SUDBURY NEUTRINO OBSERVATORY.

Draft Report SNO-STR-91-048

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ULTRAFILTRATION TECHNOLOGY AND APPLICATIONS TO SNO.

Introduction.

The purpose of this report is to describe the technology of water treatment by ultrafiltration and to consider how it might be applied to SNO. Some estimates of the space requirements and costs are made, but these are very provisional at this stage.

Contents.

1. Membrane Processes.

1.1. Conventional process filtration is performed with media which have pore sizes ranging from fairly coarse screens down to about one micron. For some purposes finer filters may be used, down to 0.4 or even 0.2 micron, but in this region conventional or "dead-end" filtration is at its practical limits, because flow-rates are low and rapid filter blockage is a common event.

1.2. Processes using media with pore sizes below about one micron normally differ from conventional filtration in two major ways. Firstly the filter media are asymmetric; a thin membrane of material with very small pores is supported by a thicker layer of material with much coarser pores which offer little resistance to flow. Secondly the liquid to be filtered is passed tangentially across the filter surface instead of approaching it head-on. Ideally the surface of the filter should be reasonably smooth so that the substances to be rejected tend to remain entrained in the flow and do not plate out rapidly on the surface. Some of the liquid passes through the pores and is termed the permeate, the rest of the flow continues along the membrane surface and exits from the filter module as what is termed the retentate. It may be recirculated and pumped through again, depending on the particular process. Hence the terms tangential filtration or cross-flow filtration or membrane filtration are synonymous for most purposes in practice. Figure 1 shows the basic idea.

1.3. Membrane processes are further sub-divided into three (or according to some writers four) regions with different applications and different ranges of pore size. Figure 2 shows this. From the pore size where the limits of conventional filtration are reached, around one micron, down to about 0.1 micron size is generally termed microfiltration (MF). It is usually adequate for removing bacteria and fairly fine particles. Below this range, with pore sizes down to perhaps 2 nanometres, the process is normally termed ultrafiltration (UF). It is typically used for separating molecules of lar size such as proteins from smaller molecules such as salts and solvated ions. Both the processes mentioned so far can still be regarded as a type of filtration; complications due to osmotic pressure are not important and the pressure drop required across the membrane is of the order of one or two bar.

Materials with still smaller pores, in the range from about 2 nm down to about 0.2 nm, are used for purifying water by removing ions and dissolved organics, and the process is termed reverse osmosis (RO). Because the osmotic pressure of the ions has to be overcome the typical pressure drop is more like 10 bar. This process is commonly employed as a preliminary to deionisation in pure water systems but is also used on a large scale for producing drinking water from brackish water or sea-water by desalination. For many applications it is more convenient to refer to membranes, and UF (ultrafiltration) membranes in particular, by their nominal molecular weight cut-off (NMWCO) rather than pore size. Expressed in this form the range of porosity available is from less than 1000 to over 100,000 Daltons.

A fourth term, nanofiltration, is sometimes used to refer to the range of pore size around 1 or 2 nm, where the UF and RO ranges overlap. In addition there are related processes like dialysis and electrically-aided membrane separation processes which will be merely mentioned to note that they exist. Further details are available in the literature if required, for example the book by Gutman (ref.1).

2. Membranes.

Besides being available in a range of pore sizes, membranes are also made in a variety of different materials and a number of different configurations.

2.1. The earliest materials used were based on regenerated cellulose or cellulose acetates and these materials are still used. A number of other organic materials are also used, polysulphone and polyolefins for example. Membranes are also made in inorganic materials for some purposes, in graphite or alumina for example, but these tend to be more expensive than the organic materials.

2.2. Ignoring a few forms used only for small-scale laboratory work the configurations in which UF membranes are available fall into four groups.

2.2.1. Flat-plate. Flat sheets of membrane are assembled in back-to-back forms or cassettes, held apart by separators. Alternate channels between the sheets carry retentate and permeate respectively. Stacks of sheets are held together by clamps or housings to form modules. This type tends to be the most bulky for a given membrane area but is easily disassembled for cleaning if necessary.

2.2.2. Spiral-wound. Two large sheets of membrane with a separator between them are sealed together along some edges and rolled into a spiral. End fittings and a housing with a permeate outlet are added to complete a module. This type is said to be difficult to clean if it becomes blocked.

2.2.3. Tubular. The membrane is formed on the inner surface of a tubular element. A number of tubes are assembled together in a housing to form a module which may have a length of several metres. The diameter of the tubes is of the order of several mm bore, which makes them fairly robust, resistant to blocking by particulate matter and capable of being cleaned if they do get blocked. This type is also rather bulky for a given area of membrane.

2.2.4. Hollow fibre. The membrane is formed on usually the inner surface of a hollow fibre of typical diameter 1 mm or less. Bundles of fibres are assembled in a housing to form a module. This type is claimed to give the largest area of membrane surface per unit volume of plant but the smaller diameter fibres are more susceptible to blocking. Some are made with the membrane formed on the outer surface of the fibre or even with a membrane formed on both the inner and outer surfaces.

2.3. Each type of module has its advantages and disadvantages for the various applications, which vary from polishing pure water to effluent treatment. Most equipment suppliers offer more than one type of module and there are a number of factors to be considered in order to assess what types might be suitable for a particular application. For the SNO application it is difficult to identify suitable equipment at such an early stage of process development. However, brochures have been obtained from a number of process plant suppliers and very rough estimates sought on possible plant dimensions. This might normally be thought premature but is necessitated by the need to determine the excavation details now.

3. Seeded Ultrafiltration.

The process which it is thought may be applicable to SNO is termed seeded ultrafiltration.

3.1. Seeded ultrafiltration is a process which has been developed in recent years mainly as a method of further improving the decontamination of the waste streams from nuclear fuel reprocessing. Small quantities of finely-divided absorbers are added to the water to be treated, usually at the same stage at which a precipitate or floc has been produced, and the absorption of certain soluble isotopes is enhanced. (ref.2). The absorbers remain with the concentrated floc and the decontaminated permeate can then be discharged to the sea.

3.2. It is probable, although not certain, that the water-purification plant proposed to be installed in the mine will be capable of producing water of the required purity. However the very low levels of thorium and uranium desired are alone sufficient incentive to consider any other methods available. But it is well known that pure water does not remain pure; it leaches and dissolves the materials it contacts, absorbs gases such as carbon dioxide from the air and unless sterilised it readily allows bacterial activity to flourish. Thus the light water will require to be continuously recirculated through a monitoring and polishing loop in order to maintain adequate purity. Much work has been done on removing and monitoring the level of radium in the water but Ra is an alkaline earth and has well-behaved chemistry at pH 7. Work on thorium removal and monitoring has demonstrated different behaviour at pH 7. It is hydrolysed, forms polymeric macro-molecules or colloids, absorbs onto surfaces and is generally uncooperative. Absorbers used for radium may also absorb thorium but the kinetics of absorption are much slower. Contact time in a packed bed may not be sufficient and bed volume is constrained by other factors.

3.3. Seeded ultrafiltration may be able to resolve this difficulty. If a small amount of a suitable absorber in a finely-divided form, say 1 micron grain size, were added to the water being treated at the level of say 10 ppm, mixed well and kept in contact with the water for a suitable time it is thought that fairly quantitative absorption of dissolved thorium might be achieved. The loaded absorber and any colloidal species or other particles could then be removed from the water by ultrafiltration and perhaps used for monitoring the Th level by Rn counting or chemical analysis, probably by ICP-MS. The separation of the absorber from the water and its concentration up to a reasonably high solids content are seen as one of the most critical aspects of the process.

4. Suppliers.

A number of potential suppliers of membrane filtration equipment have been contacted, literature obtained and studied, information sought by telephone and by visits of technical representatives and an attempt made to collate the estimates and data obtained. All data has been sought on the basis of treating a flow of 150 litres/minute or 9 cu.m/hour, 216 tonne/day. Many plants, especially those made for use by the food or drugs industries, make extensive use of SS piping, pumps, housings and valves as standard. All these things can be made in plastics if necessary to avoid any problems with radon emanation from stainless steel so this should not be too serious. Not all known suppliers have been contacted. See appendices.

4.1. Elga Ltd., Lane End, High Wycombe, Bucks, England HP14 3JH.

Tel: (0494) 881393. Fax: (0494) 881007. Telex: 83516 ELGALE G.

This company started out as a supplier of equipment for purifying water with ion exchange resins, but has grown to cover most types of equipment for producing pure water. They have a series of UF standard models, their "INTERCEPT UF" range, with from 1 to 24 hollow-fibre modules. They do not manufacture membranes. The modules used are made by Romicron and have 80,000 NMWCO pore size. The intended application is colloid removal from water. Alternative pore sizes or membranes can be supplied. See appendices.

Allowing for the temperature correction appropriate for the planned operating temperature of SNO a flow of 9 cu.m/hr of clean water could in theory be handled by 6 modules of their standard type. In practice some spare capacity would be advisable, say 25%, so one considers 8 modules. Addition of a few ppm of fine absorber would reduce the flow-rate to some extent not yet determined but the important number is what concentration the first stage is achieving and the flow-rate at that concentration.

Assuming 10 ppm addition of absorber and that the first stage can achieve 90% recovery and raise the solids content to 100 ppm, the number of modules needed might as a first guess be doubled to 16. The required volume is then 2.4 m high by 3.3 m long by 1.4 m wide, plus space for tanks, pumps and access. Subsequent stage(s) required to bring the solids content up to say a few percent are then handling 15 l/min or less and are thus pilot-plant or laboratory-scale rigs. A worst-case assumption might be that they occupy as much space as the first stage; essentially that flow-rate is inversely proportional to solids concentration to first order. Later stage(s) could use a different type of membrane; the final stage would probably be a tubular membrane unit.

The above exercise is based on the standard 80,000 NMWCO membranes. If it was necessary to use say 20,000 NMWCO membranes the plant size would need to be considerably larger, perhaps an order of magnitude. It is doubtful if such a large plant would be feasible in the space likely to be available --- it would also be rather expensive.

4.2. Memcor, Units 37/38 Halifax Road, Greenford, Middx., England UB6 8XU.

Tel: (081) 575-1066. Fax: (081) 575-6252.

