(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 March 2010 (25.03.2010)

PCT

(10) International Publication Number
WO 2010/033020 A1

(51) International Patent Classification:
C02F 1/48 (2006.01) *C02F 1/72* (2006.01)
C02F 1/00 (2006.01) *C02F 1/78* (2006.01)
C02F 1/32 (2006.01)

(21) International Application Number:
PCT/NL2009/050554

(22) International Filing Date:
17 September 2009 (17.09.2009)

(25) Filing Language: Dutch

(26) Publication Language: English

(30) Priority Data:
1035952 18 September 2008 (18.09.2008) NL
1036431 16 January 2009 (16.01.2009) NL

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM,

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(54) Title: APPARATUS AND METHOD FOR TREATING A LIQUID

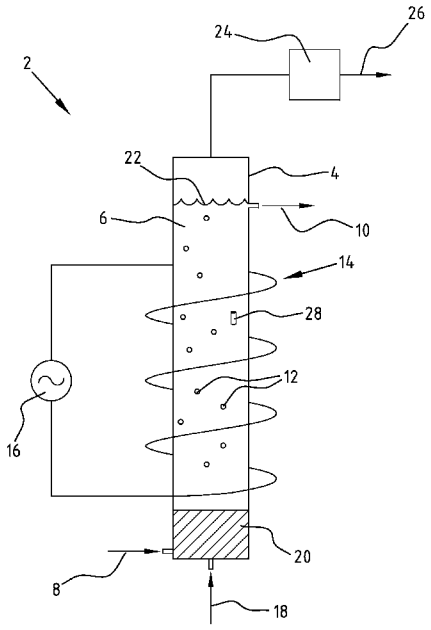

FIG. 1

(57) Abstract: The present invention relates to a device and method for purifying a liquid. The device comprises: - a container for the liquid for purifying; and - treatment means for selectively applying an electric and/or electromagnetic field in the container, wherein the electric and/or electromagnetic field is such that a gas discharge occurs in gas bubbles present in the liquid, wherein radicals are created which have a purifying effect on the liquid and/or decompose organic components in the liquid.

WO 2010/033020 A1

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

APPARATUS AND METHOD FOR TREATING A LIQUID

The present invention relates to a device for purifying a liquid. The device is more particularly aimed toward the purifying of water, and particularly drinking water. The device can also be used, among other purposes, for purifying process water and (industrial) wastewater. Such a liquid is usually contaminated with contaminants in very low concentrations, such as in the order of magnitude of ppb (micrograms per litre) to ppm (milligrams per litre). These contaminants include bacteria, viruses and fungi, as well as organic components.

Known devices for purifying a liquid make use of chemicals. These chemicals remove at least a part of the (traces of) contaminants from the liquid. The liquid is hereby disinfected. The addition of chemicals is relatively costly, requires additional process steps and has an environmental impact.

The present invention has for its object to provide a more efficient device for purifying a liquid such as water, preferably without the addition of supplementary substances such as chemicals.

This object is achieved with the device according to the present invention for purifying a liquid, comprising:

- a container for the liquid for purifying; and
- treatment means for selectively applying an electric and/or electromagnetic field in the container,

wherein the electric and/or electromagnetic field is such that a gas discharge occurs in gas bubbles present in the liquid, wherein UV radiation and/or radicals are created which have a purifying effect on the liquid and/or decompose organic components in the liquid.

A liquid can be purified by applying an (alternating) electric and/or electromagnetic field and exposing the liquid thereto. This is brought about in that, with a sufficient

strength of the field, a gas discharge is realized in gas bubbles present in the liquid. The gas bubbles are in particular air bubbles. As a result of the gas discharge in these gas bubbles radicals are created therein which have a disinfecting effect. Some examples of active radicals which can occur in a gas bubble during a gas discharge are oxygen radicals, OH radicals, halogen radicals and hydrocarbon radicals. These radicals have the result that contaminants such as micro-organisms, including for instance bacteria, viruses and fungi, are killed. An additional advantage is that these radicals can also bring about decomposition of organic components in the liquid. Hormones and other substances present in the liquid for purifying can thus be decomposed. Not only do radicals usually occur during the gas discharge, the plasma resulting during the discharge also results in the release of UV radiation. Although this can result in a kind of radical bombardment with the above described effects, the UV radiation can also have a direct effect on possible contaminants in the liquid for purifying. The UV radiation can for instance thus cause direct damage to DNA structures. The gas bubbles in the liquid comprise for instance air and/or oxygen and/or nitrogen and/or CO_2 and/or an inert gas and/or a halogen and/or a hydrocarbon, including natural gas. If desired, the occurrence of radicals and/or UV radiation can be influenced thereby.

