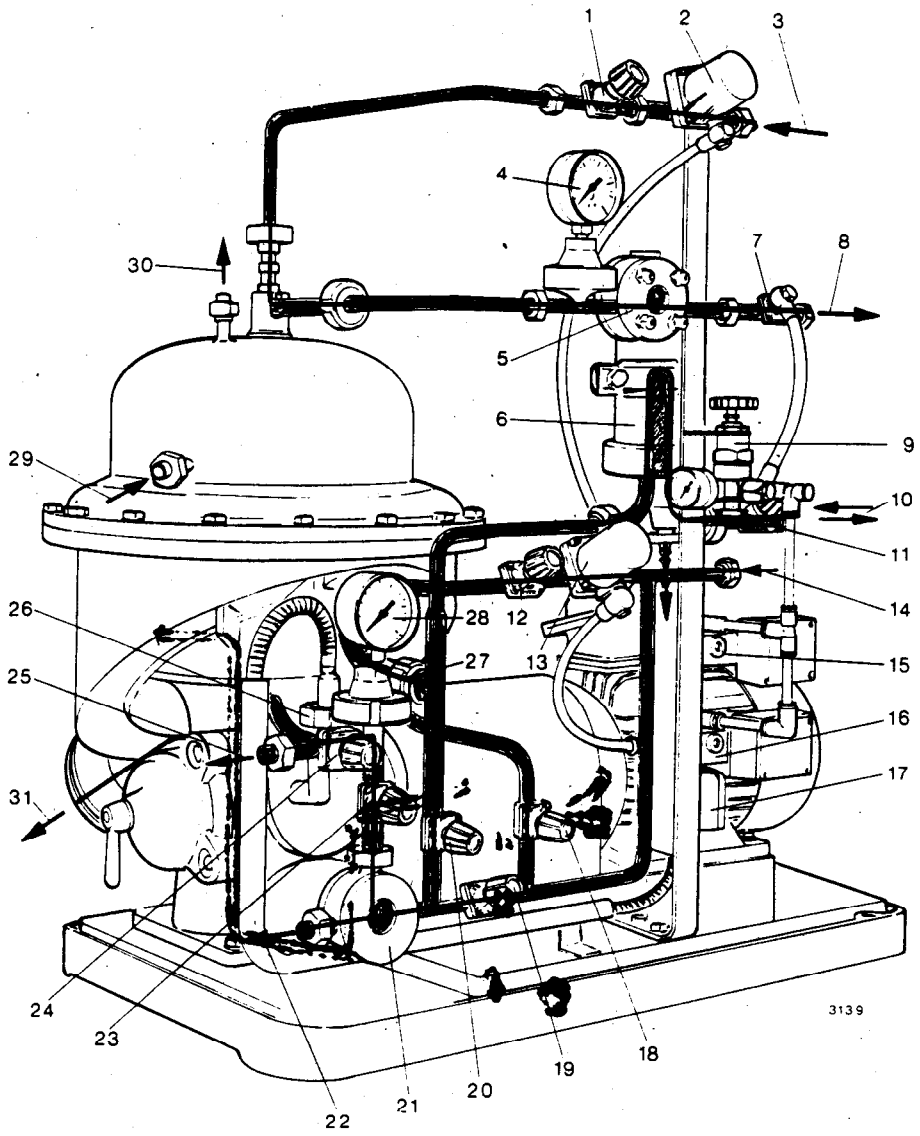


Fig. 6/7

1. Admisión de vapor por la alimentación de producto (3)

- Abrir la válvula de membrana (1).
- Abrir la válvula de membrana (2), accionando para ello el dispositivo manual de la electroválvula (15).

  Oprimir el dispositivo de accionamiento manual y girarlo 90° a la derecha.

  El dispositivo queda retenido.
- Evacuación de vapor por la salida de producto (8).

6.5.1 Esterilización de la cámara de obturación del retén de anillos deslizantes

1ª Fase

— Vapor

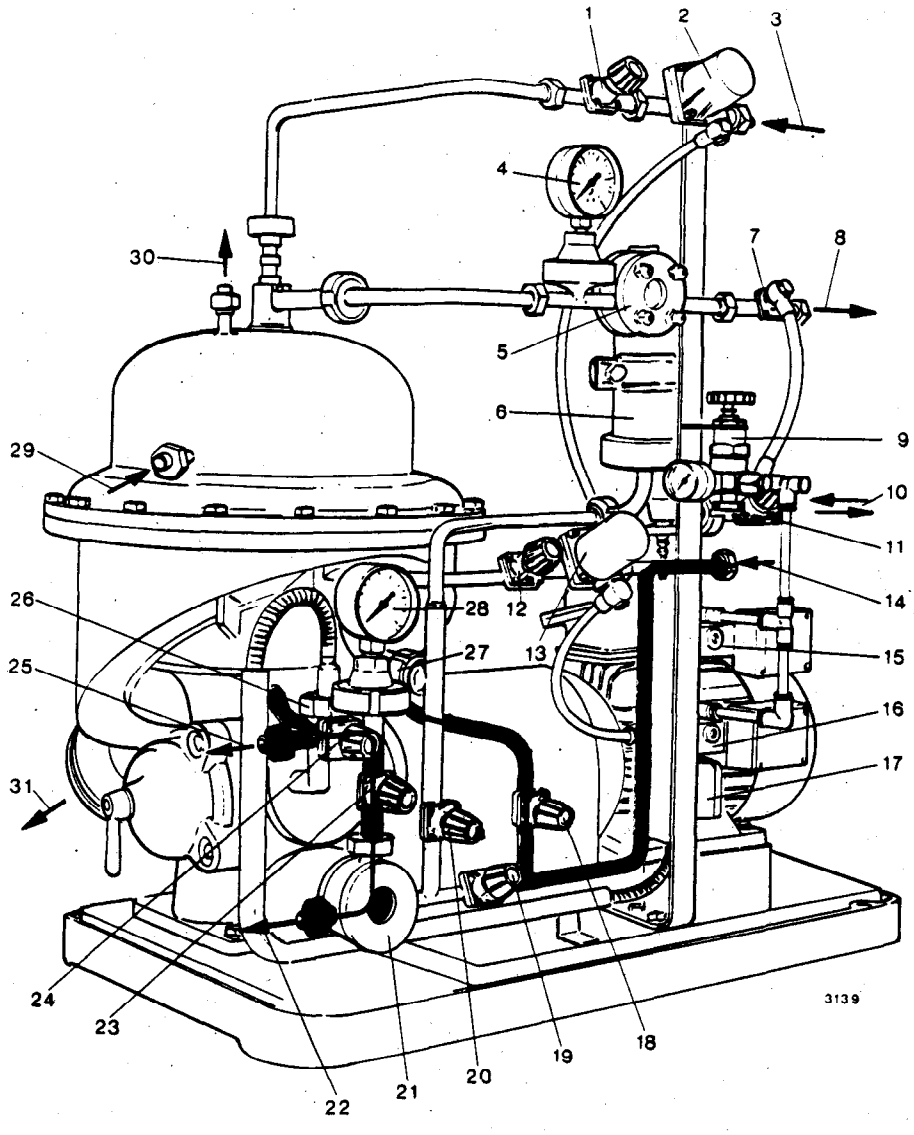


Fig. 6/6

- Admisión de vapor por la entrada de agua de maniobra y de agua de obturación (14).
- Cerrar las válvulas de membrana (12, 19, 20); la válvula de membrana (13) se encuentra cerrada cuando no pasa corriente.
- Abrir las válvulas de membrana (18, 23).
- Abrir ligeramente la válvula de membrana (24) para obtener una mínima salida de vapor.

L/S™ Variable-Speed Console Drives

A) New Economy Drives

Our lowest priced variable-speed drives are a perfect upgrade from a fixed-speed drive. These drives improve upon our previous economy drives to include a wider rpm range, better speed regulation (±5%), and UL, cUL, and CE listings.