Memcor is an English company formed to sell the equipment made by MEMTEC in Australia into the European market. There is an associated company in the USA. They sell plant using hollow-fibre modules, the membrane skin being formed on the outside of the fibres instead of on the inside. Their literature claims that this enables them to use a gas-backwashing technique to remove deposits built up on the membrane.

Units can be built in multiples of 5 modules. A standard 120M2 unit (60 modules) would be 3 m high by 5 m long by 2 m wide and initial estimates are that two such units would be needed to handle 9 cu.m/hr. Each module would contain 2 sq.m of membrane surface, so each unit would contain 120 sq.m. of membrane. This then might be the first stage of a multi-stage process, tapering down in flow-rate as suggested above. The dimensions do not include space for tanks and access (minimum 1 m). It is suggested that this equipment could be used up to 1000 ppm solids. Further information is being sought.

4.3. Koch International Ltd., Friars Mill, Friars Terrace,
Stafford, Staffs, England, ST17 4AU.
Tel: (0785) 212565. Fax: (0785) 223149. Telex: 36612 KOABCO G.

This company is a subsidiary of Koch Membrane Systems, Wilmington MA 01887. They supply equipment using spiral-wound or tubular membranes of their own manufacture in a range of sizes. Flow-rate data is being sought.

4.4. PCI Membrane Systems Ltd., Laverstock Mill, Whitchurch,
Hampshire, England RG28 7NR.
Tel: (0256) 896966. Fax: (0256) 893835. Telex: 858128 PCILAV G.

This company is part of the PWT Worldwide Ltd. group which is involved in all aspects of water treatment. It is now in its turn part of the Thames Water plc group which is the water supply and sewage treatment company responsible for the whole of the area drained by the River Thames, including the London conurbation and of course Oxford. They manufacture some tubular membrane modules and supply equipment using a wide range of membranes but we do not as yet have the details.

4.5. APV Baker Ltd., PO Box 4, Gatwick Road, Crawley, West Sussex, England RH10 2QB.

Tel: (0293) 527777. Fax: (0293) 552640. Telex: 87237.

This company sells equipment made by APV Membrantechnologie GmbH of Dusseldorf, Germany. There is an associated company in USA called APV Crepaco. They do not make membranes to any extent but build equipment to suit customer's needs using the most suitable membranes available. We have no data on flow-rates or dimensions and they do not seem to have a range of standard designs. We are expecting further information but think it more profitable to concentrate on some other contacts at this time.

4.6. Amicon Ltd., Upper Mill, Stonehouse, Gloucestershire, England GL10 2BJ.

Tel: (0453) 825181. Fax: (0453) 826686. Telex: 43532.

This company is part of the W.R. Grace & Co. group of Beverly MA 01915-1065. They offer three membrane types, spiral-wound, hollow-fibre and flat plate (Ioplate), and equipment and systems using these. They have a range of standard modular systems, and the largest, model SP240, has dimensions of 2 m high by 2.3 m long by 0.75 m wide. It is estimated that two of these units might be able to handle 9 cu.m/hr with the optimum hollow-fibre modules. These are made with NMWCO values of 3,000 or 10,000 or 30,000 or 100,000 and with fibre internal diameter of 0.5 mm or 1.1 mm. Assuming that 0.5 mm is too small to be risked with water containing any particles of absorber the 1.1 mm bore type with NMWCO of 30,000 Daltons looks a good starting point for tests. Additional space would be needed for tanks and pumps as in the exercises above, and for other stage(s) required.

4.7. Sartorius Ltd., Longmead, Blenheim Road, Epsom, Surrey, England KT19 9QN.
Tel: (0372) 745811. Fax: (0372) 726171. Telex: 925108 SARTOR G.

This company is part of the Sartorius GmbH group of Goettingen, Germany. They make flat-plate modules and systems with membranes of several materials and pore sizes down to 5,000 Daltons. They have an office in Canada, in Rexdale in fact. Although they do claim to have supplied large plants in Germany for treating milk products and for wine clarification the marketing effort in the UK seems to be concentrated on the laboratory-scale biological separation applications, such as cell-harvesting and protein separations on scales up to a few tens of litres. We have some data relevant to these applications but so far little of use for our purposes.

4.8. Millipore (UK) Ltd., The Boulevard, Blackmoor Lane, Watford, Herts, England, WD1 8YW.
Tel: (0923) 816375. Fax: (0923) 818297. Telex: 24191.

This company is part of the Millipore Corporation of Bedford, MA 01730. They have an office in Canada, in Mississauga. They sell flat-plate membranes and equipment which is very similar to the Sartorius products and is aimed at the same laboratory-scale biological separations market. Their literature has little data relevant to our purposes --- in a bibliography of nearly 100 references all except one was on biological separations, mostly viruses and enzymes. This type of equipment, like the similar equipments sold by Sartorius and a number of other suppliers, seem to be more likely to be of possible utility in a final concentration stage than in the first stage of a process for use by SNO.

4.9. There are a number of other suppliers who are agents for an overseas company, for example one offers hollow-fibre cartridges and equipment made by Microgon Inc. of Laguna Hills, CA 92653. They are rather similar to the Amicon products. Another offers the flat-plate membranes made by Filtron Technology Corporation of Northborough, MA 01532. They are similar to the Millipore products. There are thought to be a number of Japanese suppliers, but at present the only one on which we have any data is Toshiba Corporation, Kawasaki 210, who make plant using hollow-fibre polythene membranes.

As mentioned earlier, there are also various inorganic membrane materials available; sintered alumina, anodised alumina or zirconia, sintered metal, porous glass, graphite etc. These are not likely to be applicable for our purposes unless strong cleaning agents are needed or there is some unforeseen reason to use them. The Carbosep membranes made by a French company warrant more attention because a lot of work has been done using them on the decontamination of effluent from nuclear fuel reprocessing and some fairly relevant data is available. They are tubular graphite elements, normally 1.1 m long, with an inner coating of zirconia to form an abrasion-resistant membrane.

5. Estimates.

It is now necessary to make estimates of the space needed and other requirements for a UF plant and of the likely capital and operating costs, although it must be emphasized again that at this stage these are guesstimates.

5.1. Concentration by a factor of 10 per stage seems to be a reasonable objective. To go from 10 ppm to 10% therefore implies four stages, but the space required is largely fixed by how large the first stage needs to be. A few units each 2 to 3 metres high and occupying a few square metres each would, with associated tanks and pumps and space for access, require a few tens of square metres. Taking a depth of say 3 metres means a total length of 10 to 15 metres of the utility room.

5.2. On available information the capital cost of such a plant should not exceed C$ 200k.

5.3. Replacement costs, mainly due to membrane replacement, are determined by the membrane life. The estimate is C$ 20k.

5.4. Electrical power is determined by pump sizes and the operating pressures needed. The estimate is 10 to 15 kW.

5.5. Other running costs would include the cost of chemicals for membrane cleaning and the cost of disposing of the used chemicals afterwards. This can not be estimated yet.

5.6. Other factors such as frequency of back-washing and cleaning operations and the volume of waste streams produced, and hence of make-up water required, can not be estimated at this stage but might be as much as 1 or 2 tonne/hour. More information is needed but may require pilot-plant experiments to obtain it.

6. Experiments.

Two small test rigs have been set up for tests to determine absorber properties, the effect of absorber concentration on permeate rate, etc. We also have a shaker bath. The effects of different preparation methods on the absorber properties of manganese dioxide are being investigated. Other absorber materials such as hydrated titanium oxide are also being tested, using thorium 234 (24-day half-life) extracted from uranium 238 in the form of uranyl nitrate.

7. References.

1). "Membrane Filtration" by R.G.Gutman. (Adam Hilger, Bristol, 1987) ISBN 0-85274-522-2.

2). "Atom", no. 412, April 1991, p.2.


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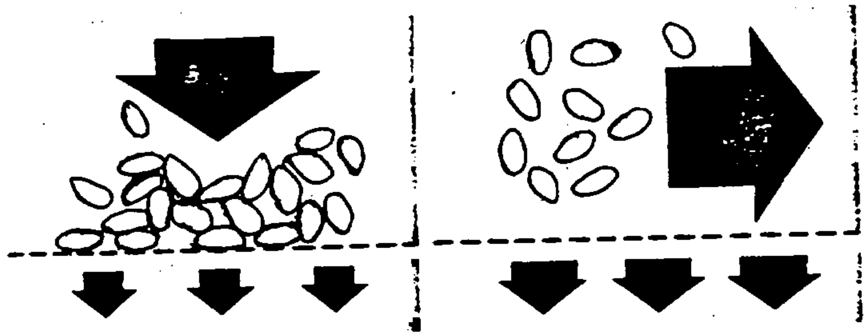


Figure 1.

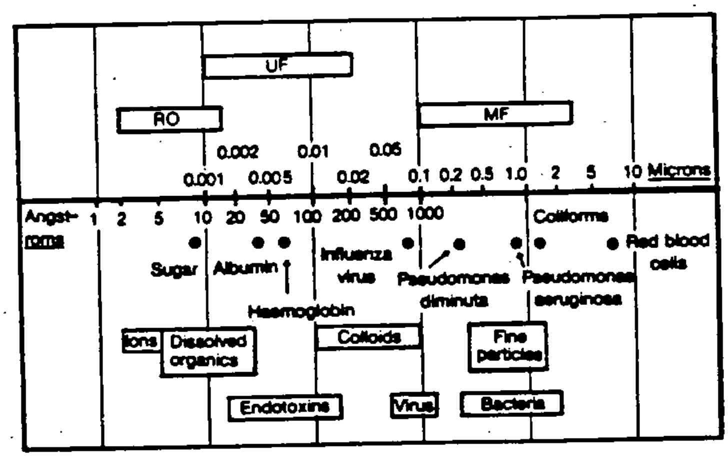


Figure 2.

INTERCEPT

ULTRAFILTRATION

Introduction

Ultrafiltration is a low pressure membrane separation process capable of removing high molecular weight dissolved materials, colloids and suspended solids from liquids. The Elgamat Intercept Ultrafiltration units have been developed to complement Elga deionisation and reverse osmosis systems, providing an alternative method of colloid removal either before or after deionisation.

All units are constructed on a corrosion resistant mild steel framework.

The Intercept Pilot UF 1-5 units are totally self-contained on a skid-frame. The Intercept UF 6-24 units are supplied with free-standing C.I.P. (Cleaning-In-Place) tanks which are piped-up on site.

