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(54) Title: DEVICE AND METHOD FOR DISINFECTION AND/OR PURIFICATION OF A FLUID

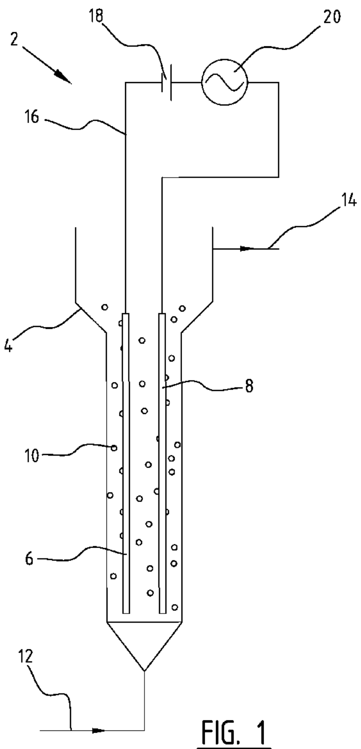

FIG. 1

(57) Abstract: The present invention relates to a device and a method for disinfection and purification of a fluid, like drinking water. The device comprises: - a fluidized bed reactor provided with a suspension of conductive particles that are capable of adsorbing contaminating elements like organisms, organic compounds and/or ions; - an anode and a cathode for providing a substantial number of particles with a charge; - means for generating an electrical and/or electromagnetic field by providing a potential difference between the anode and the cathode; and - an inlet for a fluid, possibly comprising contaminating elements, wherein the fluid is exposed in the device to the electrical and/or electromagnetic field thereby disinfecting and/or purifying the fluid.

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DEVICE AND METHOD FOR DISINFECTION AND/OR PURIFICATION OF A FLUID

The present invention relates to a device for disinfection and/or purification of a fluid, like drinking water.

Providing a sufficient amount of drinking water is important for the growing worldwide population. Existing devices for purification and disinfection of fluids like drinking water use a significant amount of energy and often require dozing additional components like chemicals to the process.

The present invention has for its object to provide a device that requires a limited amount of energy for the purification and/or disinfection. In addition, the invention aims at minimizing the dozing of chemicals to the process.

This objective is achieved with the device according to the invention, comprising:

- a fluidized bed reactor provided with a suspension of conductive particles that are capable of adsorbing contaminating elements like organisms, organic compounds and/or ions;
- an anode and a cathode for providing a substantial number of particles with a charge;
- means for generating an electrical and/or electromagnetic field by providing a potential difference between the anode and the cathode; and
- an inlet for a fluid, possibly comprising contaminating elements, wherein the fluid is exposed in the device to the electrical and/or

electro-magnetic field for disinfecting and/or purifying the fluid.

A fluidized bed reactor, according to the invention is provided with a suspension of particles. These particles are conductive and are also capable of adsorbing elements. Such elements comprise living organisms, organic compounds and/or ions. In the reactor a fluid, gas or liquid, is forced through the suspension with the conductive particles. This forcing of the fluid through the solid material is such that the particles are fluidized. In this fluidized state, the force of the fluid acting on the particles balances the weight of these particles. The particles will move around and collide with other particles and other components of the reactor. The reactor, which may have a shape of a pipe or a stirred tank, comprises at least one anode and one cathode. More electrodes may be provided. The number of the electrodes may depend, for example on the dimensions of the reactor, the throughput of fluid and the charge that is applied to the particles. The anode and the cathode are in use connected to a means for generating a potential difference between the anode and the cathode. At an inlet of the reactor, a fluid comprising contaminations is fed to the suspension of conductive particles. The incoming fluid fluidizes the conductive particles that collide with each other, the sidewall of the reactor and the electrodes in the reactor. The potential difference between the anode and the cathode has the effect that particles colliding with an electrode are given a potential. This means that between separate particles a potential difference may be present and that during a collision a transfer of charges will take place.

The electrical field between two particles in a fluidized bed is approximately inversely proportional to the distance between the particles. This electrical field is relatively strong just before two particles collide. The elements or contaminations in the incoming fluid will de adsorbed by the particles. This adsorption may take place by catalyzing the elements or contaminations by the charge on the particles. The effect of this adsorption is that the contaminations are exposed to a relatively high electrical field in case the particle to which it is adsorbed is about to collide with another particle. This electrical field can be so strong that electro-poration occurs and organisms are killed. This disinfects or purifies the fluid, like drinking water, without requiring a significant amount of energy and use of chemicals. The contaminations in the fluid may comprise (micro-) organisms, viruses, protozoa, algae, worm eggs etc. Also the contaminations may comprise organic contaminations like medicine, humus acids etc. Disinfection and/or purification also relate to bromate reduction and capacitive de-ionization.