- **Flow: 0.42 to 2900 ml/min (0.0042 to 2300 ml/min with cartridge pump head)**
  Flow rate depends on drive rpm and tubing size; please refer to table on facing page
- **Separate single-turn speed control and on/off switch with green power indicator**
  Turn drive on and off while maintaining speed setting
- **The 1/20-hp unidirectional motor has soft start and back EMF for ±5% speed control**
  Promotes smooth operation and long service life
- **Stackable painted steel housing is IP22 rated**
  Housing protects drive from water falling from directly above
- **All 115 VAC models are UL and cUL listed; all 230 VAC models comply with CE regulations**
  230 VAC drives conform to design and manufacturing standards of the European community
- **6-ft (1.8-m) line cord— U.S. standard plug on 115 VAC models, IEC 320/CEE22 socket on 230 VAC models**
  230 VAC models are shipped with country specific plug/cord set, please specify ultimate destination when ordering
- **Drive accepts eight different pump head types**
  Standard, EASY-LOAD®, EASY-LOAD® II, QUICK LOAD®, High-Performance, Cartridge, PTFE-Tubing, PTFE-Diaphragm

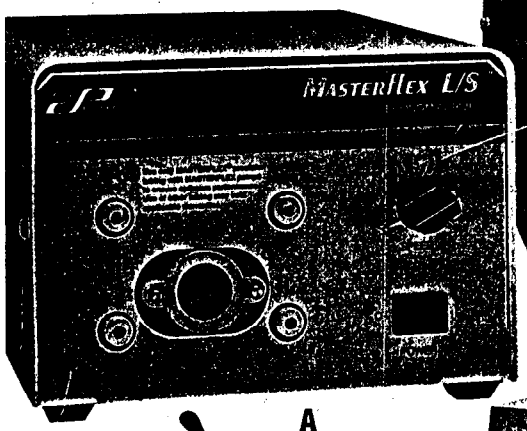
NOTE: Economy drives 07554-90, -95 cannot be used with the PTFE-Tubing and PTFE-Diaphragm pump heads due to insufficient torque. These drives can be used with the High-Performance and Cartridge heads when loaded with silicone or C-FLEX® tubing only.

B) Standard Drives

These variable-speed drives feature a reversible 1/10-hp motor. The strong motor drives up to four pump heads (depending on model). A convenient handle makes these drives easy to carry.

- **Flow: 0.06 to 3400 ml/min (0.0006 to 2300 ml/min with cartridge pump head)**
  Flow rate depends on drive rpm and tubing size; please refer to table on facing page
- **Reversible motor**
  Purge tubing before or after pumping; pump in either direction
- **Separate single-turn speed control and on/off/reverse switch with green LED power indicator**
  Turn drive on and off while maintaining speed setting
- **The 1/10-hp reversible motor has soft start and back EMF for ±5% speed control**
  Promotes smooth operation and long service life
- **Stackable painted steel housing is IP22 rated**
  Housing protects drive from water falling from directly above
- **6-ft (1.8-m) line cord— U.S. standard plug on 115 VAC models, European plug on 230 VAC models**
  Drives are ready to use without special wiring
- **Drive accepts eight different pump head types**
  Standard, EASY-LOAD®, EASY-LOAD® II, QUICK LOAD®, High-Performance, Cartridge, PTFE-Tubing, PTFE-Diaphragm

B
Standard drive 07520-00



new. **A**
Economy drive 07554-80

C
Precision standard drive 07520-40 with single-turn speed control

10-turn potentiometer of "D" drives

A, C, and D are...

C) Precision Standard Drives

Our best analog console drives have ±1% speed control for precise flow regulation—ideal for metering applications. A convenient carry handle is molded into the housing.

- **Flow: 0.06 to 3400 ml/min (0.0006 to 2300 ml/min with cartridge pump head)**
  Flow rate depends on drive rpm and tubing size; please refer to table on facing page
- **Reversible motor**
  Purge tubing before or after pumping; pump in either direction
- **Separate single-turn speed control and on/off/reverse switch with inertia center and green LED power indicator**
  Turn drive on and off while maintaining speed setting; inertia center prevents inadvertent reversing
- **The 1/10-hp reversible motor has soft start and back EMF for ±1% speed control**
  Promotes smooth operation and long service life
- **Stackable ABS plastic housing is splash- and fire-resistant and is IP53 rated**
  Housing protects drive from dust and mild water spray
- **6-ft (1.8-m) line cord— U.S. standard plug on 115 VAC models, IEC 320/CEE22 socket on 230 VAC models**
  230 VAC models are shipped with country specific plug/cord set, please specify ultimate destination when ordering
- **Drive accepts eight different pump head types**
  Standard, EASY-LOAD®, EASY-LOAD® II, QUICK LOAD®, High-Performance, Cartridge, PTFE-Tubing, PTFE-Diaphragm

D) Precision Standard Drives with 10-Turn Speed Control and Remote Capabilities

Drive models 07521-40, -47, -50, and -57 are identical to the "C" models above but also include a 10-turn speed control and remote capabilities.

- **10-turn speed control includes indexing marks**
  Tune in precise flow rates; indexing on speed control aids repetition of the same flow rate
- **Remote control capabilities via DB9 female connector on back of drive**
  Speed control (±3% linearity): requires 4-20 mA input (<4 mA stops drive)

  Start/stop: Requires interface box 07595-50 and power supply 05985-10 (115 VAC) or 05985-12 (230 VAC) all sold separately below. Interface box and power supply enable start/stop via contact closure, open collector, 5 V TTL, or footswitch 07595-35 sold separately below.

Remote Control Accessories

E-07595-45 Connector, DB9 male. Use for 4-20 mA remote control. Wire only the pins needed...$23.50
E-07595-50 Interface box. Requires DC power supply. Includes DB9 male drive connection cable. Accepts ¼" phone plug $118.00
E-05985-10 DC power supply; 115 VAC, 50/60 Hz, U.S. standard plug $29.50
E-05985-12 DC power supply; 230 VAC, 50/60 Hz, European plug.....$29.50
E-07595-35 Footswitch, ¼" phone plug $76.50

DON'T FORGET TO ORDER...
- *L/S™ Pump Heads.....812-822*
- *L/S™ Tubing 823-826*

Flow Rates in ml/min (flow rates in parentheses can only be obtained with the High-Performance pump head)

rpm	Precision tubing						High-performance precision tubing			
	L/S™ 13	L/S™ 14	L/S™ 16	L/S™ 25	L/S™ 17	L/S™ 18	L/S™ 15	L/S™ 24	L/S™ 35	L/S™ 36
	Fits Standard*, EASY-LOAD, EASY-LOAD II, QUICK-LOAD, or Cartridge* pump heads									
							Fits EASY-LOAD II or High-Performance pump heads			
(A) New economy drives										
20 to 600	1.2 to 36	4.2 to 130	16 to 480	34 to 1000	56 to 1700	76 to 2300	34 to 1000 (—)	56 to 1700 (—)	76 to 2300 (—)	96 to 2900 (—)
7 to 200	0.42 to 12	1.4 to 43	5.6 to 160	12 to 330	20 to 570	27 to 770	12 to 330 (13 to 370)	20 to 570 (21 to 600)	27 to 770 (30 to 870)	34 to 970 (41 to 1130)
(B) Standard drives										
6 to 600	0.36 to 36	1.3 to 130	4.8 to 480	10 to 1000	17 to 1700	23 to 2300	10 to 1000 (11 to 1100)	17 to 1700 (18 to 1800)	23 to 2300 (26 to 2600)	29 to 2900 (34 to 3400)
1 to 100	0.06 to 6	0.21 to 21	0.8 to 80	1.7 to 170	2.8 to 280	3.8 to 380	1.7 to 170 (1.8 to 180)	2.8 to 280 (3.0 to 300)	3.8 to 380 (4.3 to 430)	4.8 to 480 (5.8 to 580)
(C,D) Precision standard drives and precision standard drives with 10-turn speed control and remote control capabilities										
6 to 600	0.36 to 36	1.3 to 130	4.8 to 480	10 to 1000	17 to 1700	23 to 2300	10 to 1000 (11 to 1100)	17 to 1700 (18 to 1800)	23 to 2300 (26 to 2600)	29 to 2900 (34 to 3400)
1 to 100	0.06 to 6	0.21 to 21	0.8 to 80	1.7 to 170	2.8 to 280	3.8 to 380	1.7 to 170 (1.8 to 180)	2.8 to 280 (3.0 to 300)	3.8 to 380 (4.3 to 430)	4.8 to 480 (5.8 to 580)
3 to 300	0.36 to 18	1.3 to 65	4.8 to 240	10 to 500	17 to 850	23 to 1150	10 to 500 (11 to 550)	17 to 850 (18 to 900)	23 to 1150 (26 to 1300)	29 to 1450 (34 to 1700)

*Standard pump head is not available for L/S™ 25 tubing. Cartridge pump heads DO NOT accept L/S™ 15 and L/S™ 24 tubing, but DO accept microbore tubing.