All electrical components are housed in a splash-proof control cabinet constructed to IP55 standards.

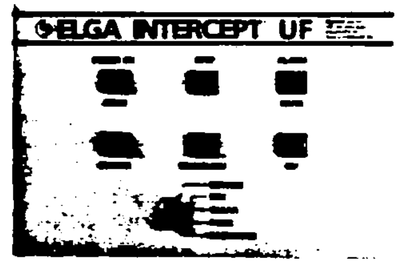
Operation

Units for pre-treatment applications incorpoate a fully automatic backflush cycle to remove accumulated material from the membrane surface, thereby maintaining optimum output and reducing the frequency of chemical cleaning.

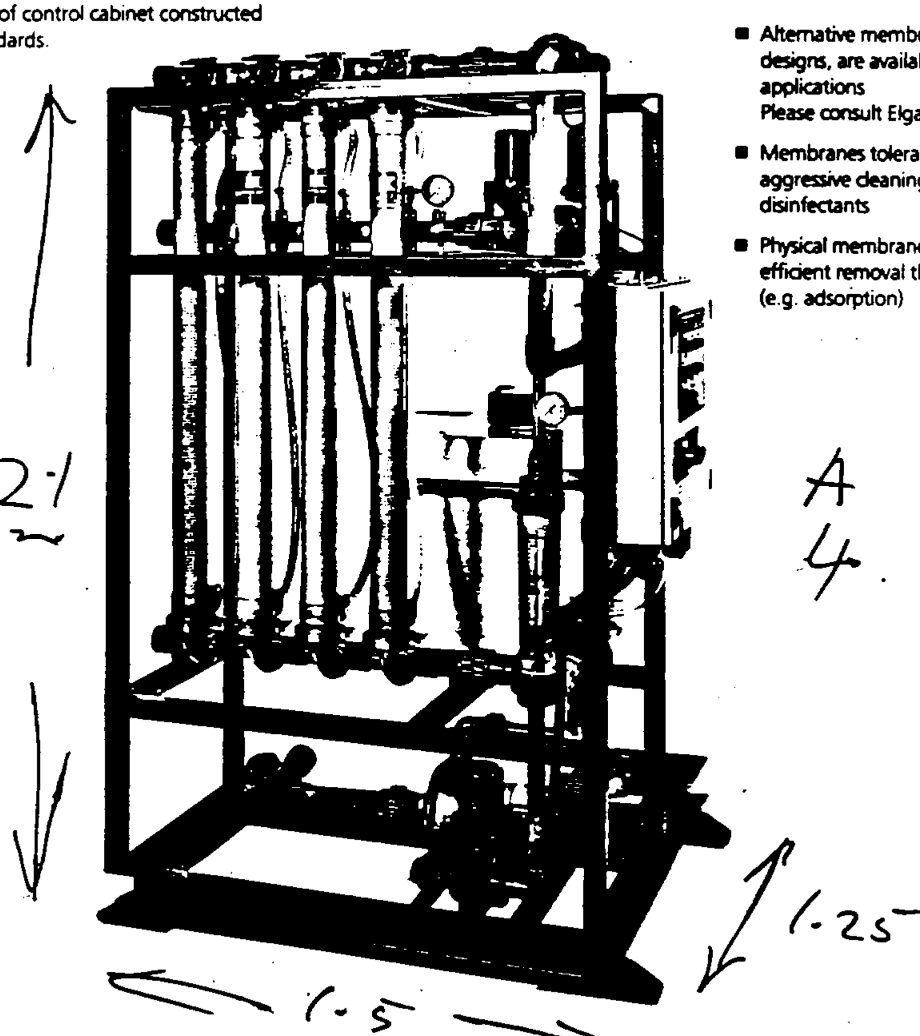
C.I.P. is semi-automatic on the Intercept Pilot UF 1-5 units requiring the operator to add and mix chemicals during the cleaning program, the Intercept UF 6-24 units incorporate a microprocessor for fully automatic operation.

Special Features

- Operates on high fouling waters
- Low pressure/energy process
- High recovery (up to 95%)
- Microprocessor control (6-24 range)



- Alternative membranes, and plant designs, are available to suit many applications
  Please consult Elga for details
- Membranes tolerate the use of aggressive cleaning chemicals and disinfectants
- Physical membrane barrier gives more efficient removal than other processes (e.g. adsorption)



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INTERCEPT

ULTRAFILTRATION

Technical Specification

Intercept UF Model	1	2	3	4	5	6	8	10	12	14	16	18	20	22	24
	Intercept Pilot UF					Intercept UF 'L'									
Frame Type	A	A	A	A	A	B	B	C	C	C	C	D	D	D	D
No. of Modules	1	2	3	4	5	6	8	10	12	14	16	18	20	22	24
Nominal Capacity (m^3/h)															
Highly Colloidal Water	0.75	1.5	2.25	3.0	3.75	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0
Normal Pretreatment	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0
Post-Deionisation	2.0	4.0	6.0	8.0	10.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0	48.0
Equipment	Self-contained package including modules, tank, pump, valves, controls, etc. on one compact skid.					Module skid incorporates modules, pump, valves, control box. CIP tank, chemical tanks and pumps are installed free standing alongside the module skid.									
Controls	Semi-Automatic					Full Microprocessor Control									
DIMENSIONS															
Overall Height (mm)	2100	2100	2100	2100	2100	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
Overall Length (mm)	1500	1500	1500	1500	1500	2900	2900	3300	3300	3300	3300	4200	4200	4200	4200
Overall Width (mm)	1250	1250	1250	1250	1250	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
TANK															
CIP Tank	250 lit. incorporated in frame					1000 lit. free standing									
Chemical Tanks	N/A					2×200 lit. free standing									
Pipe Connections															
Inlet & Outlet (ins)	1	1	1	1½	1½	2	2	3	3	3	3	3	3	3	3
Drain (ins)	1½	1½	1½	2	2	3	3	4	4	4	4	4	4	4	4
Pump Motor(s)															
CIP Pump (kW)	0.55	1.0	1.0	2.2	2.2	2.2	2.2	5.5	5.5	5.5	5.5	7.5	7.5	7.5	7.5
Chemical Pumps (kW)	N/A	N/A	N/A	N/A	N/A	2×0.4	2×0.4	2×0.4	2×0.4	2×0.4	2×0.4	2×0.4	2×0.4	2×0.4	2×0.4
Max. Pressure	6 bar (90 psi)														
Max. Pressure Differential	1.75 bar (25 psi)														
Max. Temperature	40°C														
Cleaning Chemicals	ELGALITE RU3 and UFC13														

NOTE:
1. 80,000 Molecular Weight Cut Off Membranes.
2. Nominal capacities are based on operation at 20°C. For lower temperatures, consult Temperature Correction Table.
3. Guide: Feed water (FI)<10.

Performance information quoted refers to pre-treatment and post-deionisation applications only. For polishing or special purpose applications please consult Elga.

TEMPERATURE CORRECTION TABLE:

Temperature °C	Temperature Correction Factor
20	1.0
18	0.95
16	0.92
14	0.85
12	0.81
10	0.76
8	0.72
6	0.68
4	0.64

Owing to a policy of continual improvement we reserve the right to amend this specification leaflet

Elga Ltd. Lane End, High Wycombe, Bucks, England HP14 3JH. Telephone (0494) 881393, Telex 83516 ELGALE G, Fax (0494) 881007
Elga Water Treatment Ltd. 11 James's Terrace, Malahide, County Dublin, Ireland. Telephone 450048, Telex 30409, Fax 451989
Elga s.a. 13, rue Jean Bourgey, 69100 Villeurbanne, Téléphone 78.68.98.00, Télex Lyon 305932 F, Télécopie 78.68.94.58
Members of the Elga Group plc

ELGA®
The Pure Water People

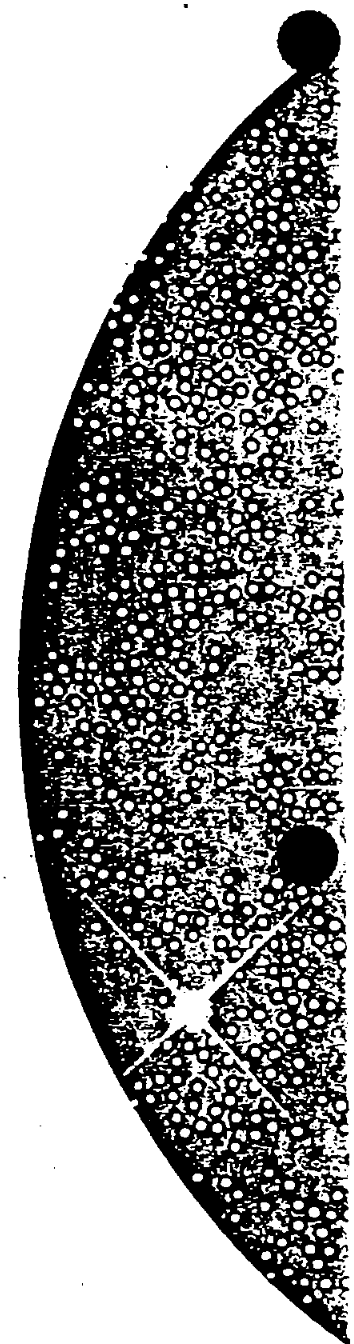
3/90

What can MEMCOR do for you?

MEMCOR's crossflow microfiltration membrane systems can process large volumes of industrial liquids. A unique, patented Gas Backwashing technique automatically cleans the membrane. This provides:

- improved economics in existing process systems
- a solution to filtration problems that were not previously economically feasible

This has been achieved by designing a system which is extremely efficient in removing some of the most difficult suspended solids including colloidal iron and titanium dioxide, metal hydroxides, algae, yeast and the smallest bacteria.



