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(71) Applicant *(for all designated States except US)*: **HYDROPATH HOLDINGS LIMITED** [GB/GB]; 2nd Floor, Mansfield House, 1 Southhampton Street, London WC2R 0LR (GB).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **STEFANINI, Daniel** [GB/GB]; 22 Beeston Fields Drive, Beeston, Nottingham NG9 3DB (GB).

(74) Agent: **FORRESTER KETLEY & CO**; Chamberlain House, Paradise Place, Birmingham B3 3HP (GB).

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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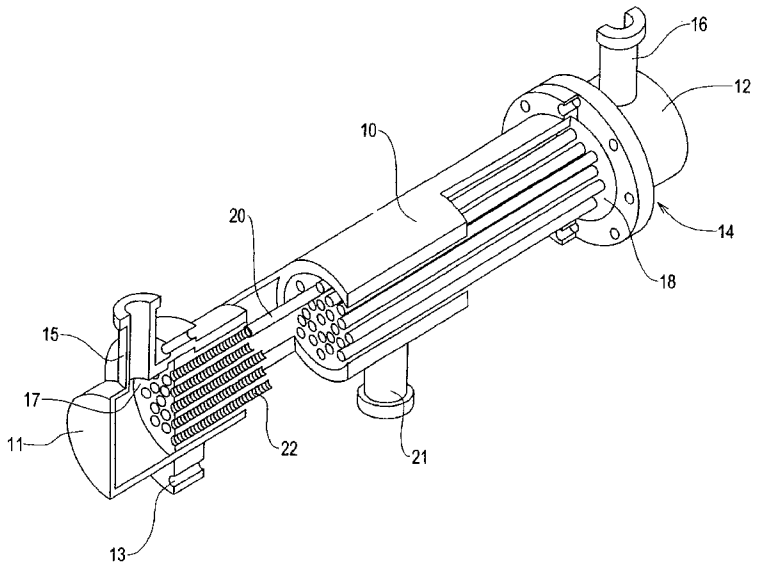
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** WATER PURIFICATION METHOD AND APPARATUS INVOLVING GENERATION OF BIPOLAR LAYER



(57) **Abstract:** Water treatment method and apparatus according to which supply water containing dissolved matter is delivered to at least one treatment surface. An electric field is created in the vicinity of the treatment surface to cause a hydration layer to be established due to the bipolar nature of the water molecules. Water is then extracted from the hydration layer. Such extraction may be effected by osmosis or by removal of the element (s) from the supply water with the hydration layer water thereon, dehydration layer water subsequently being extracted from the element (s) . The method has been devised to reduce energy consumption for the purpose of providing potable water from seawater .

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WATER PURIFICATION METHOD AND APPARATUS INVOLVING GENERATION OF BIPOLAR LAYER

Description of Invention

This invention relates to a method of, and apparatus for, purification treatment of water. The invention has been devised in order to reduce the energy consumption in such treatment for the purpose of desalination of sea water, to provide potable water.

In many parts of the world the only way in which the demand for potable water can be met is by desalination of sea water, there being no other practicable water source. Unfortunately, known desalination techniques consume large quantities of energy, aggravating the world's problems of energy consumption.

There are two principal known desalination techniques. The first is distillation, in which the saline feed water is heated to produce steam which is then condensed to provide water of the required quality. Typically, for every 100 gallons of sea water used, 15 to 50 gallons of fresh water would be produced, the remainder being waste brine solution containing a higher quantity of dissolved solids than the original sea water. Such waste brine is discharged back to the sea.

The other principal technique used in desalination is reverse osmosis, in which the intake sea water is supplied to one side of a semi-permeable membrane and subjected to high pressure. Molecules of salt do not pass through the membrane, but the water does, so that the water on the other side of the membrane from the sea water is a useable product.

It is self evident that the energy consumption associated with distillation as a desalination technique is high, but the pressures required for the reverse osmosis technique to function are so high that this technique also has a high

energy consumption. Accordingly it is an object of the present invention to provide for water purification, e.g. desalination, in a way in which energy consumption is lower.