The container for the liquid for purifying is for instance a reactor. It is also possible to provide the device with a container in the form of a conduit. Using this application it is possible to incorporate the purification in a continuous process. By purifying the liquid, such as water and in particular drinking water, using an electric and/or electromagnetic field additional supplements of for instance chemicals are less necessary, and preferably even no longer necessary at all, for the purification. This results in an efficient and environmentally-friendly purifying operation.

The container can be a substantially vertically disposed tube or reactor. The gas bubbles will want to move upward therein. Under the pressure of the liquid column the pressure in the gas bubbles will be greater in the lower part of the column than in the upper part of the column. Alternatively, it is also possible to dispose the tube or reactor substantially horizontally or at an angle. In a horizontal disposition a more constant pressure will prevail in the gas bubbles if the tube or reactor is not fully filled. There will also be a relatively large liquid-gas boundary surface. A liquid-gas separating surface present in the container will allow a good flow of gas bubbles relative to liquid for purifying.

In an advantageous preferred embodiment according to the present invention the treatment means comprise an induction coil.

By providing an induction coil a treatment field can be applied at a desired location in a reactor or conduit. The induction coil is for instance a toroid coil. The induction coil is preferably connected to an alternating voltage source such that an alternating electric and/or electromagnetic field can be applied in the reactor or conduit. During use this alternating voltage coil preferably employs one or more frequencies in a range of 1 kHz - 100 GHz, and preferably 1 kHz - 100 MHZ. It has been found that in this range micro-organisms are killed in the treatment field and/or organic components in the liquid are decomposed. It has also been found that a frequency in the range of 10 kHz - 30 MHZ, and in particular 50 kHz - 10 MHZ, makes a major contribution toward disinfecting the liquid, wherein micro-organisms are killed and/or organic components are decomposed.

In an advantageous preferred embodiment according to the present invention the device comprises gas injection means for injecting gas bubbles into the liquid for treating.

Providing gas injection means can guarantee in active manner that sufficient gas bubbles are present in the liquid for

treating. By providing sufficient gas bubbles, such as air bubbles, it is possible to provide in the treatment field sufficient gas discharges in which radicals occur for the purpose of disinfecting a liquid. The device according to the present invention preferably comprises a gas distribution system for setting the gas bubble diameter and/or gas bubble size distribution. By applying such a per se known gas distribution system in the device according to the present invention the diameter and the bubble size distribution can be adjusted. It is hereby possible to realize an optimum diameter and size distribution of gas bubbles in the liquid so as to thus enable the best possible gas discharges in the gas bubbles in the treatment field. It is further also possible to vary these settings over time, for instance as a function of the quantity of contaminants in the liquid. A regulated system is in this way obtained, in which for instance the field strength can also be adapted to measured and/or anticipated contaminants in the liquid. This is particularly relevant in a continuous process.

In an advantageous preferred embodiment according to the present invention pump means are provided on an outlet side of the container for the purpose of realizing an underpressure.

Use can be made in advantageous manner of the natural upward movement of gas bubbles in a liquid by supplying the gas bubbles from the bottom of the container. An underpressure can be realized by providing pump means which are preferably provided on the outlet side of the container. The gas bubbles are hereby controlled more directly in the liquid. The size of the gas bubbles can also be influenced by providing such pump means and applying an underpressure on the outlet side of the container. The size can hereby be adapted to obtain the best possible gas discharge in such gas bubbles at the position of the treatment field.

In an advantageous preferred embodiment according to the present invention the container is provided with so-called

internals for the purpose of realizing field strengths which are relatively high locally.

It is possible to bring about very high field strengths locally in the container by providing fixed internals in the container which have a high permittivity, such as for instance ferrite. The distribution of internals over the treatment field can be embodied at random. It is however possible here to provide a grid in which these internals are positioned relative to each other in a specific manner whereby the best possible purification of the liquid is realized. The distribution can be adapted here to the type of liquid and/or the type of contamination therein.

In a further advantageous preferred embodiment according to the present invention the container is provided with at least one rod-like element around which a coil is provided for the purpose of generating the electric and/or electromagnetic field.