System Advantages

- Continuous high filtration rates – through automated gas backwashing
- Low running costs – by elimination of disposable cartridges
- Recovery of valuable by-products – by concentration of suspended solids
- Reliability – with convenience of operation
- Membrane integrity test – built in to provide quality assurance

Current Applications

Water
- Clarification and bacterial filtration of surface & ground water
- Removal of colloidal iron, organics and bacteria prior to reverse osmosis and deionisation
- Bacteria and suspended solids removal from mains water
- Recovery of rinse and waste water for re-use

Food
- Clarification and bacterial filtration of wines and ciders
- Clarification of apple and citrus juices
- Vinegar clarification
- Recovery of process cleaning liquids

Waste
- Reduction in BOD and COD levels by removal of suspended solids
- Removal of metal hydroxides and other flocculants
- Algae removal
- Removal of oil emulsions from water
- Colloidal solids removal to meet discharge levels

Removing suspended solids	**● Particle removal ● Source water cleaning ● Algae elimination ● Boiler pretreatment ● Re-use of effluent ● Military applications ● Pretreatment for reverse osmosis and deionisation ● Purifying water in cooling systems**
Separating fine flocculants and metal hydroxides	**● Treatment of plating shop effluents ● White water clarification ● Activated carbon control**
Bacteria and colloid separation	**● Drinking water purification ● Water mains purification ● Clarification of fluids in the food industry ● Removal of yeasts from wines and vinegars ● Clarification of juices and vinegars**

The MEMCOR system

The heart of the MEMCOR system is the filter module. Inside the module casing is a bundle of approximately 3,000 hollow fibres made of a permeable polyolefin polymer membrane manufactured to an accurate 0.2 micron pore specification. This provides the capacity to filter out and separate all suspended solids, bacteria, colloids, emulsified oils, and certain dissolved organic and inorganic substances.

Custom design. But the filter modules are only part of a whole system. Banked together in multiples of five modules, the system can be designed to meet any required filtration capacity. And to control the process, MEMCOR has married the modules to a straightforward delivery system. The whole system will be tailored to suit your needs.

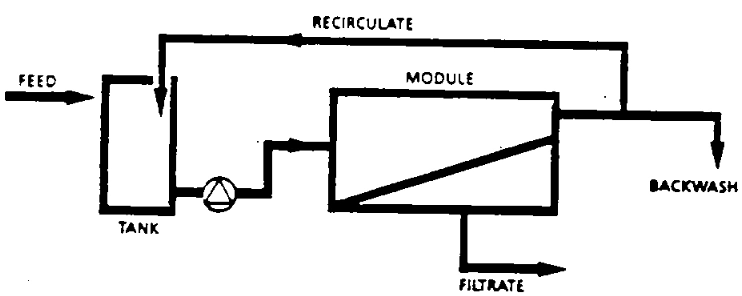
Hydraulic system. The normal MEMCOR system consists of a break tank, a centrifugal pump, and a flow-control pattern that enables you to retain, discard or recirculate the concentrate as required. Where necessary the feed stream can be passed through a pretreatment filter to remove gross contaminants more efficiently.

Computerised control. The operation is controlled by a microprocessor which automates your filter operations, and manages the Gas Backwashing operation.

Crucial to the reliability of the system is a built-in integrity check on all the modules. This provides on-line quality assurance and is supplied as standard.

All MEMCOR's fibres and other components are resistant to most chemicals. This allows the treatment of fluids that contain powerful chemicals. In addition, chemical cleaning can be used to maintain the module at optimum efficiency over an extended period of time. This cleaning process can be automated if required.

SCHEMATIC LAYOUT OF A MEMCOR SYSTEM



Lower operating costs

- Higher filtration rates at lower system cost
- Lower operating pressures give lower energy costs
- Long-life filter modules eliminate replacement costs
- Long-life filter modules reduce labour costs
- Computerised controls reduce labour costs and maximise operating efficiency
- Compact size reduces space requirements
- Valuable by-products retained

The MEMCOR technology described in this brochure is the subject of granted and pending patents in the UK and throughout most countries in the world. MEMCOR has taken precautions to ensure that the information contained in the brochure represents a fair and accurate description of its products and services at the time of publication. However MEMCOR reserves the right to further develop, change or modify the technology and systems described herein at any time.

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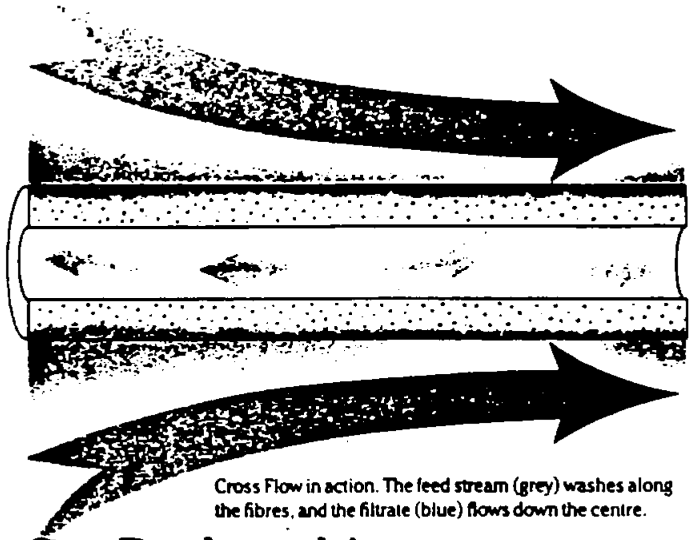
 PS RJ 1883 77

MEMCOR

'Outside-in' fibres

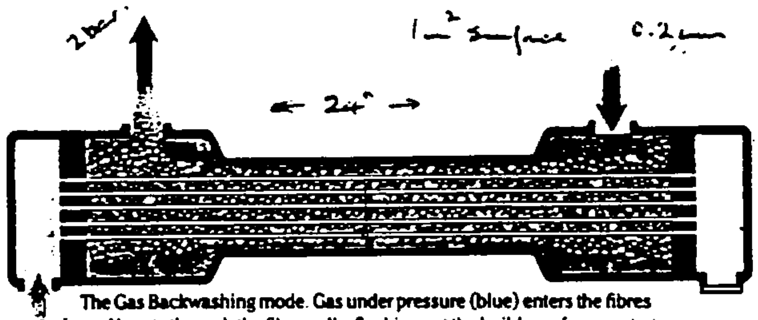
MEMCOR technology has solved this problem by taking the hollow fibre technique and reversing the flow. Instead of passing the feed stream through the centre of the hollow fibres, it is passed across the outside of the fibres while the filtrate runs off down the hollow centre. The build-up of deposits on the porous membrane continues, of course, since this is the function of a filter, but this simple design innovation has made possible a breakthrough that sets MEMCOR's filtration systems apart from all other systems – they can be automatically cleaned.



Cross Flow in action. The feed stream (grey) washes along the fibres, and the filtrate (blue) flows down the centre.

Gas Backwashing

MEMCOR's unique patented Gas Backwashing technique allows high filtration rates with variable dirt loadings to be maintained by regular cleaning of the filter module. And the Gas Backwashing technique also results in a long-life module that does not have to be replaced as soon as filtration rates drop off.

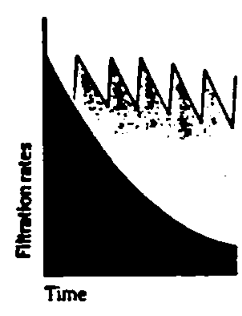


The Gas Backwashing mode. Gas under pressure (blue) enters the fibres and bursts through the fibre walls, flushing out the build up of concentrate.

Gas 'explodes' through a single hollow fibre.

By sealing off one filtrate exit, and by pressurising air or an inert gas into the hollow fibres through the other (see diagram), the fibre walls can be cleaned. The pressurised gas 'explodes' through the microscopic pores of the membrane, flushing out deposits of fouling material.

By combining crossflow membrane fibre technology with Gas Backwashing, MEMCOR has produced a filtration system of high efficiency which will improve the quality of your filtration operation at the same time as reducing operating costs.



With Gas Backwashing, MEMCOR's filter modules have a prolonged life. The efficiency of non-cleanable filters drops off rapidly.

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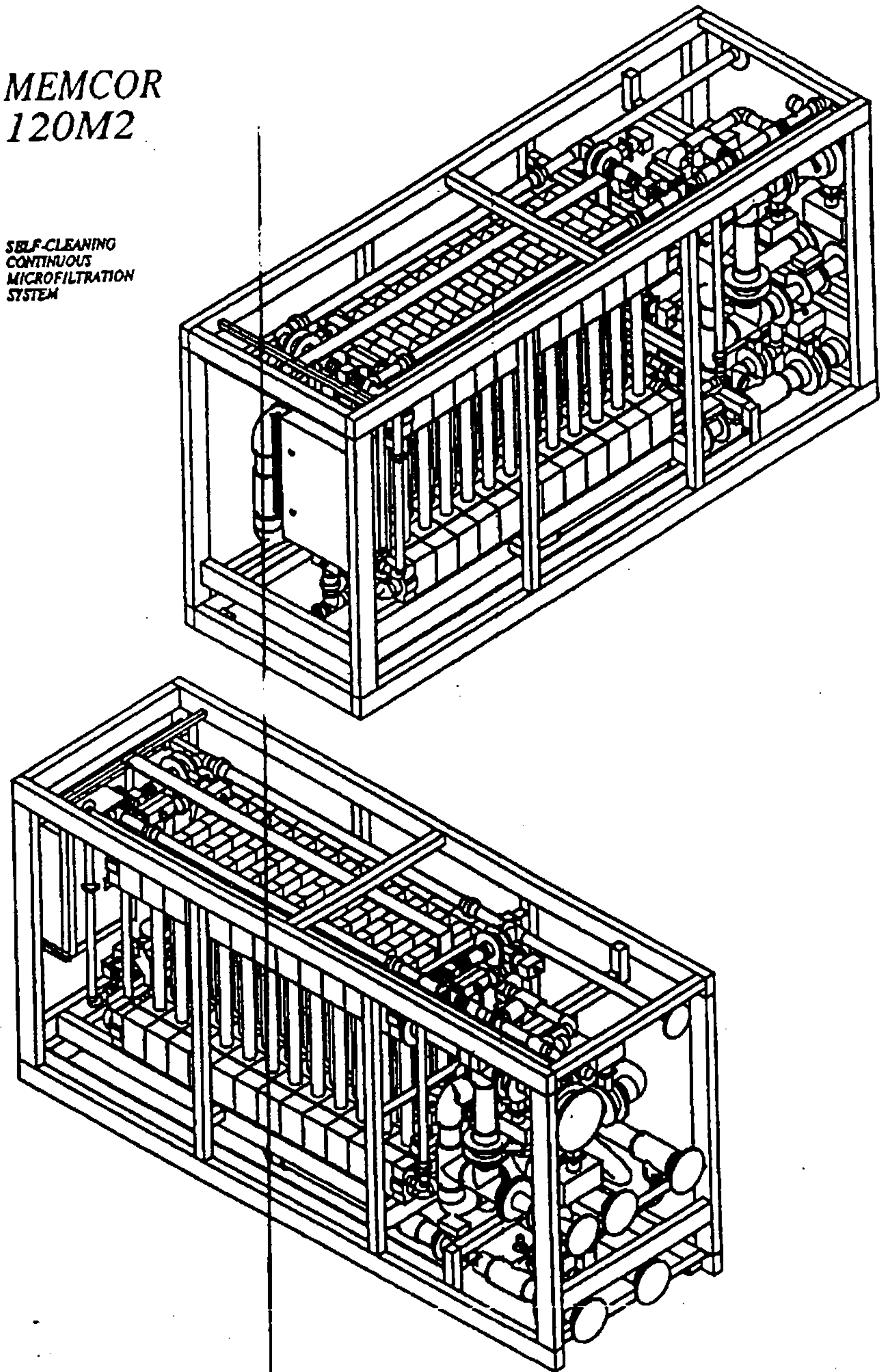
MODEL : 120M2
ISSUED : 91-03-05
SUPERCEDES : PRELIMINARY