According to one aspect of the invention, we provide a method of water treatment to provide relatively purified water from a supply containing dissolved matter, comprising creating an electric field to cause a hydration layer of water molecules to be established in the supply water, and extracting the water from the hydration layer.

Preferably the method comprises delivering the supply water to at least one treatment surface; creating the electric field, to cause a hydration layer to be established, in the vicinity of the surface(s); and extracting the hydration layer water from the vicinity of the surface(s).

The invention also provides apparatus for treating water to provide relatively purified water from a supply containing dissolved matter, comprising means for creating an electric field in the supply water to cause a hydration layer to be established therein, and means for extracting the water from the hydration layer.

There may be means for delivering the supply water to at least one treatment surface; means for creating the electric field in the vicinity of the treatment surface(s); and means for extracting the hydration layer water from the vicinity of the surface(s).

The invention makes use of the principle that when subject to an electric field, e.g. adjacent a surface having an electric charge, water molecules orient themselves in accordance with the field and being polar molecules the structure of the hydrogen bond network in the water molecules is changed. Around a charged particle a hydration shell is established comprising a thin

layer of oriented water molecules. The thickness of the layer, in terms of molecules, depends on the magnitude of the charge. In the hydration layer the water molecules exclude other molecules and ions. Thus, although the hydration layer is thin and of thickness only that of a few molecules (the thickness depending on the strength of the electric field at the surface) the water in the hydration layer is substantially pure water, which can be extracted for use with much less energy being consumed in such extraction than if the hydration layer were not present. Although establishing the electric field involves some energy consumption, the overall result is a reduction in energy consumption.

The treatment surface or surfaces, at or in the vicinity of which an electric field is created, may comprise a semi-permeable membrane, and the water from the hydration layer in the vicinity thereof may be extracted by subjecting the supply water to pressure to cause osmotic flow of the hydration layer water through the membrane.

Then, the water which is on the other side of the membrane from the supply water, having passed through the membrane, is substantially purified e.g. desalinated.

When the extraction of the water from the hydration shell is effected by osmosis, the pressure required to cause such osmosis is substantially less than that required for conventional desalination by reverse osmosis. Hence, the energy consumption in the desalination process can be greatly reduced.

The electric field at the treatment surface may be created by applying an electric charge thereto, or to an electrode adjacent the surface. The charge may be applied as a square wave signal including square shaped pulses separated by spaces (of zero signal).

The advantage of using such a wave form to create the electric field in the vicinity of the surface is that during the pulses the electric field is applied quickly, and the hydration layer established (which takes a finite albeit small time). During the spaces between the pulses, the hydration layer is released and is able to pass through the membrane under pressure.

As an alternative to extraction of the hydration layer water by causing it to pass through a membrane, the water may be extracted by providing the at least one treatment surface on an element moveable relative to the supply of water and a part of which is able to be withdrawn from the supply water with the hydration layer water thereon, to a position in which the hydration layer water can be removed from the element.

The element may be rotatable and have a circumferential part immersed in the supply water and a part extending above the supply water, so that hydration layer water can, by rotation of the element, be lifted above the supply water to a position in which it can be extracted from the element.

Such a rotatable element may have a surface which is able to be electrically charged to establish the hydration layer thereon and discharged to release the hydration layer water. It may be in the form of a hollow roller, having an internal charging electrode to charge the surface thereof at a position within the supply water and a discharge electrode at a position above the level of the supply water, where the hydration layer water on the surface thereof is to extracted.

In another embodiment, the treatment surface may be afforded by a plurality of discreet elements movable within the supply water and able to be removed therefrom bearing the hydration layer water which is subsequently removed from the elements.

Such elements may be of a material able to have an electric charge applied thereto and discharged therefrom respectively when introduced into and removed from the supply water. They may also have magnetic properties so that the removal thereof from the supply water can be effected by a magnetic removal element.