A treatment field can be realized locally in the container by providing in the tube a rod-like element, for instance of ferrite, on which a coil is provided. The rod-like element is preferably connected to a source of alternating voltage for the purpose of thereby realizing the above described gas discharge in the gas bubbles. It is also possible according to the present invention to provide a plurality of rod-like elements in the container. Through the positioning of these rod-like elements it is possible to provide in the container a number of compartments which are in series. It is hereby possible to allow the liquid for purifying to flow through a plurality of sub-fields and to herein realize gas bubbles at for instance a plurality of locations. It is possible here to adapt the field strengths to specific micro-organisms in order for instance to give each compartment a very specific function aimed at a specific micro-organism. It is further possible to provide the rod-like elements according to the present invention with electrodes between which gas discharge can take place in the gas bubble. These electrodes are preferably connected to LEDs or to a rectifier. A gas discharge is hereby generated in a gas bubble

as soon as such a gas bubble collides with an electrode. A very local purification can hereby be realized in the liquid.

In a further preferred embodiment according to the present invention the passage opening for the liquid in the container is of a form such that accumulation of air bubbles occurs during use.

As a result of the relatively high conductivity of the liquid compared to the relatively low conductivity of the gas bubbles present in the liquid, the gas discharge is impeded to some extent in a number of cases. According to the present invention, the volume fraction of liquid relative to gas can be reduced by providing the container with a form such that air accumulation occurs locally, this in order to enhance gas discharge at this location. One possible way of forming a passage opening is by applying a column configuration in the container in which gas accumulates, creating large gas bubbles at the position of the coil, wherein the relatively large gas bubbles burst apart after gas discharge, and/or creating a liquid in gas fluid. Gas discharge can hereby be further enhanced.

In a further preferred embodiment according to the present invention the device is provided with a transmitter and receiver for generating an electric and/or electromagnetic field.

A treatment field can be realized in efficient manner by making use of energy transfer from transmitter to receiver. Use is preferably made here of tuned circuits and/or antenna tuners. The receiver absorbs the high-frequency energy. The receiver can for instance be gas bubbles and pieces of metal. The receiver is preferably one or more metal rod-like elements. By providing such metal rod-like elements in the liquid for purifying they will behave as antenna. As a result (high-frequency) alternating currents will begin to flow through these rods, thereby effecting a purification of the liquid.

In a further preferred embodiment according to the present invention the device is provided with energy supply means for

supplying energy to gas bubbles at selective moments for the purpose of realizing a gas discharge.

In an embodiment according to the invention, in which a gas bubble can be positioned between two electrodes and wherein there is simultaneously liquid contact between these two electrodes, a small electric field can result in the gas due to the "electrical short-circuit" caused by the liquid. This effect can be counteracted by making use of a system design with for instance the above described internals and/or narrowed portions. It is also possible to introduce energy into the system at selective moments. Energy can for instance thus be transferred in an efficient manner from a transmitting device to the gas bubbles using capacitors and/or tuned circuits. Such a tuned circuit (serial circuit or parallel circuit) has a resonance frequency. If such a circuit is connected to a power source with a frequency substantially equal to the resonance frequency, the electrical energy supplied by the power source will result in resonance. Stated briefly, this means that the electrical energy supplied by the power source is stored alternately in the form of a magnetic field induced in the coil and a charge difference between the capacitor plates. Supply of new energy via the power source results in greater charge differences between the capacitor plates (a greater potential difference) and to a larger alternating magnetic field. This amplification effect continues until the amount of energy supplied by the power source is equal to the losses in the tuned circuit. These losses occur because a coil and capacitor do not behave ideally in practice (ohmic losses in the circuit, particularly in the coil, and leakage currents in the capacitor). At equilibrium the amount of electrical energy supplied to the tuned circuit is equal to the development of heat in the tuned circuit. The mechanical equivalent of such a system is a swing. Each time the swing is given a push at the correct moment, the amplitude the swing reaches will increase until the moment that the kinetic energy supplied is equal to the friction energy. The greater the quality