SPECIFICATION SHEET

NOTE : DESIGN, DATA AND DIMENSIONS ARE SUBJECT TO MODIFICATION WITHOUT NOTICE

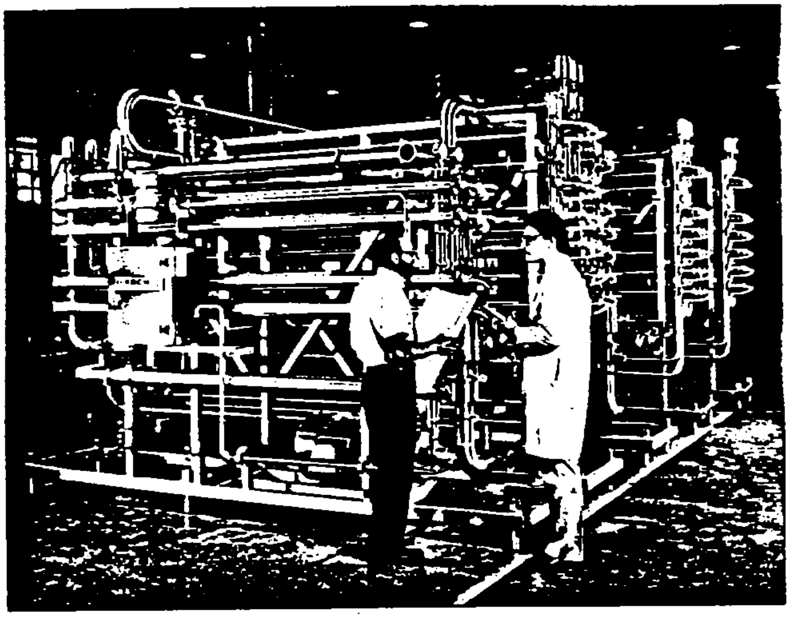
MEMCOR 120M2

SELF-CLEANING
CONTINUOUS
MICROFILTRATION
SYSTEM



KOCH AND THE CUSTOMER: A PARTNERSHIP

We see the relationship between supplier and customer as a partnership, one in which both parties work together, each contributing different strengths to the task at hand. Koch senior engineers and project managers work closely with the customer to satisfy specialized needs while remaining adaptable to changing project requirements. The highest professional standards are applied to every project because our people take pride in their work.

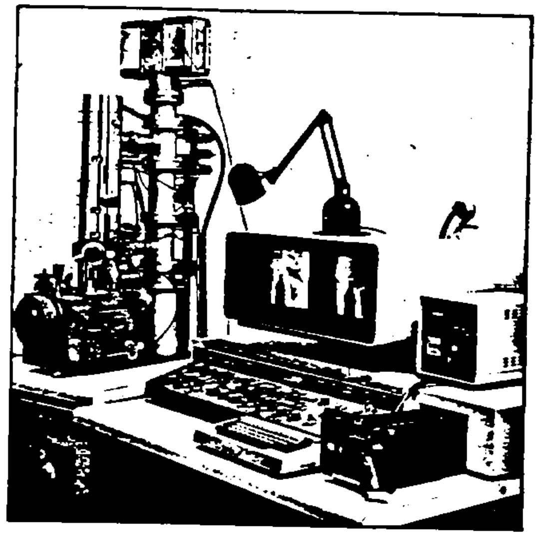


We work closely with customers to satisfy specialized needs while remaining adaptable to changing project requirements.

Incorporated as Abcor in 1963, and known as Koch Membrane Systems since 1985, we are a wholly-owned subsidiary of Koch Industries of Wichita, Kansas, a highly diversified international corporation. For over a quarter century Koch Membrane Systems has continued to set industry standards against which other products are measured. Strong support from the parent company ensures us the stability and strength to remain a major force in filtration worldwide.

Koch Membrane Systems' U.S. headquarters in Wilmington, Massachusetts.

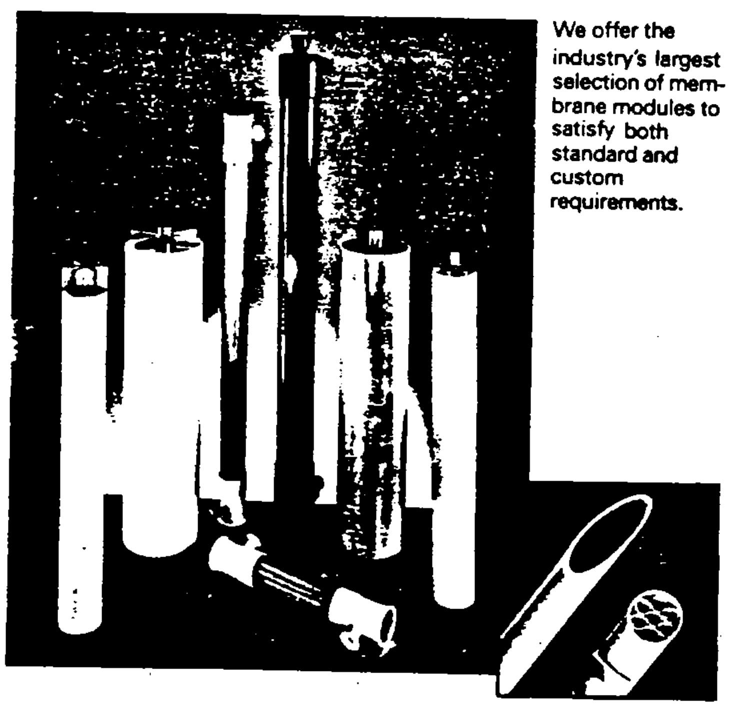
Focused research and development programs are centered around meeting current and future needs of the customer.



A STRONG COMMITME TO RESEARCH AND DEVELOPMENT

Koch Membrane Systems has an ongoing commitment to the research an development of new membrane products as well as continued improvements in membrane an module manufacturing. Recent R&D efforts have produced inn vative products such as our line microfiltration membranes for replacing diatomaceous earth ir clarification applications. This product also reflects our belief that new product development must be centered around meetin current and future needs of the customer.

Clear expertise in materials science, the availability of adequate research tools and equipment, and proven technical ability are all essential to effective new product development. Koch's worldwide leadership in membrane systems is partly due to our ability to integrate these elements into a focused research and development program that results in solutions to customer problems.



We offer the industry's largest selection of membrane modules to satisfy both standard and custom requirements.

QUALITY AND SELECTION IN MEMBRANE MODULES

Koch Membrane Systems has earned a reputation as an innovator in membrane development, and offers the industry's largest selection of membrane modules to satisfy both standard and custom requirements. We off an extensive line of products, from modules that are readily available as off-the-shelf products to "in-development" products that may be close to commercialization. Involve us in your special projects—we may be able to offer a unique application solution in addition to the standard approaches.

Koch . . . With Over 20 Years Experience in Membrane Processing

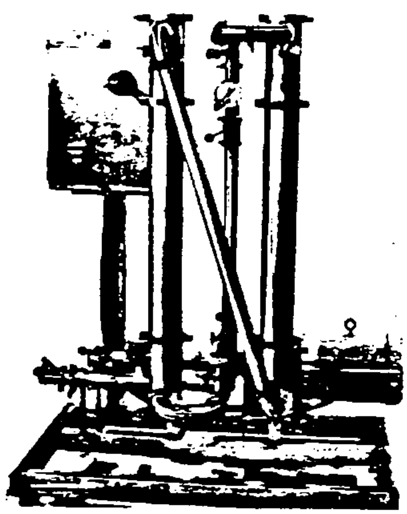
The Koch Difference

Koch Membrane Systems is exclusively a membrane company, manufacturing its own ultrafiltration and cross-flow microfiltration membranes and systems to match specific customer needs. And, Koch offers customers in-house testing and expert process and technical support.

There are more than 3,000 Koch tubular and spiral commercial systems in operation worldwide in a variety of industries, including food, dairy, beverage, pharmaceutical, automotive, textile, and metalworking, among others, ranging in size from pilot plants to large production systems.

Koch pilot systems are available on a rental basis. We will even put them side by side with traditional filtration equipment so you can judge for yourself the many benefits of Koch technology.

To see how Koch can improve your system capability with high production spiral membranes, call today.



200 series pilot unit capable of processing two gallons (8 liters) per minute.

Ultrafiltration

A low pressure (10-150 psi) membrane process for separating high molecular weight dissolved materials from liquids. A semi-permeable membrane, incorporated into membrane modules, performs the separation.

Low molecular weight species (for example, salts, sugars, and most surfactants) pass through the membrane and are removed as permeate. Suspended solids, colloids, and macro-molecules are rejected by the membrane and are concentrated. Ultrafiltration membranes can retain material as low as 1,000 molecular weight.

A process fluid flows tangentially across the membrane surface at high velocity. This cross-flow characteristic differs from the perpendicular flow of ordinary filtration, where a "cake" builds up on the filter surface, requiring frequent filter replacement or cleaning. Cross-flow prevents filter-cake buildup, resulting in high filtration rates that can be maintained continuously, eliminating the cost for frequent filter replacements.