The invention will now be described by way of example with reference to the accompanying drawings of which:

Figure 1 is a perspective view of a first embodiment of apparatus to carrying out the method of the invention.

Figure 2 illustrates diagrammatically a second apparatus for carrying out the method of the invention.

Figure 3 illustrates diagrammatically a third embodiment of apparatus for carrying out the invention.

Figure 4 is a cross-section through an element for use in the apparatus in figure 3.

Referring firstly to figure 1 of the drawings, this shows a first embodiment of apparatus accordingly to the invention. It comprises a hollow cylindrical casing 10 having end caps 11, 12 respectively joined to the casing 10 at bolted flanged pressure-tight joints 13, 14. The end caps 11, 12 have respective pipes 15, 16 one of which is for inlet of supply water to the treatment apparatus and the other for outlet thereof. At the ends of the casing 10 there are provided tube plates 17, 18 and between these two plates extend a number of tubular treatment elements 20 which incorporate semi-permeable membranes allowing reverse osmosis between their inner and outer surface. Generally in its mid-region the casing 10 has an outlet pipe 21 communicating with the space surrounding the tubes 20, between the tube plates 17, 18.

Within each of the tubes 20 there is disposed a helical wire electrode lying closely adjacent to its inner surface, as indicated at 22.

In use, supply water e.g. sea water is introduced through one of the pipes 15, 16 and passes through the tubular elements 20 to be discharged through the other of the pipes 15, 16. A square-wave voltage is applied to the electrodes 22, comprising square-shaped pulses with spaces therebetween. During such pulses, hydration layers are formed on the electrodes in the vicinity of the internal surfaces of the elements 20. In the spaces between the pulses of the square-wave, the pure hydration layer water is released and is able to pass through the membranes of the elements 20. A sufficient pressure is maintained in the supply water for such osmotic transportation of the hydration layer water to take place effectively. Having passed through the membranes of the elements 20, the purified hydration layer water is discharged through the pipe 21. The supply water discharged from the apparatus is of course of higher saline concentration than that introduced to the apparatus.

In a possible alternative, the electrodes 22 may be substituted by providing the inner surface of the tubular elements 20 with a porous conductive layer so that the hydration layer is established at the internal surface of the elements 20 rather than closely in the vicinity thereof as is the case with the helical electrodes 22. A porous conductive layer affording as large a surface area as possible at which a hydration layer can be established, may be provided by a conductive open-cell foamed material.

Referring now to figure 2 of the drawings, an alternative apparatus for carrying out the invention illustrates a hollow cylindrical treatment element 30 in a receptacle 31 containing supply water to be treated e.g. sea water. The element 30 is rotatable about its central longitudinal axis indicated at 32, in the direction of arrow 33, and it will be noted that part indicated at 34 of the

surface of the element 30 extends above the normal level 35 of supply water within the receptacle 31.

Within the element 30 there is disposed a charging electrode 36 and a discharge electrode 37, the element 30 being of a material such that it can be electrically charged by the electrode 36 and maintain the electric field caused by such charge on its exterior surface until discharged by the electrode 37. The electrodes 36, 37 are, in effect, capacitively coupled to the surface of the element 30 on which the electric field is established.

Adjacent the discharge electrode 37, a fresh water outlet conduit 38 contacts the external surface of the element 30.

In use, with the element 30 rotating in the direction of arrow 33 the charge established thereon by the charge electrode 36 causes a hydration layer40 of pure water to be established on its external surface and the rotation of the element 30 causes such layer of water to be carried above the surface 35 of the supply water to the vicinity of the discharge electrode 37. When the electric field on the element is reduced to zero by the discharge electrode 37, the hydration layer water is free to flow into the fresh water conduit 38 to be delivered to wherever it is required.

Referring now to figures 3 and 4 of the drawings, these show a receptacle, e.g. a conduit, 50 containing supply water e.g. sea water. The apparatus makes use of a large number of treatment elements as shown in figure 4, each comprising a ferrite core 51 able to be magnetised and also electrically charged to maintain an electric field. The core 51 is coated with a conductive material 52 giving the element sufficient buoyancy to float in the supply water. Such an element, if charged with a negative electric charge, will be surrounded by a hydration layer 53 of water.