of the coil(s) and capacitor(s) applied in the tuned circuit, the greater will be the amplification effect of the voltage between the capacitor plates (at the same voltage difference there are then fewer electrical losses). The quality of a tuned circuit can be calculated in per se known manner from the quality factor of the applied coil(s) and capacitor(s). Very large voltage differences and (electro)magnetic fields can in this way be generated in a tuned circuit. If such a tuned circuit is connected to two electrodes, for instance by parallel connection of these electrodes to the capacitor, electrical energy is drained from the circuit. This may be desirable, although it damps the amplitude of the alternating voltage difference over the capacitor. This means that it is well-advised to drain electrical energy from the tuned circuit only at the moment that this energy can be usefully employed. In the case of the present invention this moment corresponds to the point in time at which an air bubble is situated between the electrodes connected to the tuned circuit. The presence of an air bubble in a liquid can be detected in per se known manner, for instance capacitively, by making use of the fact that the dielectric constant of air (or other gas (mixture)) differs greatly from that of liquid. In a preferred embodiment of the present invention electrical energy is supplied, making use of a power source, to a preferably non-loaded tuned circuit with a high quality factor. This non-loaded tuned circuit is preferably connected electrically to two electrodes by means of a switch. Preferably situated in the vicinity of the electrodes is an optical and/or electrical sensor which determines whether an air bubble is situated between the electrodes. If this is the case, the switch closes automatically and gas discharge occurs in the air bubble. The switch then opens again until the moment that a subsequent gas bubble passes. The switch can be a so-called solid-state circuit with for instance a FET (Field Effect Transistor). If desired, a single tuned circuit can in this way control a very large number of individual electrodes. The electrodes can further be in direct

galvanic contact with the transmitting device as well as in indirect contact therewith. The indirect contact between the transmitting device (= the power source) and the receiving device (the electrodes, gas bubbles, ferrite cores with coil, tuned circuits) is also possible by means of induction, electromagnetic waves with coils and/or antennas as means for energy transfer.

The invention also relates to a method for purifying a liquid, comprising the steps of:

- providing a device as described above;
- applying an electric and/or electromagnetic field during use such that a gas discharge occurs in gas bubbles present in the liquid, wherein UV radiation and/or radicals are created which have a purifying effect on the liquid and/or decompose organic components in the liquid.

The same effects and advantages apply in respect of such a method as those described in respect of the device. The method according to the present invention can be applied to both a reactor and to a conduit. It is possible to apply this method in both batchwise purification and continuous purification. The method can also be used in a regulated system wherein the treatment field is adapted to the degree of measured and/or anticipated contaminants in the liquid.

Further advantages, features and details of the invention are elucidated on the basis of preferred embodiments thereof, wherein reference is made to the accompanying drawings, in which:

figure 1 shows a schematic outline of a device according to the invention;

figure 2 shows an alternative embodiment according to the invention; and

figure 3 shows a further alternative embodiment according to the invention.

A device 2 (figure 1) comprises a reactor 4 in which a liquid 6, for instance wastewater, is situated. The cylindrical reactor

4 is provided with an inlet 8 for the purpose of supplying liquid 6. Outlet 10 is provided on the other side of reactor 4 for discharge of liquid 6 out of reactor 4. There are gas bubbles 12 in liquid 6. Arranged on the outside of reactor 4 is a coil 14 which is connected to voltage source 16. An air feed 18 is provided in order to ensure sufficient gas bubbles 12 in liquid 6. A gas bubble distributor 20 is provided close to gas feed 18 for the purpose of providing gas bubbles 12 with the correct properties, such as diameter and size distribution. Reactor 4 is not wholly filled with liquid 6, so that a boundary surface 22 is present. The space above boundary surface 22 is connected to a vacuum pump 24 and gas outlet 26. Vacuum pump 24 can for instance be a water jet pump or an oil pump. Using vacuum pump 24 it is possible to set, among other settings, a water pressure of gas bubbles 12. In the shown embodiment a ferrite core 28 is arranged in the reactor.

Device 2 can be used to purify for instance wastewater. This wastewater, containing for instance harmful micro-organisms and hormones, is carried via inlet 8 to reactor 4. At the same moment air is supplied via gas feed 18 to the reactor, whereby air bubbles are created in liquid 6 which rise due to buoyant force. A gas discharge is brought about in gas bubbles 12 by a correct choice of the magnitude of the alternating (electro)magnetic field. Such a gas discharge has the result that radicals are created in the air which have a disinfecting effect and also result in decomposing of organic components in the water. The magnitude of the (electro)magnetic field at which gas discharge will occur in gas bubbles 12 can be influenced, among other ways, by using vacuum pump 24. The gas pressure in air bubbles 12 can be modified with this vacuum pump 24. A low gas pressure in bubbles 24 results for instance in gas discharge at a relatively low field strength. Liquid 6 is discharged via outlet 10 after passing through the (electro)magnetic field. This outgoing liquid 6 is purified without additional chemicals being added here. It is also possible to optimize the behaviour of the bubble

column with traces of surfactant. The field strength can be influenced locally by providing a ferrite core 28 in the form of an internal with a high permittivity. The distribution of more of such a ferrite cores 28 relative to each other over reactor 4 can be embodied at random as well as in accordance with a grid. The choice depends here on, among other factors, the type of anticipated contaminants.