Specifications and Ordering Information (for all drives on these two pages)

Catalog number	rpm	Speed control	Pump heads accepted	Motor size	IP rating	Dimensions (L x W x H)	Shpg wt	Power (50/60 Hz)	Price
(A) New economy drives									
E-07554-90	20 to 600	±5%	1	1/20 hp (37 W)	IP22	9" x 7" x 6" (22.9 cm x 17.8 cm x 15.2 cm)	8.0 lbs (3.7 kg)	90 to 130 VAC, 1.5 A	$429.00
E-07554-95								180 to 260 VAC, 0.8 A	453.00
E-07554-80	7 to 200		2					90 to 130 VAC, 1.5 A	429.00
E-07554-85								180 to 260 VAC, 0.8 A	453.00
(B) Standard drives									
E-07520-00	6 to 600	±5%	2	1/10 hp (75 W)	IP22	12¾" x 6½" x 5⅞" (32.4 cm x 16.5 cm x 14.9 cm)	14.3 lbs (6.5 kg)	90 to 130 VAC, 1.5 A	617.00
E-07521-00								200 to 260 VAC, 0.8 A	617.00
E-07520-10	1 to 100		4					90 to 130 VAC, 1.5 A	617.00
E-07521-10								200 to 260 VAC, 0.8 A	617.00
(C) Precision standard drives									
E-07520-40	6 to 600	±1% (1-turn speed control)	2	1/10 hp (75 W)	IP53	11½" x 7" x 7" (29.2 cm x 17.8 cm x 17.8 cm)	15.0 lbs (6.9 kg)	90 to 130 VAC, 1.5 A	711.00
E-07520-47								190 to 260 VAC, 0.8 A	747.00
E-07520-50	1 to 100		4					90 to 130 VAC, 1.5 A	711.00
E-07520-57								190 to 260 VAC, 0.8 A	747.00
E-07520-60	6 to 300		2					90 to 130 VAC, 1.5 A	711.00
E-07520-67								190 to 260 VAC, 0.8 A	747.00
(D) Precision standard drives with 10-turn speed control and remote control capabilities									
E-07521-40	6 to 600	±1% (10-turn speed control)	2	1/10 hp (75 W)	IP53	11½" x 7" x 7" (29.2 cm x 17.8 cm x 17.8 cm)	13.5 lbs (6.2 kg)	90 to 130 VAC, 1.5 A	799.00
E-07521-47								190 to 260 VAC, 0.8 A	835.00
E-07521-50	1 to 100		4					90 to 130 VAC, 1.5 A	799.00
E-07521-57								190 to 260 VAC, 0.8 A	835.00

L/S P T D

2 YEAR WARRANTY

ISO 9001 VENDOR CERTIFIED

A New Way to Order a Complete Pump

new

In response to your suggestions, we have simplified ordering of a complete pump. Now you can purchase a pump head, tubing, and drive with just one catalog number.

Complete Pump

E-77910-10 L/S Economy Pump, 115 VAC, 50/60 Hz. Shpg wt 12.0 lbs (5.5 kg) $635.00

E-77910-15 L/S Economy Pump, 230 VAC, 50/60 Hz. Shpg wt 12.0 lbs (5.5 kg) $658.00

What's included

- EASY-LOAD® pump head 07518-12 (page 814)
- 10-ft (3-m) of Tygon® LFL L/S™ 24 tubing 06429-24 (pages 804-809)
- 20 to 600 rpm economy drive model 07554-90 (115 VAC) or model 07554-95 (230 VAC) (pages 832-833)

E-77910-10 = E-07518-12 + E-06429-24 + E-07554-90
E-77910-15 = E-07518-12 + E-06429-24 + E-07554-95

Complete Pump

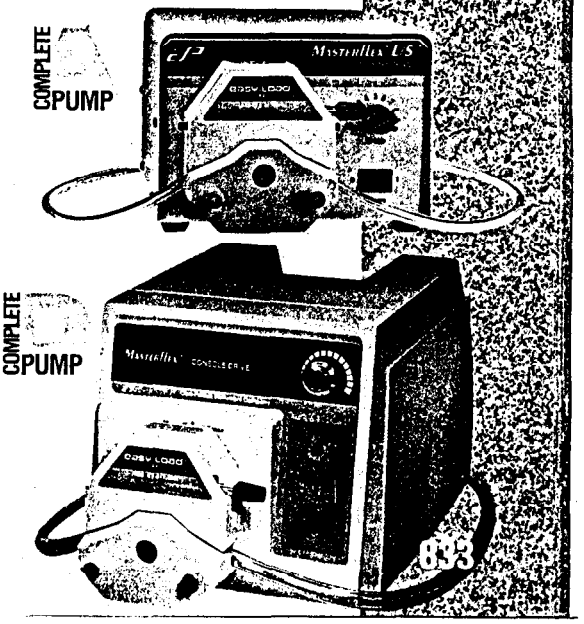
E-77911-00 L/S Precision Standard Pump, 115 VAC, 50/60 Hz Shpg wt. 16.0 lbs (7.3 kg).....$1010.00

E-77911-07 L/S Precision Standard Pump, 230 VAC, 50/60 Hz Shpg wt. 16.0 lbs (7.3 kg).....$1040.00

What's included

- EASY-LOAD® pump head 07518-12 (page 814)
- 10-ft (3-m) of Tygon® LFL L/S™ 24 tubing 06429-24 (pages 804-809)
- 6 to 600 rpm precision standard drive model 07521-40 (115 VAC) or model 07521-47 (230 VAC) (pages 832-833)

E-77911-00 = E-07518-12 + E-06429-24 + E-07521-40
E-77911-07 = E-07518-12 + E-06429-24 + E-07521-47

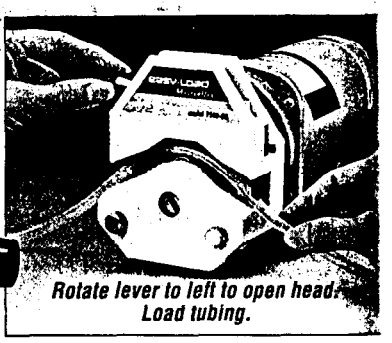


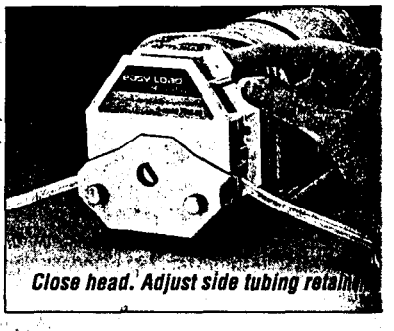
L/S™ easy-load® Pump Heads

These pump heads let you load tubing easily for faster tubing changes and reduced maintenance time. The patented unique design combines an overcenter cam with adjustable tubing retention to hold tubing securely in place. Choose pump head style "A" for precision tubing or pump head style "B" for high-performance precision tubing.

- **PSF housing with CRS or SS rotor, or PPS housing with SS rotor available**
  PPS has better chemical resistance than PSF; SS rotors are more durable than CRS rotors
- **Fast tubing loading and unloading**
  Ideal for applications that require frequent tubing changes; OEM discounts available
- **Manually adjustable side retainers**
  Adjust to hold tubing securely in place
- **Single-channel mounting hardware and a 15" (38-cm) length of silicone tubing are included (order replacement hardware below)**
  Pump head comes ready for mounting to drive
- **Two-, three-, and four-channel mounting hardware available (order separately below)**
  Mount up to four pump heads on a single drive; see individual drive specifications for maximum number of heads that can be mounted

EASY-LOAD pump head 07518-00


Rotate lever to left to open head. Load tubing.