Microfiltration

Microfiltration is another low-pressure (typically 10-100 psi) membrane process for separating suspended materials in the .05 to 5 micrometer range from water. Water, some macro-molecules, and dissolved species pass through the semi-permeable membrane, while suspended materials such as colloidal silica and bacteria, among others, are retained.

Like ultrafiltration and reverse osmosis, the process fluid flow is across the membrane, not perpendicular to it.

Reverse Osmosis

A high pressure membrane process, normally operating in the range of 600 psi. A semi-permeable membrane which retains dissolved salts but allows pure water to pass through is incorporated into membrane modules.

More than 99.5 percent of all salts and low molecular weight (200) solutes are retained and concentrated by the membranes. Both separated phases can be valuable because the concentrate can be a reclaimed product, and the permeate is a purified product.

Like ultrafiltration, the process fluid flow is across the membrane surface, not perpendicular to it.

Call Today For More Information

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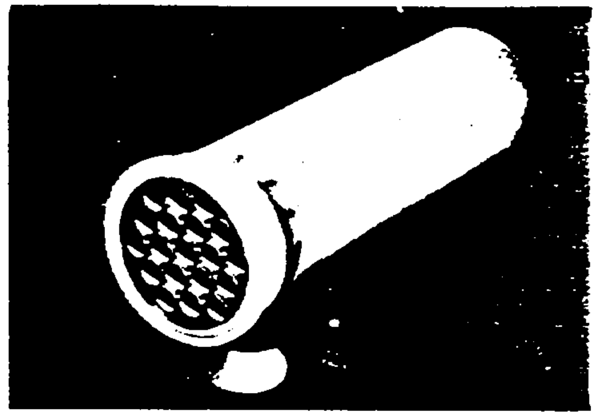
KOCH

KOCH MEMBRANE SYSTEMS INC

Abcor®

SUPER-COR™ Membranes Combine the Benefits of Open and Thin Channel Cross-Flow Filtration

Making the highest quality apple, pear, pineapple, cranberry and grape juice now takes fewer steps and is more economical than ever before thanks to SUPER-COR™ open-channel cross-flow filtration by Koch Membrane Systems.



Eliminate all Conventional Filtration Techniques

Totally eliminate pre-filtration, diatomaceous earth filtration, and associated handling equipment such as centrifuges, screens, rotary drum filters, and fining agents. That's because Koch's SUPER-COR membranes allow a much more efficient and consistent process than conventional methods for removing unwanted product components.

24 Square Feet of Membrane Area in Each Tubular Module

Each SUPER-COR membrane has 19 half-inch tubules inside a 4-inch diameter housing that is 120 inches long. That provides 24 square feet of active membrane area per tube for concentrating the maximum in suspended solids.

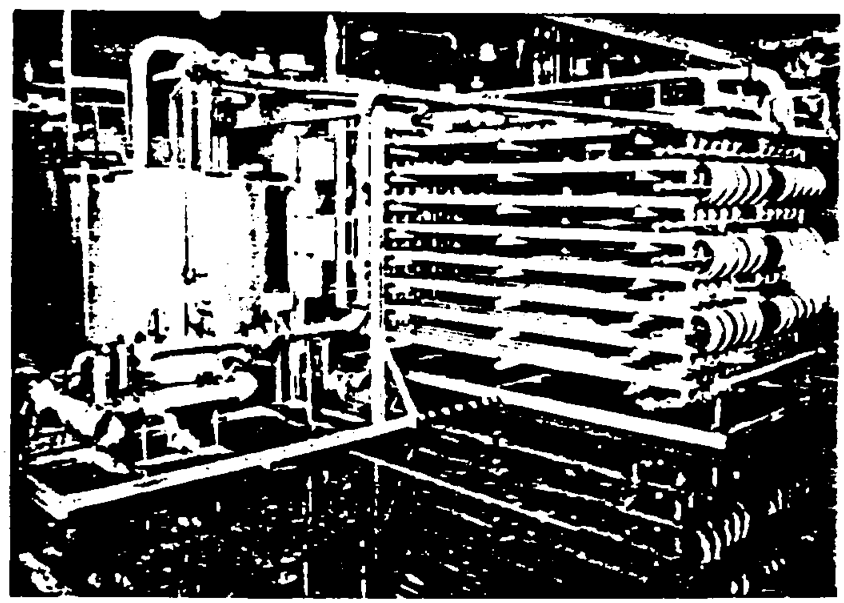
Within the system, SUPER-COR, modules are arranged in a series configuration to maximize the ratio of membrane surface area to product volume, which ultimately maximizes system efficiency.

Ideal for Removing Suspended Solids

Increased product recovery is entirely dependent on how high a concentration of suspended solids you can obtain. Koch's supported, SUPER-COR™ open-channel membranes are especially designed for high suspended solids concentration without the need for expensive prefiltration to prevent plugging.

Use SUPER-COR Membranes on These Products:

- Fruit juices
- Wine
- Beer
- Enzymes
- Cells Broths
- High Temperature Processes



A typical Koch SUPER-COR system, capable of processing various juice, broth and other liquid streams.

KOCH
KOCH MEMBRANE SYSTEMS INC

Abcor®

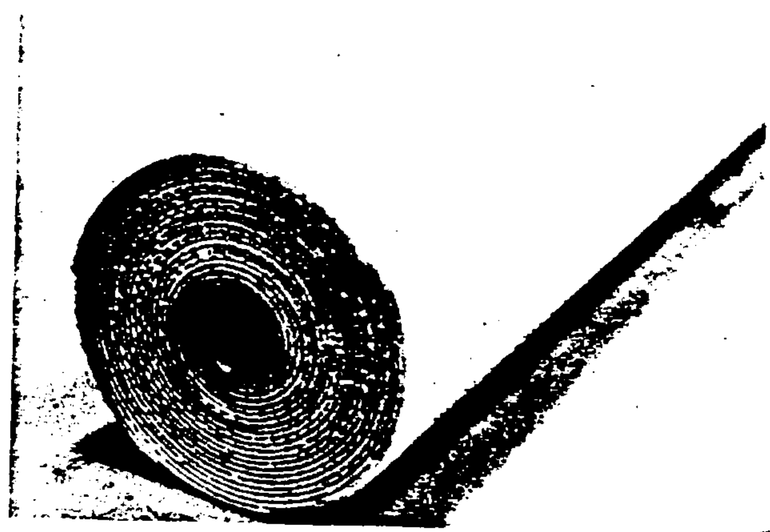
Koch Introduces It's New High Productivity/Long Life Spiral Module

Koch Membrane Systems' new high capacity spiral membrane will give you the greater productivity and longer membrane life that is not achievable with other membranes.

Koch has combined its custom design capabilities and proven leadership in membrane technology to develop this product to reflect the ever-changing marketplace in which it is used.

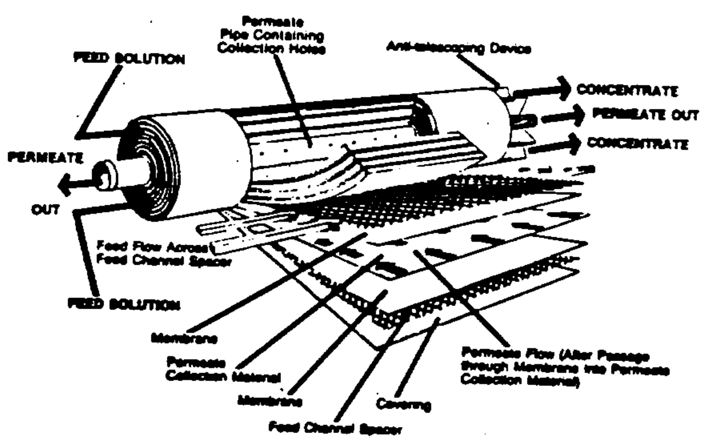
The high-productivity spiral will give you superior protein retention, and is available for immediate installation in any spiral design system.

Backed by Koch's expert technical and process support, the high productivity membrane is the answer to your questions concerning greater output of your existing equipment.



Koch 4-inch spiral module.

SPIRAL WOUND MODULE



Benefits of Koch's High Productivity Spiral Module

- Economical
  Low capital and operating costs.
- Energy Efficient
  Minimal energy required for operation, saving power costs.
- Rugged
  Unique support system means excellent temperature and operating pressure resistance.
- MADE IN 2, 4 AND 8 INCH DIAMETER MODULES.

The Technology

For over 20 years, Koch has been refining membrane technology and developing large-scale systems to meet industry's separation needs. At the heart of every Koch system are precise, durable Abcor® membranes especially made to withstand the toughest processing conditions.

APV

Membrane Technologies

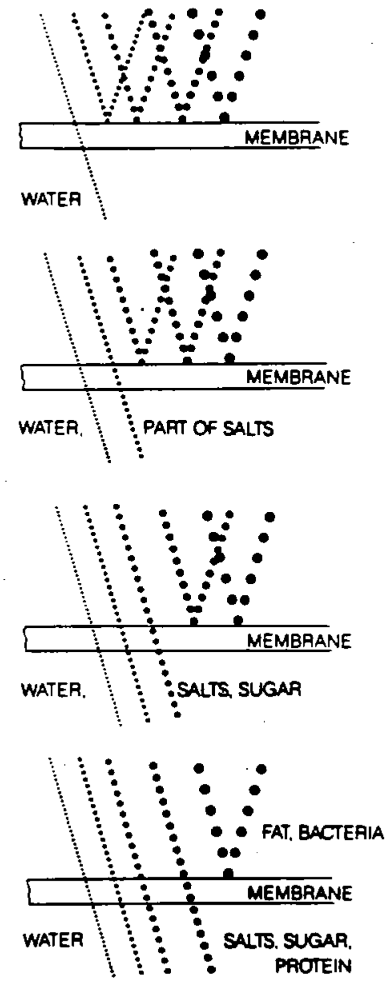
Whether your problem involves Microfiltration, Ultrafiltration, Nanofiltration, Reverse Osmosis or Dialysis — APV Membrantechnologie is your one source for intelligent solutions. Expert and experienced in all of these methods, our knowledge of their individual advantages and limitations can benefit your bottom line.

Only a company with extensive experience in all five major filtration processes, along with the expertise to implement them, can develop optimal solutions to specific membrane problems.

At APV Membrantechnologie GmbH, we have the ability, the experience and the specialists needed to get the job done, plus the highly beneficial knowledge transfer provided by our close contact with the process engineering experts of the APV Group.