In an alternative embodiment 30 (figure 2) reactor 4 is provided with three ferrite rods 32,36,40. Ferrite rods 32,36,40 are placed in the interior of reactor 4. Each of the ferrite rods 32,36,40 is provided with a coil 34,38,42 connected to an alternating voltage source 16. In the shown embodiment three ferrite rods 32,36,40 are provided, each provided with a coil 34,38,42. In the shown embodiment ferrite rods 32,36,40 are each connected to the same alternating voltage source 16. It is also possible to provide separate alternating voltage sources for these ferrite rods 32,36,40. It will be apparent that, instead of three ferrite rods 32,36,40, it is also possible to provide a single ferrite rod placed in the interior of reactor 4, and for instance also ten or more ferrite rods. Through the use of one or more ferrite rods reactor 4 consists as it were of a plurality of compartments placed in series, wherein each compartment is able to realize a gas discharge in air bubbles 12. It is of course also possible, instead of placing a plurality of ferrite rods 32,36,40 in series, to place them in parallel so as to be able to utilize for instance a larger cross-section of reactor 4. Combinations of parallel and serial placing of these rods 32,36,40 are also possible.

In an alternative embodiment the ferrite cores 32,36,40 with coils 34,38,42 wound therearound are equipped with electrodes connected to LEDs or to a rectifier. As soon as a rising air bubble 12 comes into contact with the electrodes, a gas discharge can occur in air bubble 12.

In a further alternative embodiment 44 (figure 3) the energy for realizing an (electro)magnetic field in reactor 4 is provided

using a transmitter 46. Transmitter 46 sends the required energy to receivers 48 which are placed in liquid 6. Receivers are any device or any means intended for absorbing high-frequency energy. This can be understood to mean, among others, air bubbles and metal parts. The energy transfer from transmitter to receiver is increased by making use of so-called tuned circuits and/or antenna tuners.

In the shown embodiment the receivers are embodied as metal rods 48 placed in liquid 6. These metal rods 48 therefore behave as antenna and high-frequency alternating currents will begin to flow through these rods during use. Liquid 6 is hereby disinfected.

The present invention is by no means limited to the above described preferred embodiments thereof. The rights sought are defined by the following claims, within the scope of which many modifications can be envisaged. It is thus possible for instance to make a combination of measures from the different embodiments. It is for instance possible to choose the geometry of reactor 4 such that air accumulation will occur such that the volume fraction of water 6 is low compared to that of gas bubbles 12.

CLAIMS

1. Device for purifying a liquid, comprising:
- a container for the liquid for purifying; and
- treatment means for selectively applying an electric and/or electromagnetic field in the container,
wherein the electric and/or electromagnetic field is such that a gas discharge occurs in gas bubbles present in the liquid, wherein radicals and/or UV radiation are created which have a purifying effect on the liquid and/or decompose organic components in the liquid.

2. Device as claimed in claim 1, wherein the treatment means comprise an induction coil.

3. Device as claimed in claim 1 or 2, wherein the treatment means comprise an alternating voltage source.

4. Device as claimed in claim 3, wherein during use the alternating voltage source employs a frequency in the range of 1 kHz - 100 GHz, preferably 1 kHz - 100 MHZ, more preferably 10 kHz - 30 MHZ, and most preferably 50 kHz - 10 MHZ.

5. Device as claimed in one or more of the claims 1-4, further comprising gas injection means for injecting gas bubbles into the liquid for treating.

6. Device as claimed in claim 5, further comprising a gas distribution system for setting the gas bubble diameter and/or gas bubble size distribution.

7. Device as claimed in one or more of the claims 1-6, wherein pump means are provided on an outlet side of the container for the purpose of realizing an underpressure.

8. Device as claimed in one or more of the claims 1-7, wherein the container is provided with internals for the purpose of realizing field strengths which are relatively high locally.

9. Device as claimed in one or more of the claims 1-8, wherein the container is provided with at least one rod-like element around which a coil is provided for the purpose of generating the electric and/or electromagnetic field.

10. Device as claimed in claim 9, wherein the rod-like element is provided with electrodes between which gas discharge can take place in the gas bubble.

11. Device as claimed in one or more of the claims 1-10, wherein the passage opening for the liquid in the container has a form such that accumulation of air bubbles occurs during use.

12. Device as claimed in one or more of the claims 1-11, wherein a transmitter and receiver are provided for generating the electric and/or electromagnetic field.