Close head. Adjust side tubing retain

A) EASY-LOAD Pump Heads for Precision Tubing

Each EASY-LOAD pump head for precision tubing accepts all six precision tubing sizes, enabling a wide range of flow rates from a single pump head.

- **Flow rates:** 0.06 to 2300 ml/min
- **Tubing:** Each pump head accepts all six precision tubing options—L/S™ 13, L/S™ 14, L/S™ 16, L/S™ 25, L/S™ 17, and L/S™ 18
- **Occlusion:** Average fixed
- **Maximum pressure:**

L/S™ Tubing	Continuous	Intermittent
13, 14, 16	25 psig (1.7 bar)	40 psig (2.7 bar)
25	20 psig (1.4 bar)	35 psig (2.4 bar)
17	15 psig (1.0 bar)	20 psig (1.4 bar)
18	10 psig (0.7 bar)	15 psig (1.0 bar)

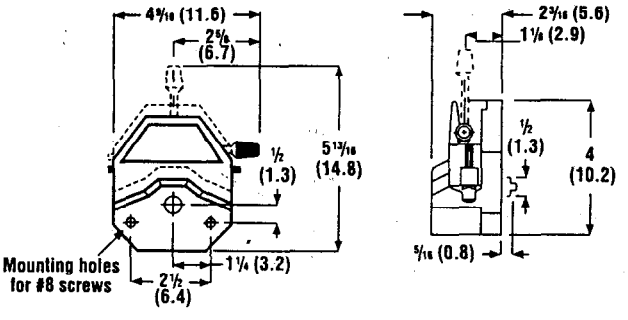
- **Shpg wt:** 1.9 lbs (0.9 kg)

B) EASY-LOAD Pump Heads for High-Performance Precision Tubing

These pump heads are identical to the heads above but accept two of our high-performance precision tubing sizes. High-performance precision tubing has a thicker wall than precision tubing; this enables better pressure generation, suction lift, ability to pump viscous fluids, and promotes longer tubing life.

- **Flow rates:** 1.7 to 1700 ml/min
- **Tubing:** Each pump head accepts two high-performance precision tubing options—L/S™ 15 and L/S™ 24
- **Occlusion:** Average fixed
- **Maximum pressure for L/S™ 15 and L/S™ 24:**
  25 psi (1.7 bar) continuous
  40 psi (2.7 bar) intermittent
- **Shpg wt:** 1.9 lbs (0.9 kg)

L/S™ EASY-LOAD Pump Head—dimensions in inches (cm)



Use only MASTERFLEX® tubing with MASTERFLEX pumps to ensure optimum performance. Use of other tubing may void applicable warranties.

■ NOTE

ISO 9001 VENDOR CERTIFIED

Pump Head Ordering Information (order tubing separately on pages 824-826)

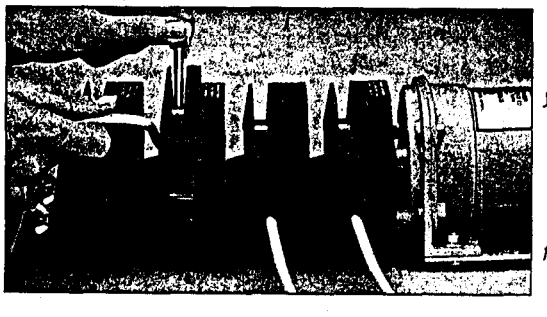
Tubing	ml per rev	Flow rates in ml/min at various rpm		Pump heads		
				PSF housing		PPS housing
		1 to 100	6 to 600	CRS rotor	SS rotor	SS rotor
A) EASY-LOAD pump heads for precision tubing						
L/S™ 13	0.06	0.06 to 6	0.36 to 36	E-07518-00	E-07518-10	E-07518-60
L/S™ 14	0.21	0.21 to 21	1.3 to 130			
L/S™ 16	0.8	0.8 to 80	4.8 to 480			
L/S™ 25	1.7	1.7 to 170	10 to 1000			
L/S™ 17	2.8	2.8 to 280	17 to 1700			
L/S™ 18	3.8	3.8 to 380	23 to 2300			
B) EASY-LOAD pump heads for high-performance precision tubing						
L/S™ 15	1.7	1.7 to 170	10 to 1000	E-07518-02	E-07518-12	E-07518-62
L/S™ 24	2.8	2.8 to 280	17 to 1700			
Price				$153.00	$206.00	$224.00

PSF = polysulfone PPS = polyphenylene sulfide CRS = cold-rolled steel SS = stainless steel

Mounting Hardware

Stack up to four L/S EASY-LOAD pump heads on one drive (see individual drive specifications for recommended number of heads).

Total number of heads to be mounted	Stainless steel hardware	
	Cat. no.	Price/st
One	E-07013-04	$14.25
Two	E-07013-05	15.50
Three	E-07013-08	26.00
Four	E-07013-09	31.00



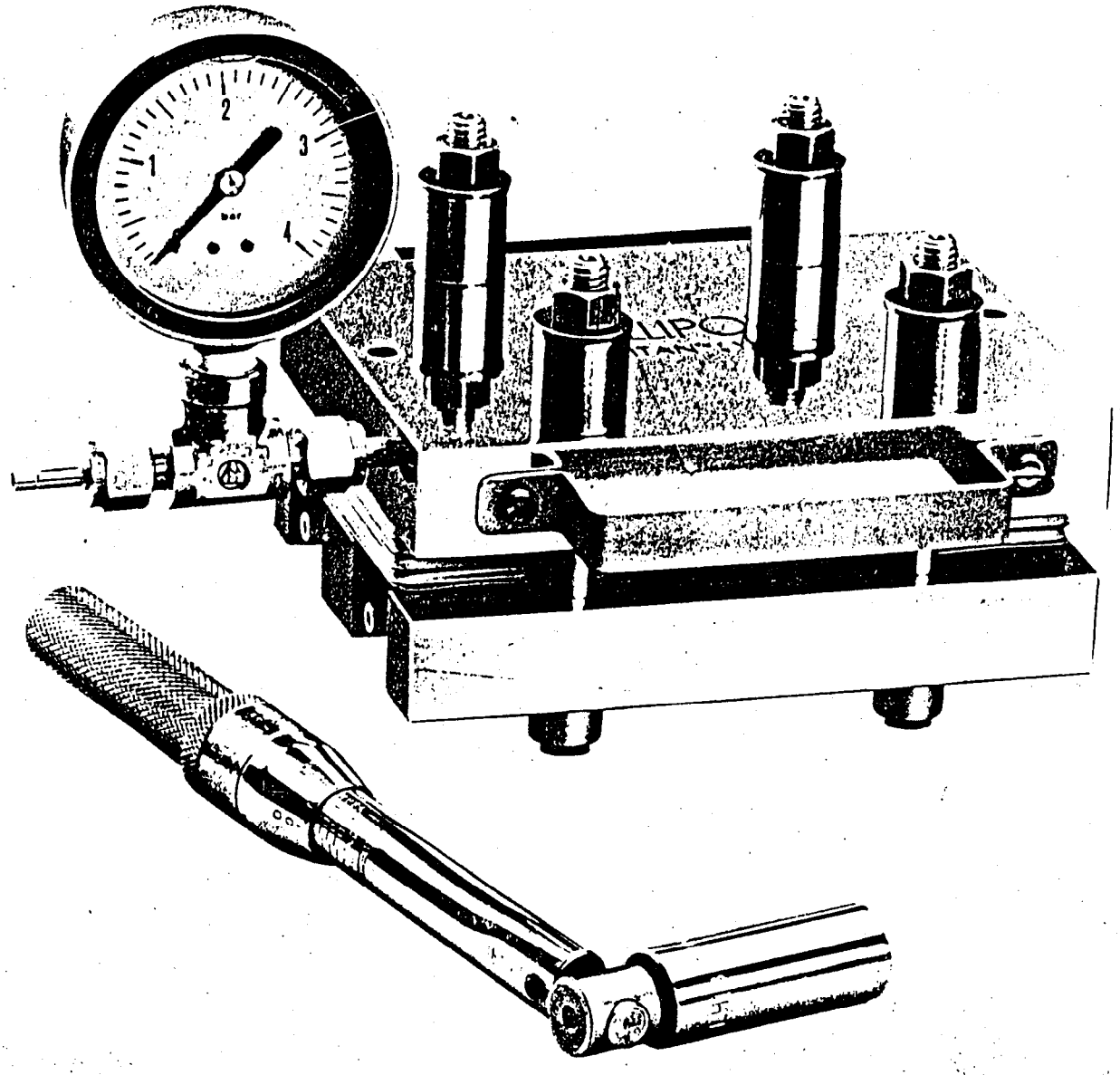
■ HOT

With single or multiple channels, you can change tubing in each channel without removing the EASY-LOAD pump head(s) from your drive.