Figure 3 shows feed screw 55 provided in the bottom of the receptacle 15, delivering elements as shown in figure 4 continuously to a rotatable charge electrode 56 which is magnetised on three quarters of its circumference. The elements are collected by the electrode and charged electrically, and as the electrode 56 rotates its magnetic field is switched off and the charged elements released into the salt water. The elements flow towards the top of the receptacle 50, and are collected by a collecting roller 57 which is similar in construction to the charge electrode. A discharge electrode 58 discharges the electric field from the elements, releasing the pure water to flow into a water outlet conduit 59, while the treatment elements are delivered at 60 to the feed screw 55.

When used in this specification and claims, the terms "comprises" and "comprising" and variations thereof mean that the specified features, steps or integers are included. The terms are not to be interpreted to exclude the presence of other features, steps or components.

The features disclosed in the foregoing description, or the following claims, or the accompanying drawings, expressed in their specific forms or in terms of a means for performing the disclosed function, or a method or process for attaining the disclosed result, as appropriate, may, separately, or in any combination of such features, be utilised for realising the invention in diverse forms thereof.

Claims

1 A method of water treatment to provide relatively-purified water from a supply containing dissolved matter, comprising creating an electric field to cause a hydration layer of water molecules to be established in the supply water; and extracting the water from the hydration layer.

2 A method according to claim 1, comprising delivering the supply water to at least one treatment surface; creating the electric field, to cause the hydration layer of water molecules to be established, in the vicinity of the surface(s); and extracting the hydration layer water from the vicinity of the surface(s).

3 A method according to claim 2 wherein the treatment surface(s), at or in the vicinity of which an electric field is established, comprises a semi-permeable membrane, and the water from the hydration layer is extracted by subjecting the supply water to pressure to cause osmotic flow of the hydration layer water through the membrane.

4 A method according to claim 3 wherein the electric field at the treatment surface(s) is created by applying an electric charge to the surface or to an electrode adjacent the surface.

5 A method according to claim 4 wherein the electric charge is applied as a square wave signal including square-shaped pulses separated by spaces.

6 A method according to claim 2 wherein the treatment surface is provided on at least one element moveable relative to the supply of water and at least a part of which is able to be withdrawn from the supply water with the hydration layer water thereon, subsequent to which the hydration layer water is removed from the at least one element.

7 A method according to claim 6 comprising a rotating an element having a circumference of which part is immersed in the supply water and part extends above the supply water, so that hydration layer water can by said rotation be lifted above the supply water to a position in which it can be extracted from the element.

8 A method according to claim 6 comprising providing treatment surfaces on a plurality of discreet elements moveable within the supply water and able to be removed therefrom bearing hydration layer water, which is subsequently removed from the elements.

9 Apparatus for treating water to provide relatively-purified water from a supply containing dissolved matter, comprising means for creating an electric field in the supply water to cause a hydration layer to be established therein; and means for extracting the water from the hydration layer.

10 Apparatus according to claim 9 comprising means for delivering the supply water to at least one treatment surface; means for creating the electric field in the vicinity of the treatment surface(s), and means for extracting the hydration layer water from the vicinity of the surface(s).

11 Apparatus according to claim 10 wherein the at least one treatment surface comprises a semi-permeable membrane, and there is means for subjecting the supply water to pressure to cause osmotic flow of the hydration layer water through the membrane.

12 Apparatus according to claim 11 wherein the semi-permeable membrane has an electrically conductive element for application of an electric charge to create the electric field.

13 Apparatus according to claim 11 comprising an electrode adjacent the semi-permeable membrane to provide full creation of the electric field in the vicinity thereof.

14 Apparatus according to claim 12 or claim 13 comprising means for applying a square wave electrical signal to the membrane or electrode.