13. Device as claimed in claim 12, wherein the receiver comprises one or more metal rod-like elements.

14. Device as claimed in one or more of the claims 1-13, the device further comprising energy supply means for supplying energy to gas bubbles at selective moments for the purpose of realizing a gas discharge.

15. Method for purifying and/or disinfecting a liquid, comprising the steps of:

- providing a device as claimed in one or more of the claims 1-14;
- applying an electric and/or electromagnetic field during use such that a gas discharge occurs in gas bubbles present in

the liquid, wherein radicals are created which have a purifying effect on the liquid and/or decompose organic components in the liquid.

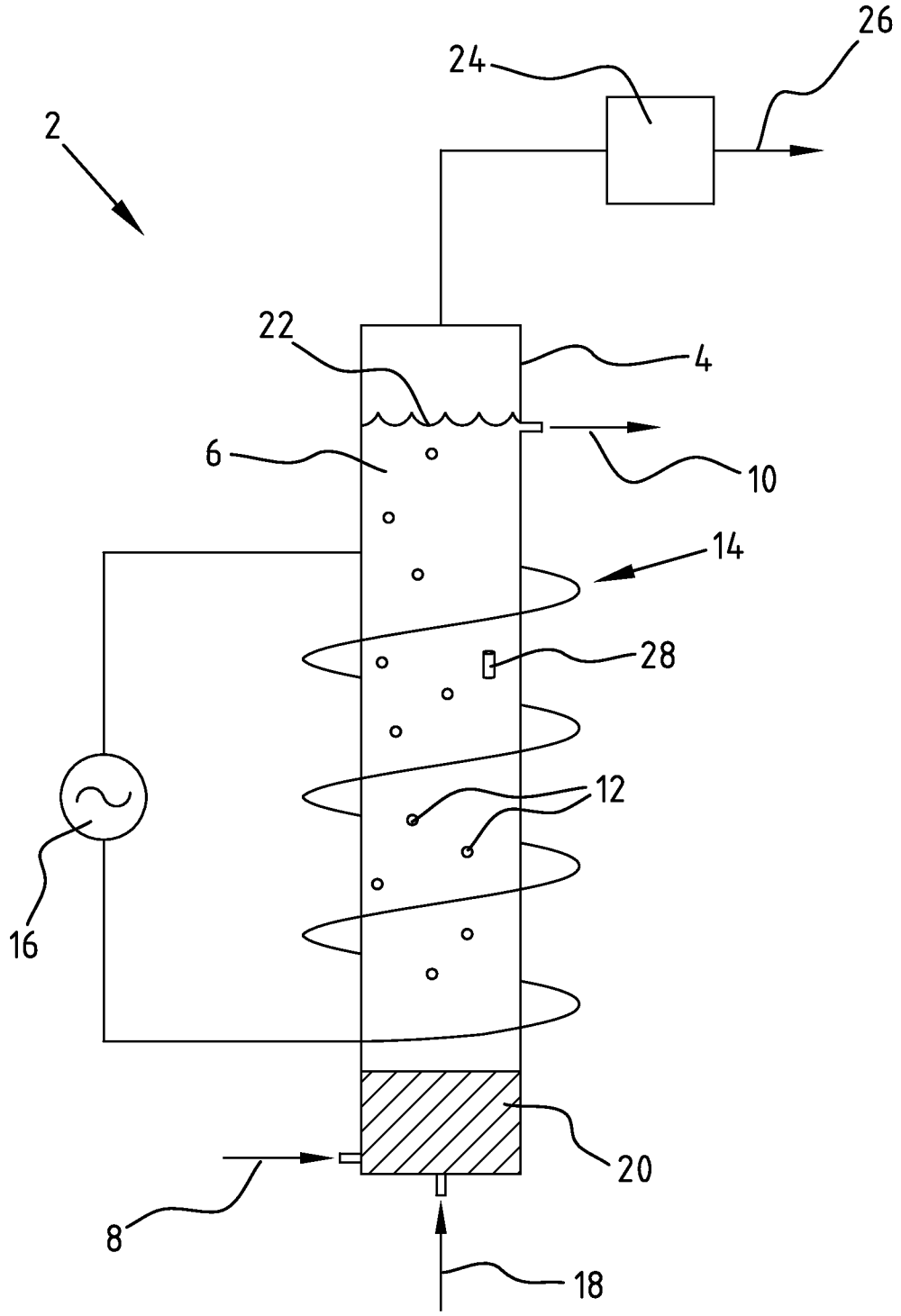

