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(54) Title: HIGH EFFICIENCY MEMBRANE FILTRATION

(57) Abstract: In an filter apparatus comprising at least two pressure vessels, each pressure vessel containing at least one membrane filter, at least two of the pressure vessels are arranged in a circle by connecting the concentrate outlet (104) of a pressure vessel to the liquid feed inlet (102) of the adjacent pressure vessel. Also is presented a method for arranging liquid circulation in membrane filtration by circulating concentrate of a membrane filter at least partly back to be filtrated in said membrane filter via one or more further membrane filters.

HIGH EFFICIENCY MEMBRANE FILTRATION

The object of the invention is membrane filtration, more particularly the invention relates to an apparatus, to method and an arrangement, with which membrane filtration is delivered. One object of the invention is reverse osmosis filtration or inverted filtration separation.

Membrane filters are very widely used in industry and elsewhere for water purification as well as for other purposes. Membrane filtration technology is also a developing field, in which new techniques and opportunities for different applications and uses are emerging.

The operation of a membrane filter, which can also be called a membrane separator, can be described in a simplified manner as follows: The permeable membrane to be used, which possesses certain properties, allows a permeate, e.g. water, to pass through it and retains other materials. In practice, the separation in membrane filters is not perfect, in which case the result of the separation is permeate that passed through the membrane and the concentrate, or corresponding, obtained from the material to be filtered. Often permeate is the intended product, e.g. when purifying water, but membrane separation can be used for concentrating the sought material, e.g. when recovering process chemicals or when concentrating solutions. A generally used membrane filtration method for liquids is so-called cross flow filtering. Cross flow filtering is in use in many different types of membrane filtering methods, e.g. in reverse osmosis filtration, nanofiltration, ultrafiltration and microfiltration. In cross flow filtering the material to be purified is brought to flow in the direction of the surface of the filtering membrane in which case, although some of the material filters through the membrane, the material to be purified rinses the surface of the membrane and in this way keeps the membrane permeable while preventing clogging or a large local concentration on the surface of the membrane. The

driving force in membrane filtration is a pressure difference across the membrane. Energy is also needed, apart from overcoming the resistance caused by the membrane, for moving and conducting the liquids in the different phases of the process as well as for raising
5 the pressure of the liquid to the operating pressure needed. Membrane filter devices and their components are generally available for various purposes. Membrane filter plants and devices are fabricated from commercially available components and are based on generally known techniques. For example, reverse osmosis filters are com-
10 mercially available for various applications and suitably also for the treatment of various solutions and for the separation of many types of substances, and, inter alia, filters for salt removal can be optimized and also the salt content ratio of the water to be treated can be selected.

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The aim of this invention is to develop membrane filtration and to achieve inexpensive, reliable, safe and well functioning membrane filtration solutions. More particularly the invention aims for reverse osmosis filtration solutions, nanofiltration solutions, ul-
20 trafiltration solutions and microfiltration solutions and especially the type of solutions that are suitable for use in the reverse osmosis enrichment or reverse osmosis purification of aqueous solutions. The features characteristic to the invention are presented in the claims, in which also the embodiments of the invention that are be-
25 lieved to be advantageous are disclosed.

An important advantage to be achieved with the invention is a high coefficient of efficiency for membrane filtration. In particular, the favorable, at least momentary, avoidance of pressure losses to
30 be achieved with an implementation of the invention assists in reaching a high coefficient of efficiency. An advantageous aspect of the invention relates savings in pipelines which are result from using vessels equipped with filter membranes as return paths for a circular liquid flow. These savings of pipelines are not only mate-

rial savings, but shorter pipelines also contribute for lower energy losses due to the shorter flow paths. The invention may appear as a water treatment apparatus, which advantageously is used for desalination or water purifying purposes. Also other advantages can be
5 achieved with the invention.

A preferred embodiment of the invention is a filter apparatus in which at least two pressure vessels, each pressure vessel containing at least one membrane filter, are arranged in a circle so that con-
10 centrate outlet of one pressure vessel is connected to the liquid feed inlet of the adjacent pressure vessel.

Preferably the invention appears as a filter apparatus comprising at least two pressure vessels, each pressure vessel containing at least
15 one membrane filter, the membrane filter or the membrane filters arranged in the pressure vessels according the cross-filtration principle so that liquid feed entered to a pressure vessel is divided to a permeate part and to a concentrate part, each pressure vessel comprising an inlet for liquid feed and a concentrate outlet for con-
20 centrate and a permeate outlet for permeate, and at least two of the pressure vessels are arranged in a circle by connecting the concentrate outlet of a pressure vessel to the liquid feed inlet of the adjacent pressure vessel.