Tell us your problems, and we'll solve them for you. Our elegant yet cost-effective solutions will incorporate the membrane technology that is appropriate for you — providing optimum quality, yield and return on investment. Plus, APV Membrantechnologie will supply all materials and install a complete, custom system.

Primary filtration technologies available today include:

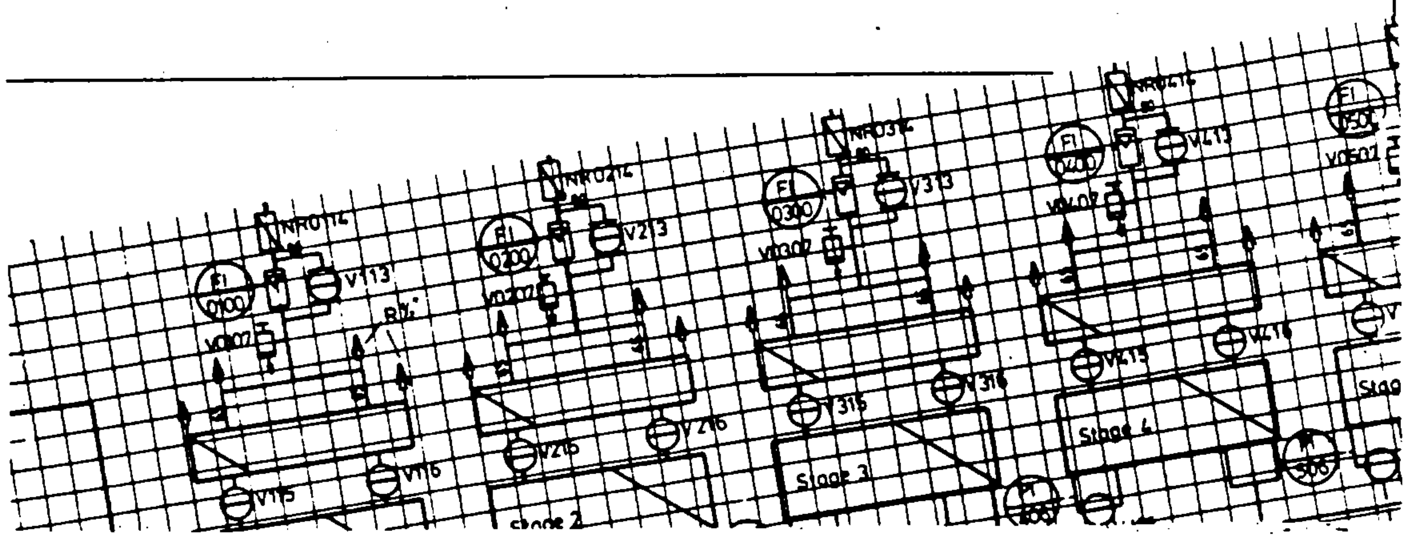


REVERSE OSMOSIS
A filtration process used for complete desalination.

NANOFILTRATION
This filtration process provides partial desalination.

ULTRAFILTRATION
A process which selectively filters only molecules of specified size and weight.

MICROFILTRATION
Filtration by particle size only.



The Various Types of Membranes

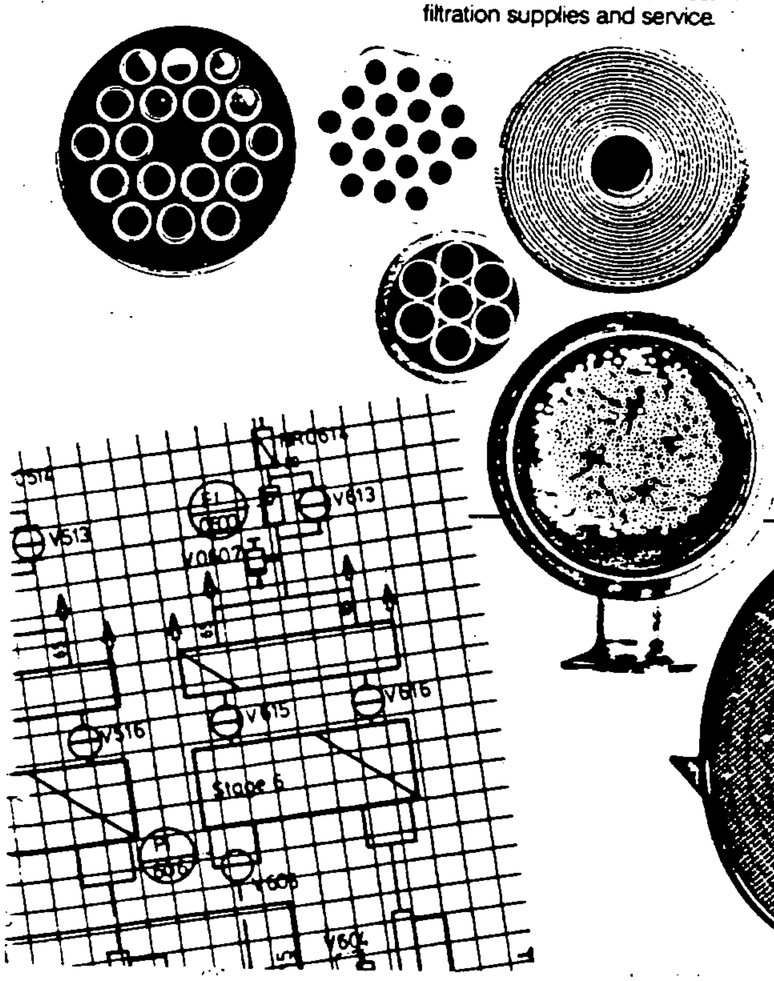
The nature of the process control problem determines the choice of a membrane solution, including: spiral membranes, a variety of tubular membranes, hollow-fibre membranes and plate and frame membranes made of organic material (polymers). Metallic, sintered ceramic and acetate membranes may also be specified, depending upon customer preference and suitability for the application.

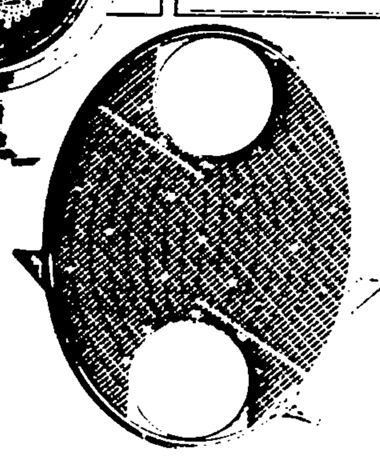
APV Membrantechnologie is not a membrane manufacturer, so we can be truly objective in our assessments of currently available membranes, offering solutions based entirely upon qualitative, functional and economic factors.

Our in-depth, working knowledge of the strengths and weaknesses of all membrane types now available and under development is of inestimable value to our customers, who depend upon us for optimal solutions to process control problems.

With APV Membrantechnologie on your membrane technology team, you can be assured of obtaining the best membranes for your specific applications. Plus, we do much more than specify and deliver materials — our skilled technicians offer complete installation, as well as professional servicing of all brands and types of filtration systems.

APV Membrantechnologie is your one best source for the finest in filtration supplies and service.





The key determining factors influencing the decision to use membrane filtration technology include:

- Improvement in product quality
- More efficient use of raw materials
- Recycling of valuable materials
- Effluent discharge and disposal requirements
- Lack of viable alternatives

Add economic efficiency to the list — in recognition of its surprisingly short amortization period — and discover why more and more industries are turning to membrane filtration.

Leading beneficiaries of the advantages of membrane technology include industries such as:

Water Treatment

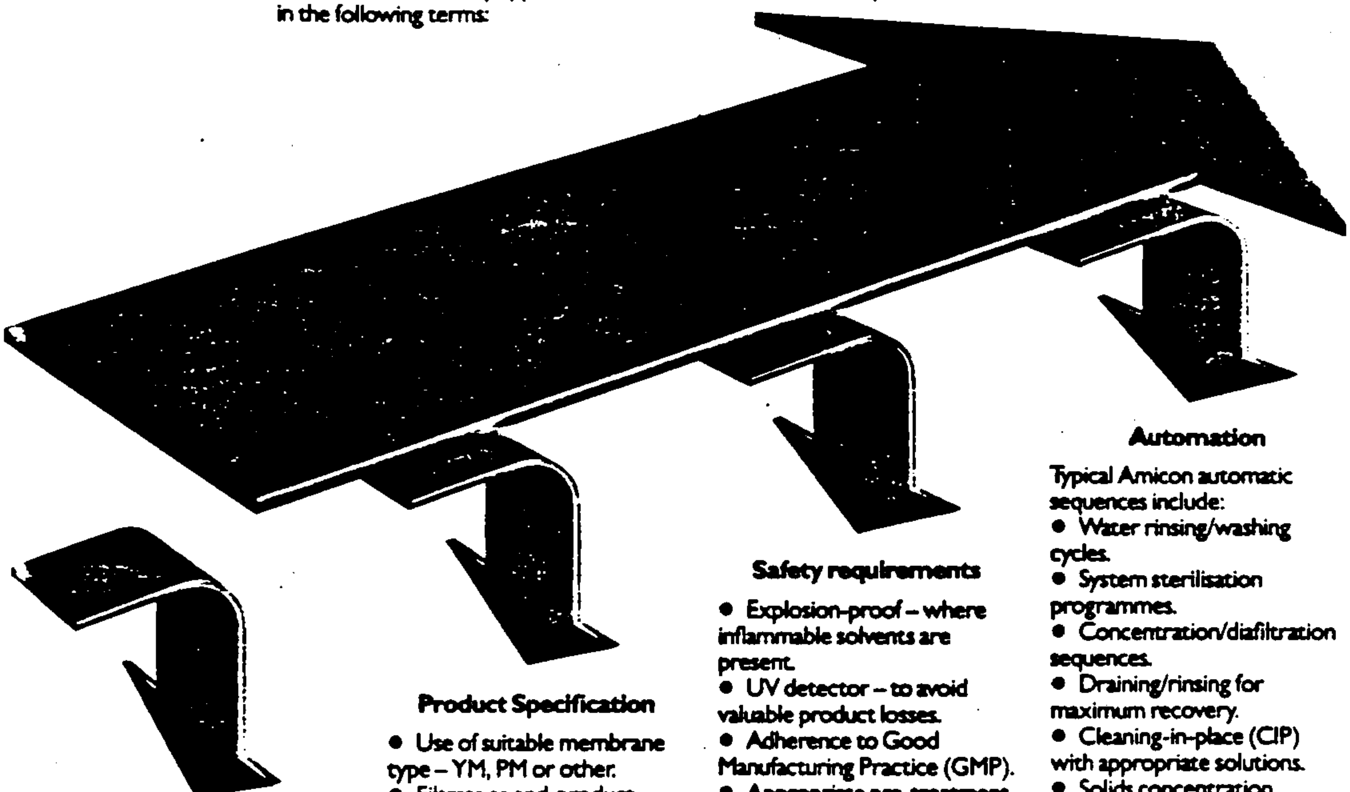
Membrane technology can:

- purify drinking water for improved quality;
- make possible the economical recirculation of water used for industrial purposes;
- provide safe water treatment in compliance with governmental standards for wastewater treatment systems, including emulsion separation, raw material recycling and pollution control;
- produce pyrogen free water for pharmaceutical use.