Minitan™

Sistema de ultrafiltración en acero inoxidable

Instrucciones de montaje, operación y mantenimiento



MILLIPORE

Operación

Acondicionamiento de temperatura

'ara obtener los mejores rendimientos, el material iltrante debe acondicionarse previamente con una olución tampón o un medio lo más similar posible al)roducto a filtrar. Deben tenerse en cuenta la emperatura, pH y contenido salino del fluido. l acondicionamiento previo mejora la solubilidad y ı recuperación del producto.

i la solución ha de mantenerse en frío durante el roceso, enfriar previamente la célula Minitan en un efrigerador, o recircular el fluido de acondicionamiento ío, utilizando un baño de hielo.

rocesado de la muestra

. Sumergir el tubo de entrada y el de salida de tenido en el recipiente con el producto a procesar.

Fijar los tubos con cinta adhesiva o una pinza.

Insertar una pieza de tubo rígido de 25 a 50 mm de rgo en el tubo de entrada, para evitar que el extremo el tubo de silicona se tapone al tocar las paredes o el ndo del recipiente.

Introducir el tubo de salida de filtrado en un recipiente ıcío.

Conectar la bomba y llevarla a la posición 6 a 8. Con salida de retenido totalmente abierta, dejar que el uido recircule durante unos minutos. Medir y anotar la esión y los caudales de retenido y de filtrado (ml/min). on membranas de ultrafiltración, el caudal de filtrado rá mínimo en estas condiciones.

Ejemplo : agua limpia	
Placa	PTGC
Número de placas	4
Ajuste de bomba	6
Presión	0,7 kg/cm²
Caudal de retenido	800 ml/min
Caudal de filtrado	40 ml/min

13 Datos experimentales de rendimiento.

Optimización de caudales

Ajustes de presión

Si se utilizan membranas microporosas con soluciones colmatantes como sueros, lisados y suspensiones de virus o de células, no debe restringirse el caudal de retenido, ya que esto aceleraría la obturación de las membranas. Si se utilizan ultrafiltros, la siguiente tabla servirá de orientación sobre los valores iniciales de presión :

Tipo de filtro	Presión (kg/cm²)
PTMK	0,1 - 0,3
PTHK	0,1 - 0,3
PTTK	0,3 - 1
PTGC	0,3 - 1,4

El aumento de presión hará aumentar el caudal de filtración para soluciones "limpias". La presión máxima aplicable al Minitan es de 1,4 kg/cm² en operación contínua. La duración del tubo se acorta en gran medida por el uso de presiones mayores. Trabajando a un máximo de 1,4 kg/cm², el tubo debe cambiarse cada 20 ó 24 horas. Si se trabaja a presiones mayores (máximo 2,8 kg/cm²), debe cambiarse cada 3 ó 4 horas.

Optimización de la presión y flujo tangencial

Puesto que en el Minitan no se utilizan mallas en los canales de retenido, la presión transmembrana se debe casi exclusivamente a la restricción de la salida de retenido. La bomba de 1 l/min es suficiente para trabajar con una célula con 10 placas. Sin embargo, utilizando sólo dos placas, se recomienda un caudal minimo de 600 ml/min para obtener un buen efecto de barrido. La adición de placas no reduce el flujo tangencial, ya que éstas se disponen en serie. Por ello, el ajuste de presión es prácticamente la única variable para la mayoría de las aplicaciones.

Cuando se filtran fluidos limpios, como el agua, el aumento de presión hará aumentar de forma lineal el caudal a través de la membrana (fig. 14 pág. III).

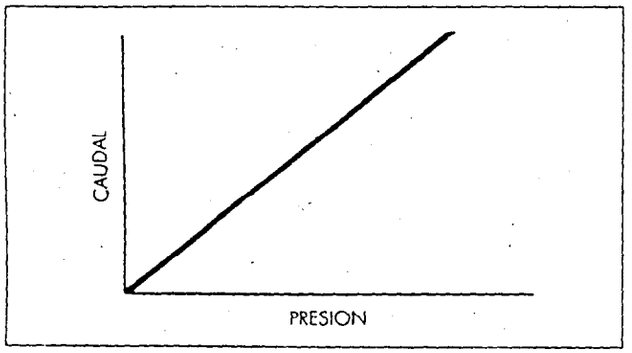


Fig. 14 Relación presión-caudal con fluidos limpios.

Cuando se retienen y recirculan proteínas, células o cualquier otro producto, se forma sobre el filtro una capa de gel que limita el caudal de trabajo.
Un aumento del flujo tangencial reduce la capa de gel, pero un incremento de presión la hace aumentar.
Con un flujo tangencial máximo de 1 l/min, la gráfica de caudal frente a la presión tiene este aspecto:

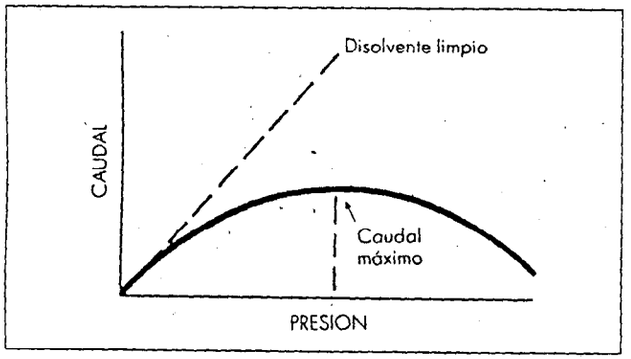


Fig. 15

Esta gráfica sólo se obtiene manteniendo constante la concentración del soluto ("recirculación total").
De hecho, los solutos se concentran durante la filtración, y el caudal disminuirá según aumenta la concentración:

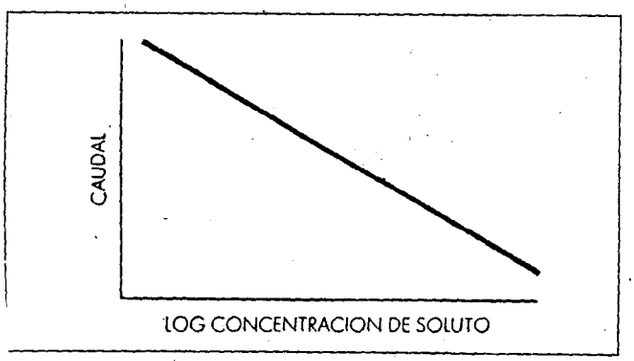


Fig. 16

Por ello, la presión que produce el máximo caudal inicial, puede resultar demasiada alta para el proceso completo, y se recomienda una presión inicial más baja:

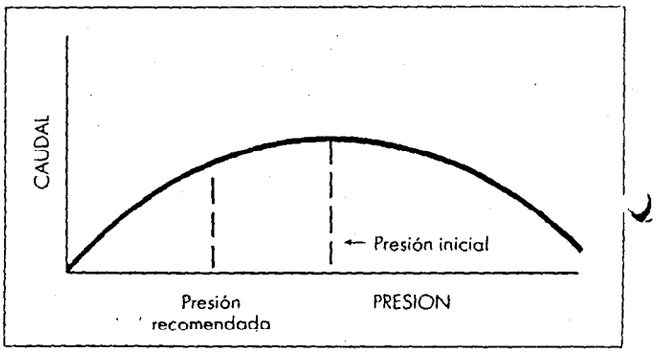


Fig. 17

Una vez se ha determinado esta presión, es conveniente controlar el caudal a lo largo del proceso, para determinar la necesidad de hacer correcciones en el flujo tangencial o en la presión:

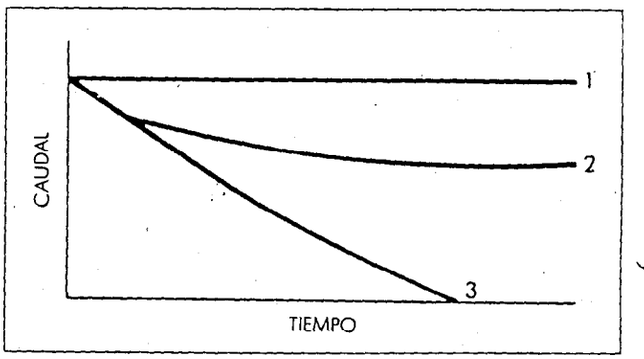


Fig. 18

La línea 1 (fig. 18) indica una filtración constante sin disminución de caudal. Esto ocurre con soluciones muy diluídas de proteínas (menos de 0,1 mg/ml). Puede incrementarse el caudal aumentando la presión.

La línea 2 (fig. 18) indica una disminución de caudal lenta y gradual, tras la primera bajada que se produce en los primeros 5 - 20 minutos. Esto se debe a la formación de una capa de gel sobre la membrana. El flujo tangencial controla esta capa. Si aumenta la presión, debe mantenerse o incluso incrementarse el flujo tangencial para mantener constante el caudal.

La línea 3 (fig. 18) indica un caudal de filtración que disminuye rápidamente sin estabilizarse. Este efecto puede darse con membranas microporosas y suspensiones celulares muy cargadas, lisados o sueros. Los antiespumantes pueden también producir este efecto.

Uso de vacío

Para algunas aplicaciones, especialmente en ultrafiltración, puede aumentarse la presión transmembrana hasta 1 kg/cm² aplicando vacío a la salida del líquido filtrado. La aplicación de vacío sin restricción de la salida del retenido disminuirá el esfuerzo del tubo de la bomba peristáltica. En estas condiciones, debe utilizarse un caudal de retenido capaz de mantener un flujo tangencial adecuado. Para la protección de la línea de vacío debe utilizarse un filtro hidrófobo Millex®-FG_{50}.

Otros factores que afectan al caudal

Antiespumantes

Para evitar la colmatación de las membranas, debe limitarse el uso de antiespumantes durante la fermentación. Un ml de antiespumante por litro de medio puede resultar tan efectivo como 3 ml, y colmatar menos. El tipo de antiespumante también hará variar la posibilidad de colmatación.

Solubilidad de proteínas

La mayoría de las proteínas precipitan a una determinada concentración o según las condiciones del disolvente. Una desalinización rápida o un cambio de solución tampón, pueden disminuir la solubilidad. Es importante optimizar la solubilidad de las proteínas, para obtener caudales y recuperaciones óptimos.

Caudal del agua

Las partículas y coloides presentes en el agua utilizada para preparar los medios de cultivo o soluciones tampón contribuyen a la colmatación de las placas Pellicon. Millipore recomienda utilizar agua del sistema Milli-Q para la preparación de medios de cultivo de tejidos y otras soluciones de uso crítico.

pH

Si se conoce el punto isoeléctrico de la proteína, se recomienda trabajar a 1 punto de pH por encima o por debajo del mismo, para evitar su precipitación durante la filtración.

Temperatura

La máxima recuperación de proteínas se obtiene entre 4 y 10 °C. Por ello, se recomienda trabajar en una cámara fría. A temperaturas más bajas de 4 °C disminuye el caudal con soluciones acuosas, y aumenta la viscosidad de las proteínas. La vida del tubo y de la propia bomba se prolongan trabajando a baja temperatura.
El enfriamiento previo de todo el equipo proporciona los mejores resultados.

Lavado a volumen constante (diafiltración)

El lavado celular o desalinización de proteínas se realiza por la simple adición de diluyente al recipiente original sobre el que se recircula el retenido, al mismo caudal de filtración. Un volumen de diluyente 5 veces mayor que el de la muestra original produce normalmente la eliminación de un 95 % a 99 % de las sales u otros solutos de bajo peso molecular presentes en la muestra.

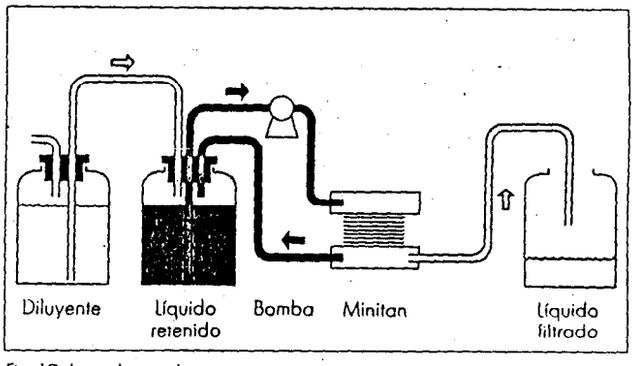


Fig. 19 Lavado a volumen constante.

Este proceso es una modificación de la técnica de concentración con recirculación de retenido.
El recipiente original de la muestra se cierra herméticamente, y se conecta al recipiente del diluyente. El vacío creado por la disminución de volumen produce la succión de diluyente al mismo caudal de producción del líquido filtrado.

Nota: Ciertos productos (EDTA, polietilén-glicol, colorantes, y ciertos carbohidratos) no atraviesan fácilmente las membranas de ultrafiltración y pueden requerir un volumen de diluyente de 10 a 20 veces mayor que la muestra original.

SPECIFICATIONS

	Plates	S Sheets
Filter Area	60 cm^2	30 cm^2
Dimensions:		
Length:	6.0" (15.2 cm)	5.9" (15 cm)
Width:	3.25" (8.3 cm)	3.20" (8.1 cm)
Thickness:	0.10" (2.54 mm)	120-160 um
Materials:		
UF membranes: PTGC, PTTK, PTHK and PTMK	polysulfone membrane on polyolefin support, polypropylene plate	polysulfone membrane on polyolefin support
PLGC, and PLMK	*regenerated cellulose, polypropy.ene plate*	regenerated cellulose
PKMK	N/A	polyvinylidene flouride
PCAC	N/A	cellulose acetate
Microporous membranes:	hydrophilic Durapore membrane, polyvinylidene difluoride plate	hydrophilic Durapore membrane
Maximum Operating Temperature:	50°C	50°C, except 35°C for PCAC and PLGC.
Torque Pressure:	75-80 in-lbs	N/A (80-120 in-lbs)*
Maximum Transmembrane Pressure:	50 psi (3.5 Kg/cm^2)	50 psi (3.5 Kg/cm^2)
Minimum Crossflow Rate	500 mL/min	300 mL/min

* A torque wrench may be used to tighten the Minitan-S filter holder, if desired.

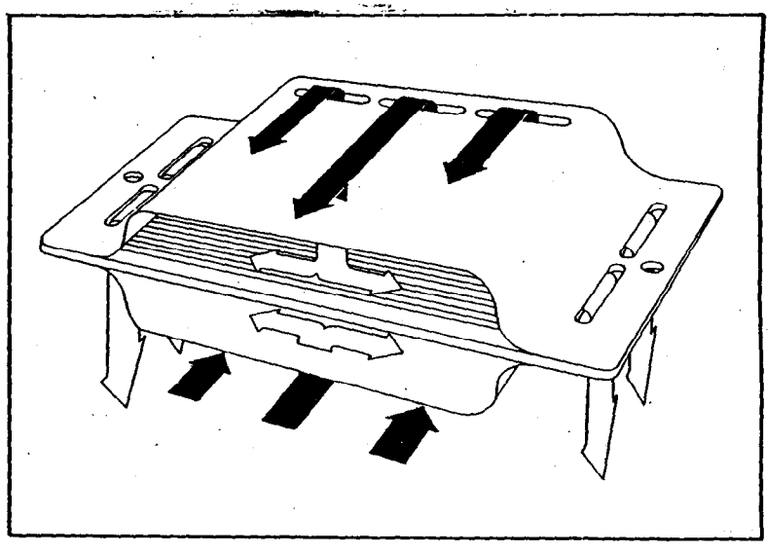
TECHNICAL ASSISTANCE

Contact your local Millipore sales or service representative, or the Millipore office nearest you, for assistance with your system.