Besides one inlet to the reactor, it is also possible to provide the reactor according to the invention with a second inlet for the supply of for example a gas to influence the fluidization of the particles and the transfer of charges to and from the particles. Furthermore, it is possible to circulate the contents of the rector, according to the invention, to obtain a type of residence time reactor, using for example an agitator or stirrer. This type of reactor is preferably used in case of relatively small particles with a diameter of below 1 mm. Preferably, electrodes are provided with relatively large specific surface areas. Also preferably, the electrodes are bar-shaped.

In a preferred embodiment according to the present invention the conductive particles comprise active carbon or polymer material provided with a metal coating.

For absorbing it is beneficial for the particles to have a relatively large surface area. For this reason, active carbon particles can be used. Other particles can have polymer material or a conductive material as base material. A metal coating, for example comprising silver, can be provided on the particles. The diameter of the particles is preferably in a range of 10 nm to 10 cm, more preferably in the range of 100 nm to 5 cm and most preferably in the range of 100 μm to 1 cm. The density of the particles is preferably larger than 1000 kg/m^3, although particles with a lower density may also be used.

In a preferred embodiment according to the present invention the means for generating a potential difference varies the potential in time with an adjustable amplitude and/or frequency.

By providing a potential difference that varies in time, the charge that is given to the particles that collide with the electrodes depend on the time of the collision. This realizes more potential differences between the particles in the suspension and improves transfer of charge from these particles to each other, the reactor wall, and/or an electrode. The varying potential differences are preferably generated by providing an alternating current component to the anode and/or cathode. This alternating current component preferably comprises a frequency in the range of 1Hz-100GHz, more preferably 1kHz-1MHz, even more preferably 10kHz-500kHz, and most preferably 30kHz-200kHz. The cell membranes of the (micro-)organisms are irreversibly damaged and the organisms may be killed, using a frequency in a range of 1Hz-100GHz. Experiments have shown that smaller frequency ranges between 1kHz-1MHz and 10kHz-500 kHz have a large influence on damaging the cell membranes. In fact, experiments have shown that a frequency in the range of 30kHz-200kHz has the most impact on the cells. The amplitude of the alternating current component preferably comprises an amplitude in the range of 10mV-100kV. The alternating current can have a sinusoid, a saw tooth, a block signal etc. or combinations thereof.

In a preferred embodiment the alternating current is generated in a resonance circuit comprising at least a coil and a condensator that is connected to the electrodes of the reactor.

In a further preferred embodiment according to the present invention the potential differences between the electrodes comprise a direct current component.

By providing a direct current component between the electrodes an electrolyze may occur in the reactor that leads to the presence of radicals on the surface of the particles. These radicals include OH, Cl and O-radicals. These radicals are also capable of killing (micro-) organisms. As the charged particles collide at a relatively high frequency to the electrodes the (micro-) organisms are exposed to a relatively strong electrical field that may damage for example cell membranes of the organisms. Preferably, the direct current component is combined with an alternating current component as both components increase each other’s effects for disinfecting and purifying a fluid. Also, the organic contaminations in the fluid adsorb to the charged particles. By the presence of radicals on the surface of these particles such contaminations will be decomposed. As the organic components decompose they are removed from the surface area of the particles. This has the effect that a driving force is maintained for adsorption of new organic contaminations to the surface. This is especially relevant in case of extremely low concentrations of these contaminations, for example on ppb-level, to be removed in a sustainable way from the fluid, without using chemicals or requiring regeneration of the particles.

The invention further relates to a method for disinfecting or purifying a fluid, like drinking water, comprising the steps of:

- providing a device according to any of claims 1-11;
- providing the reactor at an inlet with fluid possibly comprising contaminations;
- disinfecting and/or purifying the fluid in the reactor; and
- outputting the disinfected and/or purified fluid to an outlet of the reactor.

Such method provides the same effects and advantages as those stated with reference to the device. 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 overview of a device according to the invention;
- figure 2 shows an alternative embodiment used in an experiment; and
- figure 3 shows a schematic overview of a further alternative embodiment according to the present invention.