AMICON ULTRAFILTRATION SYSTEMS

Through careful appraisal of the membrane type and its configuration, Amicon is able to engineer systems that are perfectly matched to a customer's application, volume throughput and investment requirements. All Amicon systems are designed on a modular concept, allowing full scale-up flexibility from small batch volumes right up to industrial throughputs.

However, in many applications further customisation is required and this is evaluated in the following terms:



Design of Liquid Flow Path

- Batch – simple, fixed volume process.
- Topped-off batch – variable process volumes.
- Closed loop batch – low hold-up volume with no air entrapment.
- Staged – continuous processing modes.
- Series membrane operation – Ioplate or 3 x S40.
- Parallel membrane operation – Hollow Fiber or S120 with 3 x S40.
- Selection of suitable pump – e.g. positive displacement trilobe for quiet, reliable operation.

Product Specification

- Use of suitable membrane type – YM, PM or other.
- Filtrate as end-product – fruit juice.
- Concentrate as end-product – dairy products.
- Dialysate – concentrate as end-product – albumin.
- Dialysate – filtrate as end-product – wine clarification.

Safety requirements

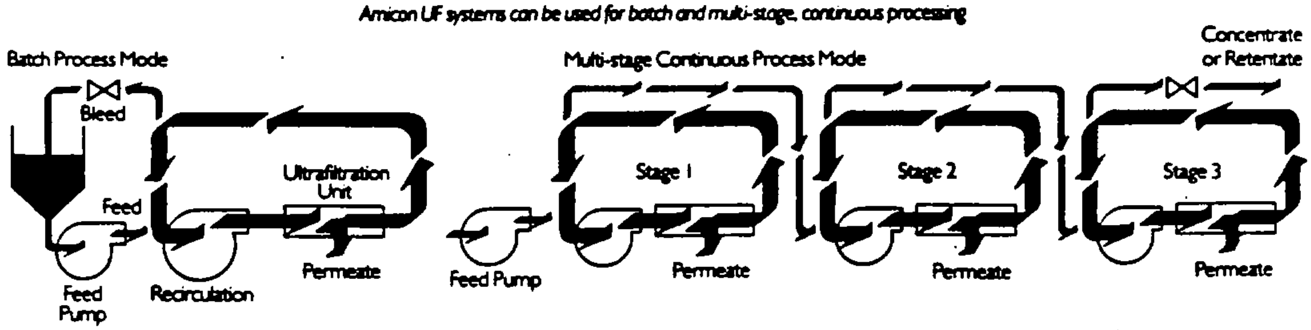
- Explosion-proof – where inflammable solvents are present.
- UV detector – to avoid valuable product losses.
- Adherence to Good Manufacturing Practice (GMP).
- Appropriate pre-treatment – selection of optimum prefiltration prior to ultrafiltration operation.
- FDA certification – systems available to fully approved FDA requirements.
- Cleaning – the simplest and most appropriate to suit the application.
- Materials of construction – 316L stainless steel for sanitary applications.

Automation

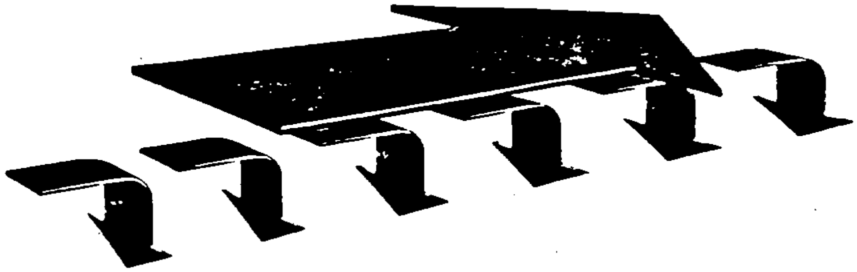
Typical Amicon automatic sequences include:

- Water rinsing/washing cycles.
- System sterilisation programmes.
- Concentration/diafiltration sequences.
- Draining/rinsing for maximum recovery.
- Cleaning-in-place (CIP) with appropriate solutions.
- Solids concentration monitoring.
- Optimal transmembrane pressure selection.

Amicon UF systems can be used for batch and multi-stage, continuous processing



AMICON 'TAILORED' SYSTEMS



Standard Modular System Types

Flux* by Application

		Membrane	SP20 S	SP20 HF	SP150 S	SP150 HF	SP240 S	SP240 HF	Ioplate L TC	Ioplate L WC	Ioplate S TC	Ioplate S WC	Ioplate 8C TC	Ioplate 8C WC
Water	Pretreatment	P100	152	100	378	2500	600	4000						
	UPW	P10	236	150	588	3750	784	6000						
	Pyrogen Free	P10	200	140	500	3500	762	5600						
Protein	Albumin 4%	Y10	336	–	840		1350				120	84	1020	660
	Factor 8	Y100	168	–	420		670				60	42	510	330
	MAB	Y30	230		575		920				84	59	714	462
	Enzyme	Y30	292		730		1168				104	73	881	572
	Interferon	Y100	480		1200		1920				170	119	1415	935
Cells	Red Cell Ghost	P100		60		762		1219	133	93	133	93	1130	731
	Virus	P100		40		508		813	57	40	57	40	481	313
	E. Coli Harvest	MP01		80		1016		1626	114	80	114	80	961	627
Beverage	Fruit Juice	PM10		54		586		1098	120	84	120	84	1020	660
	Wine	MP01		63		800		1280	140	98	140	98	1190	720
	Vinegar	P100		72		915		1463	160	112	160	112	1360	880
Food	Sugar	Y3	144		360		576		51	36	51	36	434	281
	Acid Whey	P10		80		1024		1638	178	125	178	125	1515	980
	Sweet Whey	P10		62		1166		1866	204	143	204	143	1734	1122
	Whole Milk	P100		64		813		1301	142	99	142	99	1205	780
	Gelatine	Y3	112		280		448		40	28	40	28	340	220
	Glue	Y10	448		1120		1792		160	112	160	112	1360	880
Waste Water	Flexo Ink	P10		47		597		955	104	73	104	73	884	572
	Oily Waste	P30		63		800		1280	140	98	140	98	1190	770
Particle-Laden Waste	Paint (E. Coat)	Y30	296		742		1187		106	74	106	74	901	583
	Pulp	P10		38		480		768	84	59	84	59	717	464
	Paper	P10		34		432		691	76	53	76	53	646	418

S – Spiral
HF – Hollow Fiber
L – Polyethylene Ioplate Pilot
S – Stainless Ioplate Pilot
8C – 8 Cartridge Ioplate System
TC – Thin-Channel
WC – Wide-Channel

Recommended
Acceptable
Not Recommended

*(All figures are litres/hour for maximum system membrane area at start-up concentration)

Equipment Characteristics by Specification

	SP20 S	SP20 HF	SP150 S	SP150 HF	SP240 S	SP240 HF	Ioplate L TC	Ioplate L WC	Ioplate S TC	Ioplate S WC	Ioplate 8C TC	Ioplate 8C WC
Max. Membrane Area m² (sq. ft.)	5.6 (60)	1.8 (20)	14 (150)	23 (250)	22 (240)	37 (400)	2 (22)	1.4 (15)	2 (22)	1.4 (15)	17 (184)	11 (115
Sanitary Specification	NO		YES		YES		NO		YES		YES	
Suggested Volume (l/h Processed)	2-200	2-50	15-5000		20-10000		20-500		20-500		200-2000	
pH Resistance	1-13	0.5-14	1-13	0.5-14	1-13	0.5-14	0.5-14		0.5-14		0.5-14	
Pressure Rating (bar)	4.1	1.7	4.1	1.7	8.6	1.7	4.1		4.1		4.1	
Temperature °C	2-55	4-70	2-55	4-70	2-55	4-70	4-75		4-75		4-75	
Minimum Process Volume (l)	0.9	1.1	10	11	50	30	10		10		95	
Typical Energy Consumption (kW)	0.8	1.0	1.2	1.5	2.2		2		2		5	
Recommended Recirculation (l/min)	20	30	115		185		115		115		1700	
Membrane Type (RC=Cellul., P=Polysulf.)	RC	P	RC	P	RC	P	Any Polymeric		Any Polymeric		Any Polymeric	
Cut-off Range (K Daltons)	3-100	3-1000	3-100	3-1000	3-100	3-1000	Range 0.5-1000		Range 0.5-1000		Range 0.5-1000	
Pump Specs. (T=Trilobe, C=Centrifugal)	T	T	T/C	T/C	T/C	T/C	C	C	C	C	C	C
Pressure (bar)	4.5	2.0	4.0	2.0	4.5	2.0	4.0		4.0		4.0	
Throughput m³/h (l/min)	1.8 (30)		12 (200)		20 (333)		7.8 (130)		7.8 (130)		100 (1700)	
kW	1.5		2.2		3		3		3		7.5	
Dimensions (H x W x D)	70 x 70 x 30		200 x 210 x 75		200 x 230 x 75		132 x 56 x 109		140 x 58 x 91		120 x 410 x 80	
Voltage (V)	220/240		380-415		380-415		380-415		380-415		240-480	
Weight (kg)	90		450		550		98		110		710	

(All systems are available in manual or automatic forms – electrical specifications are IP55 rated spray proof – exception SP20 – IP54 splash proof)