15 Apparatus according to claim 10 wherein the at least one treatment surface is provided on at least one element moveable so that a surface part is able to be immersed in the supply water for a hydration layer to be established thereon and withdrawn from the supply water with the hydration layer thereon to a position in which the hydration layer water can be removed from the element.

16 Apparatus according to claim 15 wherein said element is rotatable and has a circumferential part of which a portion is immersed in the supply water and a portion extends above the supply water.

17 Apparatus according to claim 16 wherein said rotatable element has a surface which is able to be electrically charged to establish the hydration layer thereon and discharged to release the hydration layer.

18 Apparatus according to claim 17 wherein the rotatable element comprises a hollow roller, having an internal charging electrode to charge the surface thereof at a position within the supply water and a discharge electrode at a position above the level of the supply water.

19 Apparatus according to claim 15 wherein the treatment surface is afforded by a plurality of discreet elements moveable within the supply water and able to be removed therefrom bearing the hydration layer water which is subsequently removed from the elements.

20 Apparatus according to claim 19 wherein said elements are a material able to have an electric charge applied thereto and discharged therefrom respectively when introduced into and removed from the supply water.

21 Apparatus according to claim 20 wherein said elements are able to be magnetically attractable, and there is provided magnetic means for effecting removable thereof from the supply water.