A further preferred embodiment of the invention is a filter apparatus comprising a first pressure vessel and a second pressure vessel,
25 each pressure vessel containing a membrane filter, the membrane filter arranged according the cross-filtration principle so that liquid feed entered to a pressure vessel is divided to a permeate part and to a concentrate part, each pressure vessel comprising an inlet for
30 liquid feed and a concentrate outlet for concentrate and a permeate outlet for permeate, and the concentrate outlet of the second pressure vessel is connected to inlet of the first pressure vessel and

the concentrate outlet of the first pressure vessel is connected to inlet of the second pressure vessel.

Advantageously the apparatuses of the invention comprise a nozzle feeding pressurized liquid towards liquid feed inlet in the liquid
5 path connecting the concentrate outlet and the liquid feed inlet.

An advantageous way to use the invention is to accommodate vessels with reverse osmosis membrane filters.

A preferred way to carry out the invention is to arrange liquid circulation in membrane filtration so, that concentrate of a membrane
10 filter is at least partly circulated back to be filtrated in said membrane filter via one or more further membrane filters.

Preferably new liquid is provided between each pressure vessel arranged in the circle.

Preferably the liquid circulation is powered by using jet pumps between each adjacent membrane filters and for feeding new liquid into
15 the circulation. Sometimes jet pumps are called Venturi pumps.

An aspect of the invention to provide a method for arranging liquid circulation in membrane filtration. New liquid is provided between each pressure vessel to a pressurized inlet of a membrane filter and
20 concentrate of a membrane filter is at least partly circulated back to be filtrated in said membrane filter via one or more further membrane filters so that said circulated concentrate is fed to the pressurized inlet of said membrane filter. A high pressure pump is used to feed new liquid to the inlet of a membrane, i.e. to the
25 inlet of the vessel containing the membrane. The high pressure pump feeds the new liquid via a nozzle of a jet pump. Preferably the circulation between adjacent membrane filters and all feeding new liquid into the circulation is arranged by jet pumps arranged between such membrane filters.

A further aspect of the invention is arrangement in which plurality of pressure vessels, each pressure vessel containing at least one membrane filter. The concentrate outlet of one of the pressure vessels is connected to the pressurized inlet of another pressure vessel and the concentrate outlet of a further pressure vessel is connected to the pressurized inlet of another pressure vessel. In the following the invention will be described in more detail by the aid of one example of its embodiment with reference to the attached drawings illustrating aspects of the invention,

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Fig. 1 presents a sub-unit suitable to be used in the invention, Fig. 2 presents a simplified two vessel configuration.

Fig. 1 presents schematically a sub-unit 101 applicable to be used in the invention. The sub-unit 101 comprises a membrane filter unit 1, typically being a pressure vessel wherein one or more membrane filters is contained, with piping connections, and a flow channel 105, into which connects a nozzle 2 feeds new liquid from pressure source, such as a pump. When sub-unit 101 is used in an apparatus according to the invention the flow channel forms or at least is a part of the connection between two pressure vessels. The membrane filter unit 1 is, in practice, a vessel that holds pressure, inside which vessel a filter membrane, e.g. a reverse osmosis filter membrane, is arranged. The membrane filter unit 1 comprises an inlet connection 102 for conducting liquid in process, e.g. aqueous solution, into the membrane filter unit 1, a first outlet connection 103 for conducting permeate from the membrane filter unit 1 and a second outlet connection 104 for conducting concentrate from the membrane filter unit 1. The connections 102, 103 and 104 can be regarded as being single ones in the membrane filter unit, to which are connected with a pipe, or the connections 102, 103, 104 can also be regarded as comprising pipes with which they are connected to other parts of sub-unit. The second outlet connection of sub-unit 101 is connected to a flow channel leading to the inlet connection 102 of

the liquid treatment device 101, in which case the concentrate is able to circulate back. Joints 111 and 112 represents schematic connection points for connecting adjacent sub-units. The inlet 102 is pressurized to the pressure which is about the output pressure of the high pressure pump 200 feeding new liquid in to the circulation. By connecting always joint 111 of one sub-unit to joint 112 of the adjacent sub-unit one builds a circle of two or more sub-units. In the flow channel 105 is a nozzle 2, with which new liquid to be treated is fed into the flow channel. The nozzle 2 feeds new liquid to be treated at quite a high speed towards the in-feed connection 102. The volume flow rate of the liquid volume supplied by the nozzle is of the same magnitude as what filters through the membrane and finally exits from the first outlet connection 103. This fast flow of the nozzle arranges a cross flow on the surface of the membrane. At the same time the nozzle simultaneously transmits into the liquid space leading to the membrane the pressure needed for the filtering function of the membrane. In many cases one nozzle is sufficient, but e.g. in very large systems, comprising a number of membrane filter units connected to each other, it can be advantageous to use a number of nozzles as the source of the flow of the flow channel or possibly even of a number of flow channels to create suitable pressure increase and/or flow.