FIG. 1

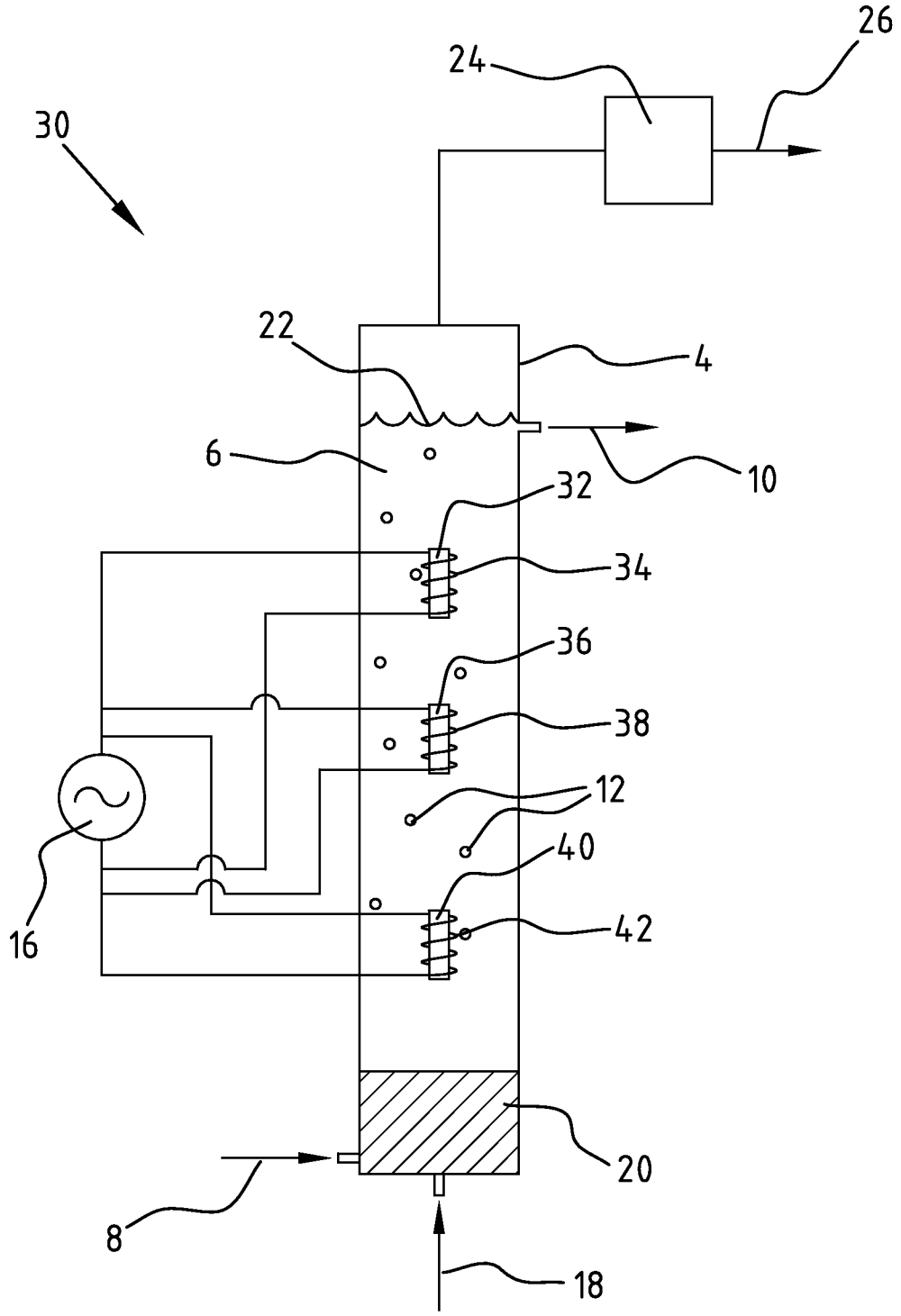

FIG. 2

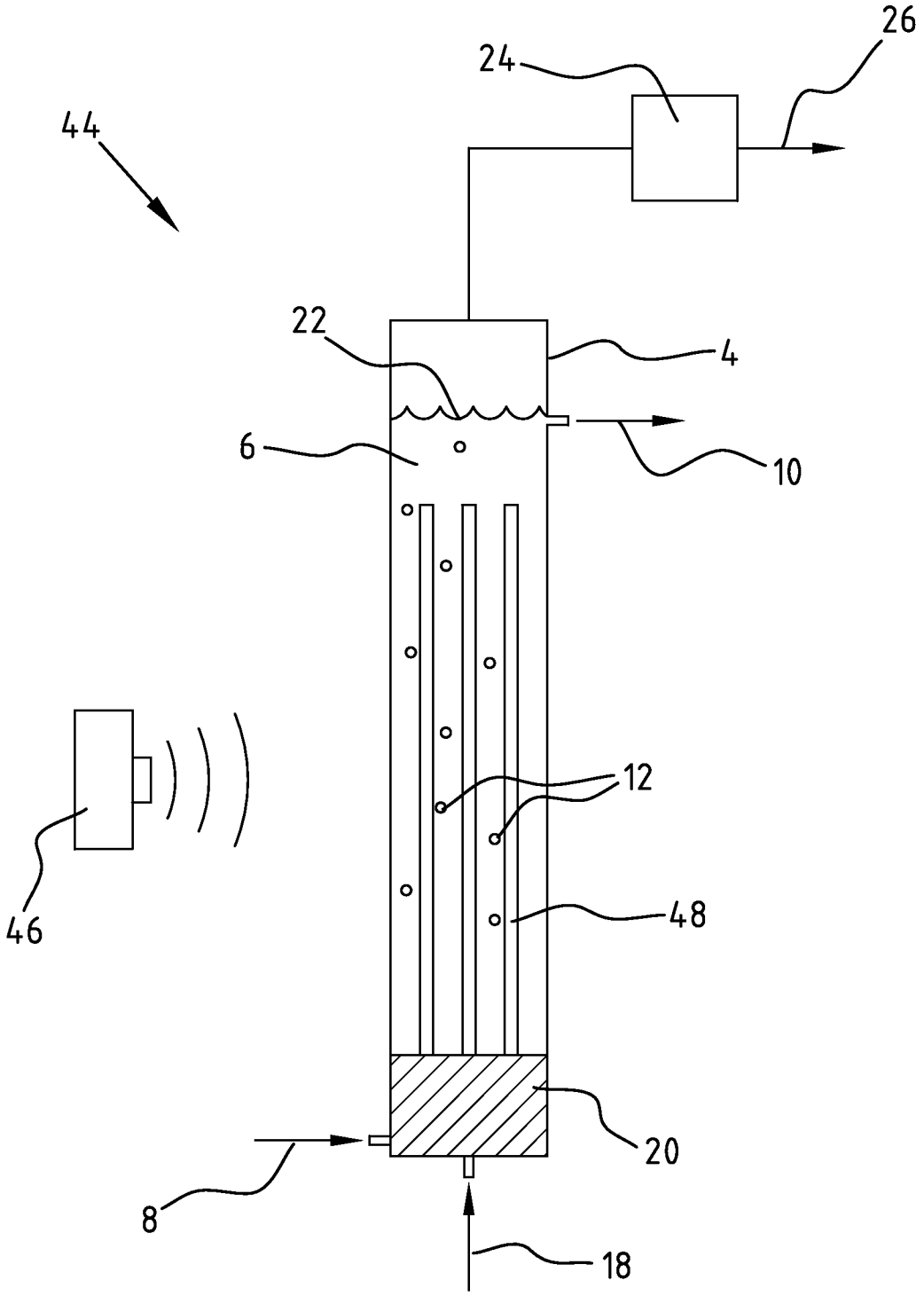

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2009/050554

A. CLASSIFICATION OF SUBJECT MATTER
INV. C02F1/48
ADD. C02F1/00 ~~C02F1/32~~ C02F1/72 C02F1/~~78~~

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, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/049116 A1 (SUBRAMANIAN KRUPAKAR M [US]) 9 March 2006 (2006-03-09) paragraph [0044] - paragraph [0047] paragraph [0053] paragraph [0059] figure 7	1-15
X	DE 100 30 735 A1 (KOBE STEEL LTD [JP]) 1 March 2001 (2001-03-01) claim 3 claim 1 column 3, line 45 - line 56 column 4, line 7 - line 16 figures 1,2,3a,3b	1-15

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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

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

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"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
3 December 2009	18/12/2009

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, Fax: (+31-70) 340-3016	Janssens, Christophe

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 02/26637 A1 (AQUA Z S R O [CZ]; ZACHAROV PETR PAVLOVIC [LT]) 4 April 2002 (2002-04-04) figure 2 page 8 page 6	1-4,8
X	WO 02/48053 A1 (UNIV STRATHCLYDE [GB]; MACGREGOR SCOTT JOHN [GB]) 20 June 2002 (2002-06-20) figures 1,2 page 2, line 27 - page 5	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

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