A device 2 (figure 1) for disinfection and/or purification of a fluid like drinking water comprises a fluid bed reactor 4. Reactor 4 is provided with a cathode 6 and an anode 8. Furthermore, reactor 4 comprises particles 10 of activated carbon. At the bottom of reactor 4 is provided an inlet 12 for supply of water to reactor 4. On top of reactor 4 is provided an outlet 14 for the output of purified water. Electrodes 6,8 are connected in circuit 16. Circuit 16 comprises a direct current source 18 and alternating source 20. Direct current source 18 is able to apply a potential difference between cathode 6 and anode 8. One of the primary objectives of providing a direct current is the decomposition of organic contaminations. The alternating current source 20 is able to provide for example a sinusoid, for example with a frequency of 100kHz, to the electrodes 6,8. The primary objective of the alternating current is disinfection of the fluid. By combining the direct current source 18 and alternating current source 20 a synergetic effect is realized in that both sources 18, 20 enhance each others effect. Contaminated water is supplied by inlet 12 to reactor 4. Particles 10, present in reactor 4 are charged by the electrodes 6,8. Organic components in the incoming water flow decompose and (micro-) organisms are damaged and possibly killed. This disinfects and purifies the water flow. Purified water is let to output 14 of reactor 4. To improve the fluidized bed behavior of the particles 10, an additional gas flow (not shown) may be provided to the reactor. Also, the content of reactor 4 may be circulated to improve its performance. Also, it is possible to supply and remove particles 10 to and from reactor 4 in a more or less continuous manner.

In an alternative embodiment of device 22 for disinfection and purification of a fluid (figure 2), a vessel 24 is filled with a fluid 26, like water. Fluid 26 comprises conductive particles. Fluid 26 is forced to move along the electrodes 36,38 and collide to these electrodes

36,38 and sidewall of vessel 24 by stirrer 28. Fluid is provided by a first input 30. A second input 32 may supply clean water to the vessel 24. Fluid 26 can be removed from vessel 24 by output 34. In vessel 24 there are provided two substantially vertically placed parallel stainless steal electrodes 36,38 with a length of about 15 cm and a diameter of about 12 mm. The electrodes 36,38 are hollow and the thickness of the steal layer is about 2 mm. The distance between the centers of the electrodes 36,38 is about 6 cm. The electrodes 36, 38 are connected in circuit 40. Also, circuit 40 comprises a source 42 for providing an alternating current to the electrodes 36,38.

Experiment

An experiment is performed using the device 22. In the experiment about 150 ml cylindrical shaped active carbon particles with a length of about 5-8 mm and a diameter of about 2.5 mm are put in a vessel with a volume of about 80 ml. An amount of 300 ml de-mineralized water is supplied to the particles after which it is stirred for 30 minutes to remove air from the pores of the particles. After 30 minutes almost all air was removed as particles did not float on the water, but sank to the bottom of the container. In a next step the particles were removed from the water and washed to remove suspended carbon particles. This resulted in about 150 ml washed active carbon, with pores filled with water. The washed active carbon is put in a container with a volume of 800 ml, containing a mixture of 150 ml tap water and 150 ml so-called grey water, i.e. domestic waste water, comprising protozoa. From a microscopic analysis a droplet of water from the containers comprised about 5 protozoa. With a droplet volume of about 0.05 ml the container would contain a concentration of protozoa of about 100 protozoa per ml. Then the electrodes are provided with an alternating current with a frequency of 100 kHz and an amplitude of 10 Volt. After 60 minutes, while the contents of the container are stirred, four samples are taken and analyzed using a microscope. The number of living protozoa significantly decreased. After 80-100 minutes of treatment in the device, analyses of samples showed that all protozoa are killed. Additionally, the experiment was repeated without providing an alternating current between the electrodes. After 100 minutes of stirring the contents of the container a large amount of the protozoa was still alive.

In another embodiment of a device 44 (figure 3) according to the invention, a fluidized bed reactor 46, comprises an anode compartment 48, wherein an anode 50 is placed. Anode 48 is filled with particles 52. Anode compartment 48 is separated by grid 54 from cathode compartment 56. Cathode compartment 56 is provided with a cathode 58 that is filled with particles 60. The pores of grid 54 have dimensions such that the conductive particles can not flow through these pores, while the fluid contaminations may flow through these openings. This tube-like reactor 46 may be used for disinfection, bromate reduction and capacitive de-ionization.