An alternate is to make the operation of this type of liquid treatment device cyclical such that with the apparatus there is alternately filtration and alternately the concentrated concentrate is removed. A rinsing connection 106, 106', comprising a valve 107, 107', is in the membrane filter unit 1 or in a branch from the second outlet connection 104, via which rinsing connection the concentrated concentrate is removed. Using a choke valve in place of the valve 107, 107' it is possible to maintain a set concentration of the concentrate and keep the process continuous and non-cyclical.

In practice it is often more advantageous to omit separate joints 111,112 between sub-units, but rather build the liquid path between

sub-units so that the outlet connection 104, the inlet connection 102 and the jet pump comprising shaped flow channel 105 and nozzle 2 feeding the jet pump are integrated into a single unit bridging from one pressure vessel to the adjacent pressure vessel.

5 Fig. 2 diagrammatically presents an apparatus working according to the invention. Simply put, the basic structure can be regarded as being two coupled sub-units of Fig. 1. The operation of apparatus of Fig. 2 is described as water purification, albeit the liquid to be processed could be other than raw water to be purified. A pump
10 200 takes raw water, possibly already pre filtered or preprocessed, from source 201 and pumps it to nozzles 2 of jet pumps, which contribute as a part of the liquid paths from concentrate outlets 104 of the membrane filter units 1a,1b to the liquid feed inlets 102 of the membrane filter units 1a,1b in such manner that filter unit 1a
15 forms a return path of concentrate back circulation of the filter unit 1b and filter unit 1b forms a return path of concentrate back circulation of the filter unit 1a. Permeate, e.g. purified water, is led out from both filter units 1a, 1b via permeate outlets 103.

A continuous type operation of this type of water treatment device
20 is achieved by using choke valves 198. Certain amount of concentrate is allowed to leak out from the circulation via choke valves 198. By setting the leak speed the concentration of the concentrate can be set to an optimum. The optimum is selected according to which use parameter is important. If the raw water supply is limited or raw
25 water is of high costs, then a higher yield is important. In case high cost electric power or limited availability electric power, then the energy efficiency may be the most important optimization criteria.

30 It is obvious to the person skilled in the art that the invention is not limited to the examples described above, but that it may be varied within the scope of the claims presented below as well as of the description and the drawings presented.

CLAIMS

1. Filter apparatus comprising at least two pressure vessels, each pressure vessel containing at least one membrane filter, the membrane filter or the membrane filters arranged in the pressure
5 vessels according the cross-filtration principle so that liquid feed entered to a pressure vessel is divided to a permeate part and to a concentrate part, each pressure vessel comprising a pressurized inlet (102) for liquid feed and a concentrate outlet (104) for con-
centrate and a permeate outlet (103) for permeate, **characterized** in
10 that, at least two of the pressure vessels are arranged in a circle by connecting the concentrate outlet (104) of a pressure vessel to the pressurized liquid feed inlet (102) of the adjacent pressure vessel.
2. Filter apparatus according to claim 1, comprising a first
15 pressure vessel and a second pressure vessel, each pressure vessel containing a membrane filter, the membrane filter arranged according the cross-filtration principle so that liquid feed entered to a pressure vessel is divided to a permeate part and to a concentrate part, each pressure vessel comprising a pressurized inlet (102) for
20 liquid feed and a concentrate outlet (104) for concentrate and a permeate outlet (103) for permeate, **characterized** in that, the concentrate outlet (104) of the second pressure vessel is connected to the pressurized inlet (102) of the first pressure vessel and the concentrate outlet (104) of the first pressure vessel is connected
25 to the pressurized inlet (102) of the second pressure vessel.
3. Filter apparatus according to any of preceding claims, **charac-
terized** in that the liquid path connecting the concentrate outlet (104) and the liquid feed inlet (102) comprises a nozzle (2) feeding pressurized liquid towards liquid feed inlet.

4. Filter apparatus according to any of preceding claims, **characterized** in that each pressure vessel contains at least one reverse osmosis membrane filter.

5. Filter apparatus according to any of preceding claims, **characterized** in that a jet pump is joined to liquid feed inlet (102) of each vessel arranged in a circle by connecting the concentrate outlet (104) of a pressure vessel to the liquid feed inlet (102) of the adjacent pressure vessel.

6. Method for arranging liquid circulation in membrane filtration, wherein new liquid is provided between each pressure vessel to a pressurized inlet of a membrane filter and wherein concentrate of a membrane filter is at least partly circulated back to be filtrated in said membrane filter via one or more further membrane filters to the pressurized inlet of said membrane filter.

7. Method according claim 6, **characterized** in that, circulation is powered by jet pumps arranged between adjacent membrane filters and feeding new liquid into the circulation.