Call our Technical Service Department toll-free at 800-225-1380 Ext. 6620.
In Western States 800-632-2708.
In Canada 800-268-4881.
In Toronto Area 416-678-2161.
In Massachusetts 617-275-9200.
In Alaska and Hawaii 415-952-9200.
In Puerto Rico 809-747-8444.
Outside the U.S.A. contact the nearest Millipore office or agent listed in the Millipore catalogue.

P16990 Rev. 11/87

Operating and Maintenance Instructions



MINITAN® FILTER PLATES
MINITAN-S FILTER SHEETS

MILLIPORE

FUNCTION

Minitan filter plates are tangential-flow filter units designed for use in Millipore Acrylic, and Stainless Steel Minitan Systems. They are composed of two membranes heat-bonded to a plastic backing. Each plate has a filter surface area of 60 cm^2. Up to 10 plates can be used at one time, giving a total filter surface area of 600 cm^2. Each plate has two alignment holes, three retentate channels, and two filtrate channels. The alignment holes are used to position the plate on the filter holder.

Minitan-S filter sheets are retangular tangential-flow ultrafiltation or microporous filter membranes, designed for use in Minitan-S filter holders. Each Minitan-S sheet provides 30 cm^2 of filtration area. Only one sheet is used at a time. Minitan-S sheets have two alignment holes. The sheets have no other openings.

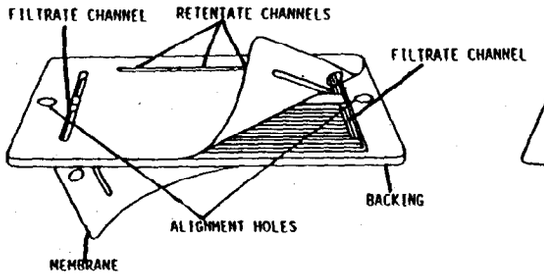


Figure 1 Minitan Filter Plate

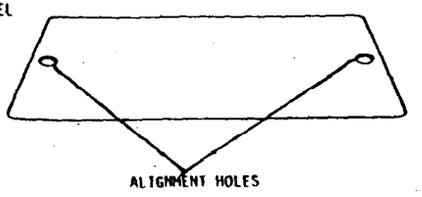


Figure 2 Minitan-S Filter Sheet

INSTALLATION

Installing Minitan Plates in the Acrylic or Stainless Steel Minitan Systems

1. Remove the four nuts and washers from the filter holder.
2. Remove the top plate and manifold.
3. Thoroughly wash and dry enough retentate separators for the installation procedure, ie. one more than the number of plates being installed.
4. Place a retentate separator on the bottom manifold of the filter holder.
5. Remove a filter plate from its packaging, taking care to not bend or flex the plate. **DO NOT REMOVE THE SHEET OF MATERIAL THAT IS ATTACHED TO THE PLATE. THIS IS THE MEMBRANE.** Avoid touching the filter surface. Inspect the filter surfaces for scratches or pinholes. Record the lot number of the filter plate.
6. Place the first plate over the separator so that the retentate channels in the plate are on the opposite side of the filter holder from the retentate well of the bottom manifold.
7. Place a retentate separator on top of the first filter plate.

8. Place a second filter plate over the retentate separator, so that the second plate's retentate channels are opposite the first plate's retentate channels.
9. Repeat steps 7 and 8 for each additional plate used with the system. Make sure additional plates are installed so that the retentate channels in adjacent plates alternate from one side to the other.
10. Place a retentate separator on top of the last plate installed.
11. Replace the top manifold. If an even number of plates are installed, the top manifold's retentate outlet port should be facing the same direction as the inlet (gauge) port. If an odd number of plates are installed, orient the manifold so that the retentate outlet port is facing away from the inlet port.

    Note: Millipore recommends the use of an even number of plates. This minimizes the amount of tubing needed, and diminishes hold-up volume.

12. Install the top plate. Replace the four washers and nuts. Simultaneously, finger-tighten diagonal pairs of nuts. Continue tightening the nuts by using a torque wrench as described below.

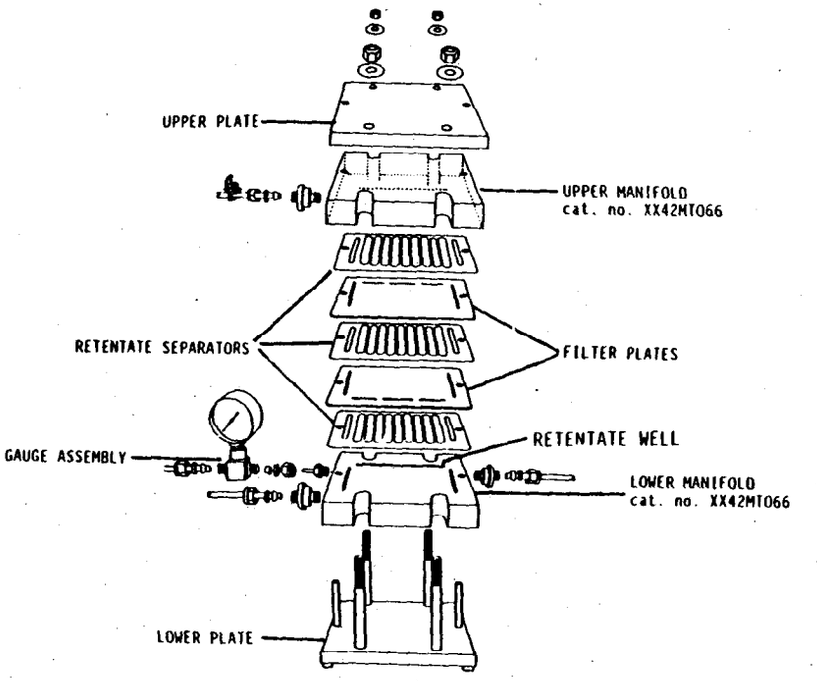
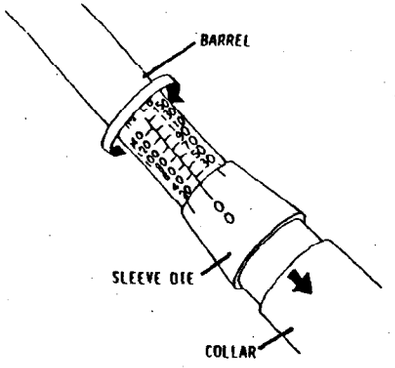


Figure 3 Installing Minitan Filter Plates
Install the first filter plate so that the plate's retentate channels are opposite the bottom manifold's retentate well. Install additional filter plates so that the retentate channels in adjacent plates are on opposite sides of the filter holder.

Tightening Instructions for the Acrylic and Stainless Steel Systems

After the filter plates have been installed, the Acrylic and Stainless Steel Systems must be tightened using a torque wrench. To ensure that tightening is even, the nuts on the top of the filter holder are tightened gradually, using three different torque settings.

1. Set the torque wrench at 20 in-lbs by sliding the collar back, and turning the wrench handle until the line corresponding to 20 in-lbs on the barrel aligns with the zero reading on the sleeve die.



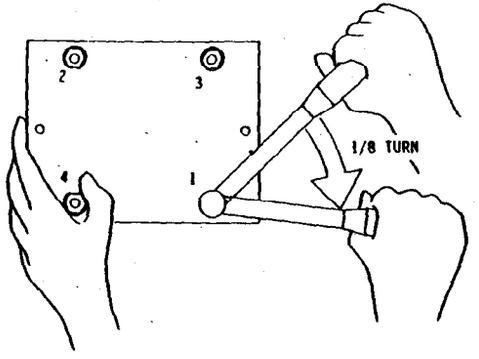


Figure 4 Setting The Torque Wrench

Figure 5 Tightening Sequence

2. Place the wrench socket over one of the nuts and rotate the nut clockwise, 1/8 of a turn. Starting with the nut diagonally across from the first nut, tighten the other nuts in the same manner. Repeat the cycle until each nut is tightened to the specified torque. The wrench will make a "clicking" sound and will give slightly when the torque is acheived.