Fluid is fed to reactor 46 by inlet 62. The fluid moves through the anode compartment 48, passes grid 52 and flows through cathode compartment 56. Finally the fluid leaves reactor 46 via outlet 64.

Anode 50 and cathode 58 are connected in a circuit 66. Circuit 66 comprises a voltage supply 68 and a NPN transistor 70. Reactor 46 is connected to the collector side of transistor 70. Resistance 72 maintains a direct current from collector to emitter. The resistance and voltage supply are selected such that electrolysis occurs in reactor 46. Between the basis of transistor 70 and the minus side of voltage supply 68, a function generator 74 is provided. With function generator 74, for example the amplitude of the alternating current can be selected.

Additionally to the circuit 66 shown in the illustrated embodiment, a coupling condensator and additional resistances between the basis and the minus of the voltage source 68 may be provided. By using function generator 74 it is possible to vary the direct current in a similar frequency as compared to the alternating current.

For bromate reduction, using device 44, the incoming fluid comprises bromate and bromide ions. In the anode compartment 48 the bromide can be transferred to bromine and/or bromate. As soon as the fluid leaves the compartment 48 and enters compartment 56 a reduction reaction can take place on cathode 58. Bromate and bromine are transferred to bromide. This causes the removal of bromate from the fluid. Although particles in the cathode compartment 56 of the fluidized bed may have a different charge, the absorption of bromide and bromated will be limited by the nett negative charge of the cathode. Of course this depends on the selected values of source 68 and function generator 64. In addition, the specific surface of the conducted particles is relatively large so that only a limited amount of bromate needs to be adsorbed to the electrode surface to enable transfer of the bromate in the reactor almost entirely to bromide. Furthermore, a restricted transport of anode particles 52 through openings in grid 54 into cathode compartment 56 and transfer of cathode particles 60 through grid 54 into anode compartment 48 may increase transfer of bromate to bromide. According to the inventors an explanation may be that positively charged particles in the cathode compartment 56 comprise a significant amount of bromate ions that are adsorbed to the surface and that after collision with the cathodes 58 almost instantaneous is transferred into bromide.

The present invention is by no means limited to the above described preferred embodiments thereof. The rights sought are defines by the following claims within the scope of which many modifications can be envisaged. One of the possible applications of the device and/or method according to the invention is the irrigation or spraying of water in horticulture and agriculture. The device and/or method according to the invention will prevent or minimize the distribution of bacteria, viruses and/or fungi. An example is in the cultivation of potatoes where irrigation or spraying of water is not always possible due to the presence of the Ralstonia solanacearum bacteria (“bruinrot”) in the water. The device and/or method according to the invention will disinfect and/or purify the water thereby killing the bacteria. This enables the irrigation or spraying of water.

CLAIMS

1. Device for disinfection or purification of a fluid, like drinking water, comprising:
   - a fluidized bed reactor provided with a suspension of conductive particles that are capable of adsorbing contaminating elements like organisms, organic compounds and/or ions;
   - an anode and a cathode for providing a substantial number of particles with a charge;
   - means for generating an electrical and/or electromagnetic field by providing a potential difference between the anode and the cathode; and
   - an inlet for a fluid, possibly comprising contaminating elements, wherein the fluid is exposed in the device to the electrical and/or electro-magnetic field for disinfecting and/or purifying the fluid.

2. Device according to claim 1, wherein the conductive particles comprise active carbon and/or polymer material provided with a metal coating.

3. Device according to claim 1 or 2, wherein the means for generating a potential difference varies the potential in time with an adjustable amplitude and/or frequency.

4. Device according to claim 3, wherein the potential difference comprising an alternating current component.

5. Device according to claim 4, wherein the alternating current component comprises a frequency in the range of 1Hz-100GHz, preferably 1kHz-1MHz, more preferably 10kHz-500 kHz, and most preferably 30kHz-200kHz.

6. Device according to claim 4 or 5, wherein the amplitude of the alternating current component comprises an amplitude in the range of 10mV-100kV.

7. Device according to any of claims 1-6, wherein the potential differences comprising a direct current component.

8. Device according to any of claims 1-7, wherein the particles having a diameter in the range of 10 nm-10 cm, preferably 100 nm-5 cm, and more preferably 100 µm-1 cm.

9. Device according to any of claims 1-8, wherein the particles having an average density of above 1000 kg/m^3.

10. Device according to any of claims 1-9, the device further comprising supply means for supplying gas to the reactor to manipulate the fluidized bed behavior of the particles and/or the transfer of potential from and to the particles.