22 A method of, or apparatus for, treating water, substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

23. Any novel feature or novel combination of features described herein and/or in the accompanying drawings.

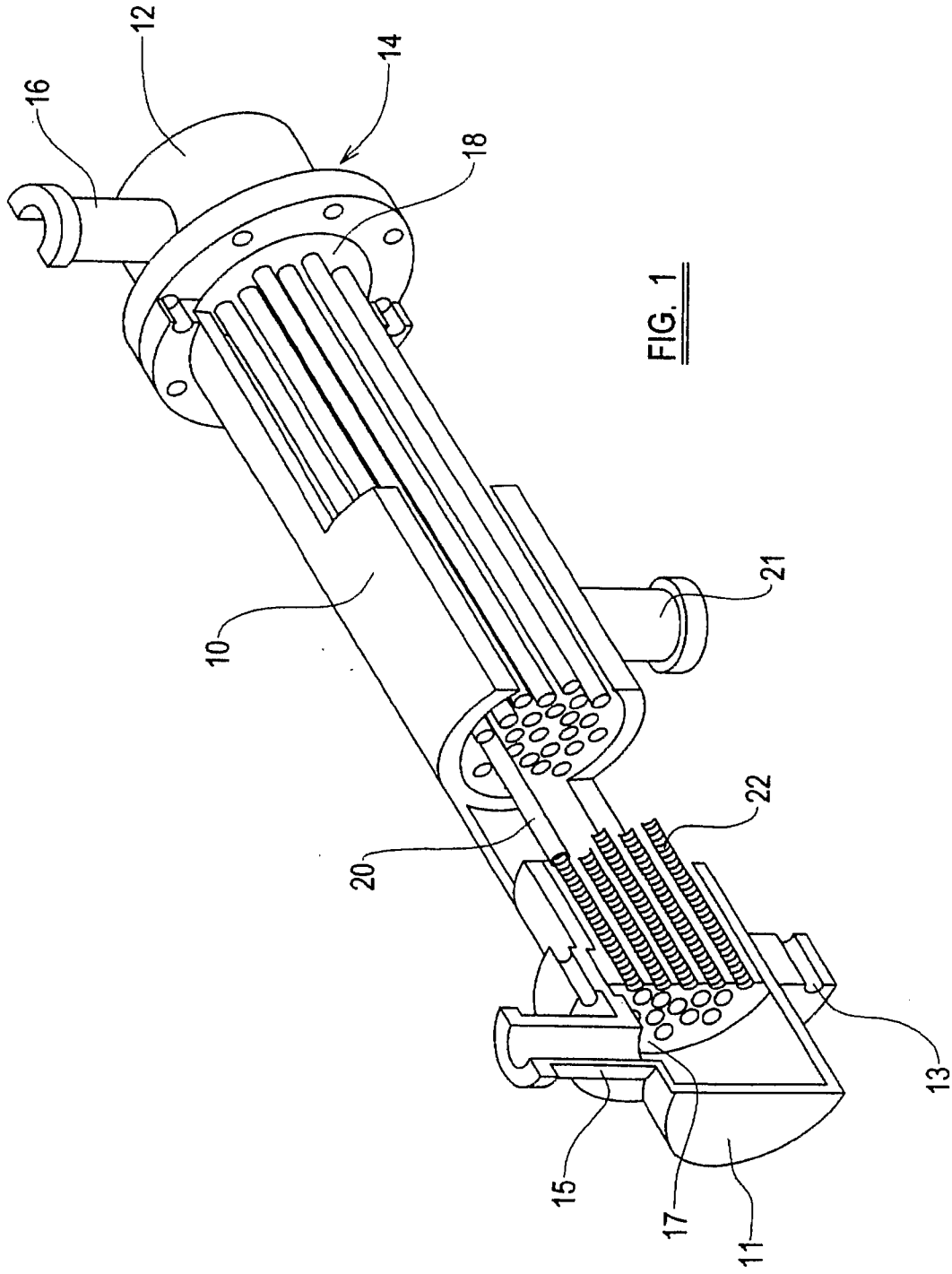

FIG. 1

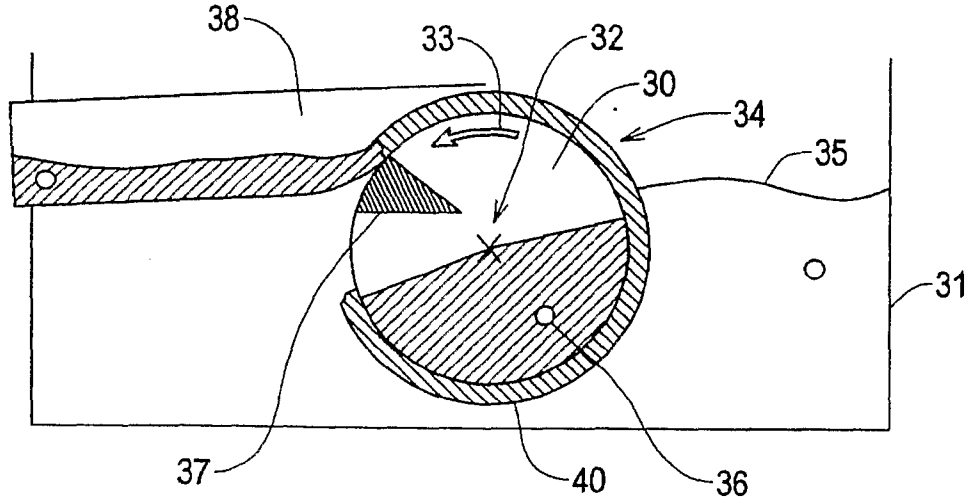

FIG. 2

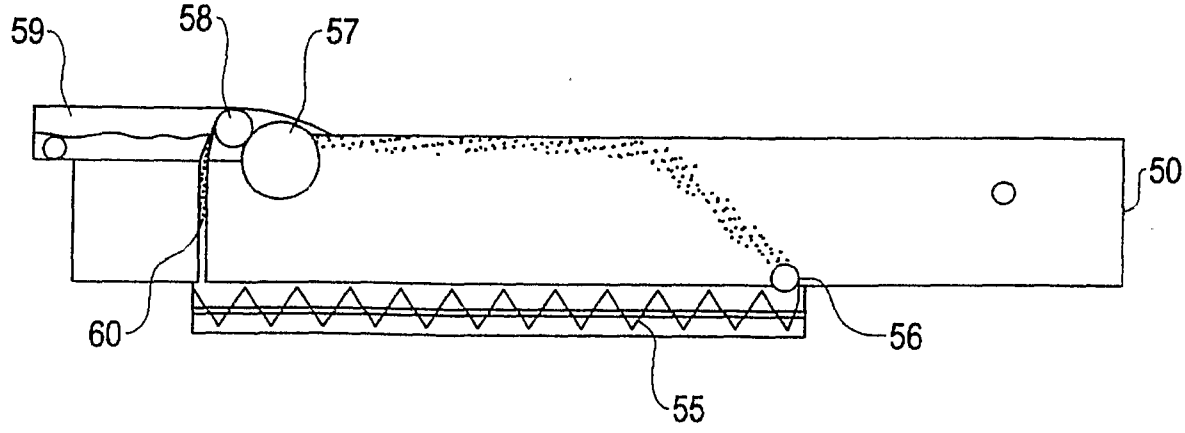

FIG. 3

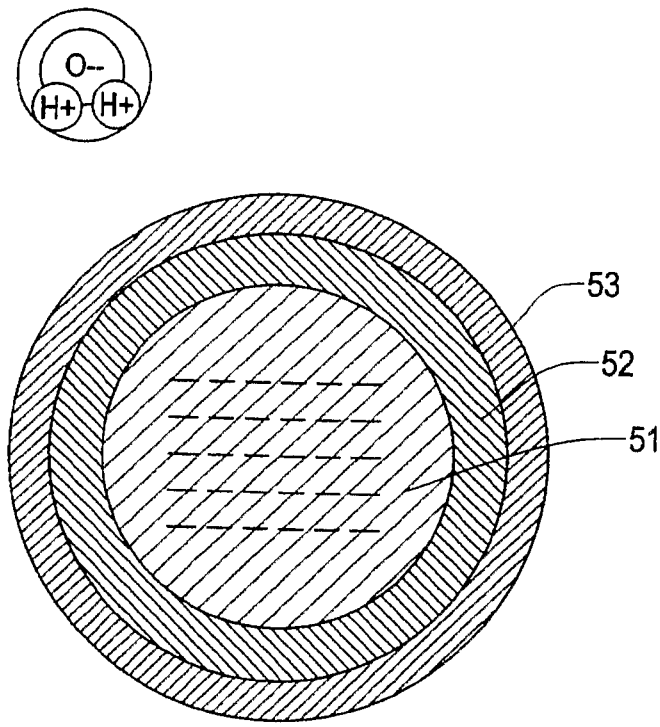

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/003794

A. CLASSIFICATION OF SUBJECT MATTER
INV. C02F1/46

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)
C02F

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 practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 319 979 A (KING ARTHUR S) 16 March 1982 (1982-03-16) column 1, line 11 - line 16; claims 1-5; figures 1-4 column 1, line 44 - line 54 column 2, line 1 - line 16 column 2, line 33 - column 3, line 5 column 3, line 37 - column 4, line 5	1-21
X	JP 10 323545 A (KURITA WATER IND LTD) 8 December 1998 (1998-12-08) abstract; figure 2	9-21

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 January 2007	18/01/2007

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Oenhausen, Claudia

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/003794

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 197 394 A (MCEUEN ROBERT B) 27 July 1965 (1965-07-27) column 2, line 41 - line 47; claims 1-16; figure 1 column 2, line 63 - column 3, line 5 column 3, line 24 - line 75	9-21
X	US 3 637 482 A (VAJDA GEZA L) 25 January 1972 (1972-01-25) column 3, line 45 - line 67; claims 1-4; figure 1 column 4, line 45 - column 5, line 17	9-21
P,X	WO 2006/039873 A1 (SCHENK DETLEF [DE]; IMRIS PAVEL [DE]) 20 April 2006 (2006-04-20) page 3, paragraph 2 - paragraph 3; claims 1-16; figures 1-7	9-21
P,X	WO 2005/108304 A (MIKHNEVICH VLADIMIR V [BY]; GOVOR GENNADIY A [BY]) 17 November 2005 (2005-11-17) page 5, lines 29-31; claims 1-18; figures 1-4	1-8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2006/003794

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2006/003794

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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WO 2005108304 A	17-11-2005	NONE	