8. Filter apparatus arrangement comprising plurality of pressure vessels, each pressure vessel containing at least one membrane filter, the membrane filter or the membrane filters arranged in the pressure vessels according the cross-filtration principle so that liquid feed entered to a pressure vessel is divided to a permeate part and to a concentrate part, each pressure vessel comprising a pressurized inlet (102) for liquid feed and a concentrate outlet (104) for concentrate and a permeate outlet (103) for permeate, **characterized** in that, the concentrate outlet (104) of one of the pressure vessels is connected to the pressurized inlet (102) of another pressure vessel and the concentrate outlet (104) of further pressure vessel is connected to the pressurized inlet (102) of another pressure vessel.

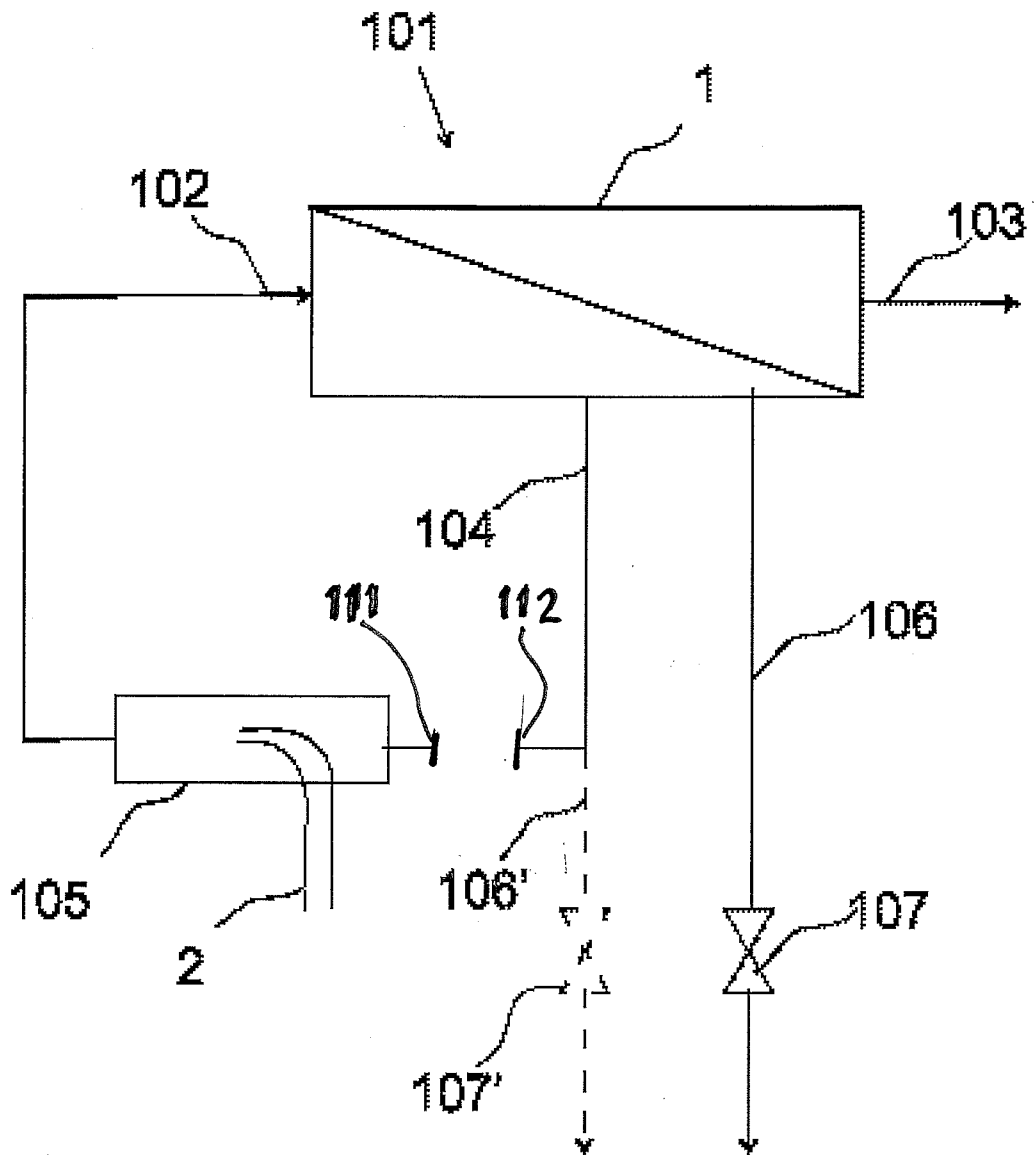


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
 INV. B01D61/02 B01D61/08 B01D61/14 B01D61/18 C02F1/00
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 ADD.
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 B01D C02F F04F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.

See patent family annex.

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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Hoyer, Michael
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INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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