Note: *The wrench will not automatically stop when the preset torque is achieved, therefore the user must be sure not to over tighten.*

3. Set the torque wrench at 50 in-lbs and repeat step 2.

4. Set the torque wrench at 80 in-lbs and repeat step 2.

5. If using filter plates for the first time, repeat step 4 after a few minutes, to allow for compression of the retentate separators.

Installation of Filter Sheets

1. Remove the four handwheels from the Minitan-S filter holder.

2. Remove the top plate and manifold.

3. Thoroughly wash and dry two retentate separators.

4. Place a clean retentate separator on the bottom manifold.

5. Remove a filter sheet from its package. Sheets are separated by colored dividers for protection during shipment. The filter sheets are white.

   Place a single filter sheet over the retentate separator. Ultrafiltration filter sheets must be installed with the smooth, shiny side face down. Microporous sheets may be placed either way.

6. When using UF filter sheets, a second retentate separator should be installed over the filter sheets. With microporous filter sheets, a second retentate separator is not necessary.

7. Install the upper manifold with the grooved side down. The upper manifold may be installed with ports facing either way.

8. Install the top steel plate. Replace the four handwheels on the extension rods. Simultaneously, hand-tighten diagonal pairs of handwheels.

9. Tighten the handwheels again using the handwheel wrench.

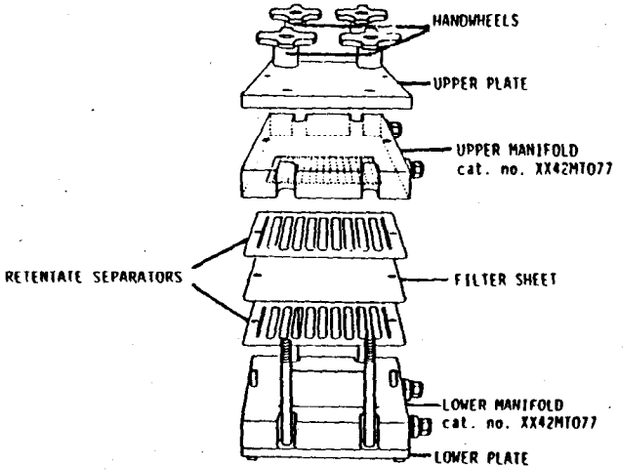


Figure 6 Installing Minitan-S Filter Sheets

OPERATION

Please refer to OM 157 (part number P16988) for operating instructions.

Integrity tests should be run at a inlet pressure of 5 psi for all membrane types except PTMK, PLMK, and PKMK, which should be run at a pressure of 3 psi.

CLEANING

Clean the Minitan filter plates and sheets immediately after each use, to remove proteins, microorganisms, and debris from the filter surface. Plates and sheets are cleaned in place by pumping a cleaning solution into the assembled filter holder, and soaking the plates and sheets.

Cleaning Agents:

For routine protein removal of PTGC, PTTK, PTHK, PTMK, PLGC and PLMK membranes, use 0.1M sodium hydroxide (NaOH) for a maximum of 30 minutes. Do not use sodium hydroxide to clean Durapore (VVLP, GVLP, HVLP, DVLP), PCAC or PKMK membranes.

For routine cleaning of PCAC and PKMK membranes, use 10 ppm of sodium hypochlorite.

For routine cleaning of Durapore (VVLP, GVLP, HVLP, DVLP) membranes, use up to 500 ppm of sodium hypochlorite for a maximum of 30 minutes. Durapore membranes can also be cleaned with Terg-A-Zyme or detergents. See OM 157 (P16988) for details.

Cleaning Procedure

Leave filter plates in the system during the cleaning procedure.

1. Place a clamp on the filtrate outlet tubing, and tighten it until the tubing is completely shut.
2. Completely loosen the clamp on the retentate outlet tubing.
3. Place the inlet tubing into the feed reservoir, then divert the filtrate and retentate outlet tubings to drain.
4. Place the cleaning agent into the feed reservoir.
5. Position the pump direction selection dial at clockwise (CW) position, and set the speed dial at 10.
6. Pump the cleaning agent into the system. Once cleaning solution has filled the whole system, and is exiting the retentate outlet tubing, turn the pump off.
7. Let the cleaning agent soak in the filter holder for 15-30 minutes.
8. After the cleaning period, set the pump speed at 10, and pump the cleaning solution out of the system. Place fresh cleaning fluid or clean water in the feed reservoir, and pump this fluid through the system.
9. Repeat steps 4-8, until the fluid exiting the retentate tubing is clear.
10. Place the retentate outlet tubing into the feed reservoir. Completely open the clamp on the filtrate tubing. Place fresh cleaning solution in the feed reservoir, and circulate the solution through the system for 15-30 minutes.

11. After the cleaning period, divert the filtrate and retentate outlet tubing to drain, and pump water through the system to flush out the cleaning solution.
12. Record the clean water flux for the system, and compare the results to the initial clean water flux. For some applications, the flux rate of the membrane may not be fully restored to the orginal rate recorded. If the flux rate is low, repeat steps 4-8 using a different cleaning agent.

ORDERING INFORMATION

Minitan plates are sold in packages of 4 and 50. The 4-packs are shipped wet with a mild formalin solution, and include 5 retentate separators. The 50-packs are shipped dry, and do not include retentate separators. Minitan-S sheets are shipped dry, in packages of 10, without retentate separators.

Type	Description	Catalogue Number	
Minitan Ultrfiltration Filter Plates		**4/PK**	**50/PK**
PTGC	10,000 NMWL, polysulfone, white	PTGC OMP 04	PTGC OMP 50
PTTK	30,000 NMWL, polysulfone, yellow	PTTK OMP 04	PTTK OMP 50
PTHK	100,000 NMWL, polysulfone, blue	PTHK OMP 04	PTHK OMP 50
PTMK	300,000 NMWL, polysulfone, red	PTMK OMP 04	PTMK OMP 50
PLGC	10,000 NMWL, regenerated cellulose, white	PLGC OMP 04	PLGC OMP 50
PLMK	300,000 NMWL, regenerated cellulose, red	PLMK OMP 04	PLMK OMP 50
PKMK	300,000 NMWL, polyvinylidene flouride	PKMK OMP 04	PKMK OMP 50
Minitan Microporous Filter Plates		**4/PK**	**50/PK**
VVLP	0.1 um, PVDF	VVLP OMP 04	VVLP OMP 50
GVLP	0.2 um, PVDF	GVLP OMP 04	GVLP OMP 50
HVLP	0.45 um, PVDF	HVLP OMP 04	HVLP OMP 50
DVLP	0.65 um, PVDF	DVLP OMP 04	DVLP OMP 50
Minitan-S Ultrafiltration Sheets			**10/PK**
PCAC	1,000 NMWL, cellulose acetate		PCAC OMS 10
PTGC	10,000 NMWL, polysulfone, white separator		PTGC OMS 10
PTTK	30,000 NMWL, polysulfone, yellow separator		PTTK OMS 10
PTHK	100,000 NMWL, polysulfone, blue separator		PTHK OMS 10
PTMK	300,000 NMWL, polysulfone, red separator		PTMK OMS 10
PLGC	10,000 NMWL, regenerated cellulose, white separator		PLGC OMS 10
PLMK	300,000 NMWL, regenerated cellulose, red separtor		PLMK OMS 10
PKMK	300,000 NMWL, polyvinylidene fluoride		PKMK OMS 10
Minitan-S Microporous Sheets			**10/PK**
VVLP	0.1 um, PVDF		VVLP OMS 10
GVLP	0.2 um, PVDF		GVLP OMS 10
HVLP	0.45 um, PVDF		HVLP OMS 10
DVLP	0.65 um, PVDF		DVLP OMS 10