11. Device according to any of claims 1-10, wherein the reactor comprising circulating means for circulating the particles.

12. Method for disinfecting and/or purifying a fluid, like drinking water, comprising the steps of:

    - providing a device according to any of claims 1-11;
    - providing the reactor at an inlet with fluid possibly comprising contaminations;
    - disinfecting and/or purifying the fluid in the reactor; and
    - outputting the disinfected and/or purified fluid to an outlet of the reactor.

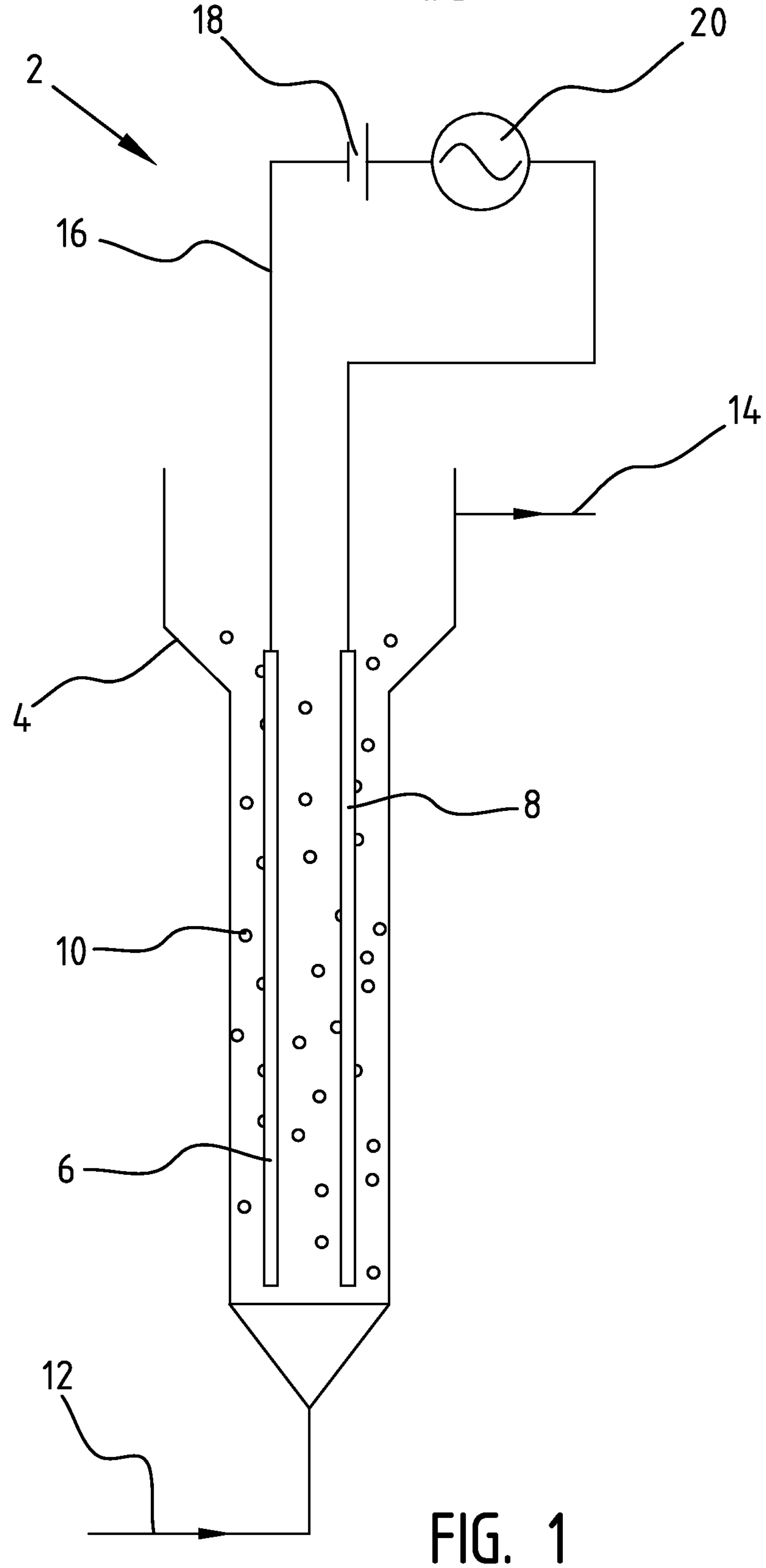

FIG. 1

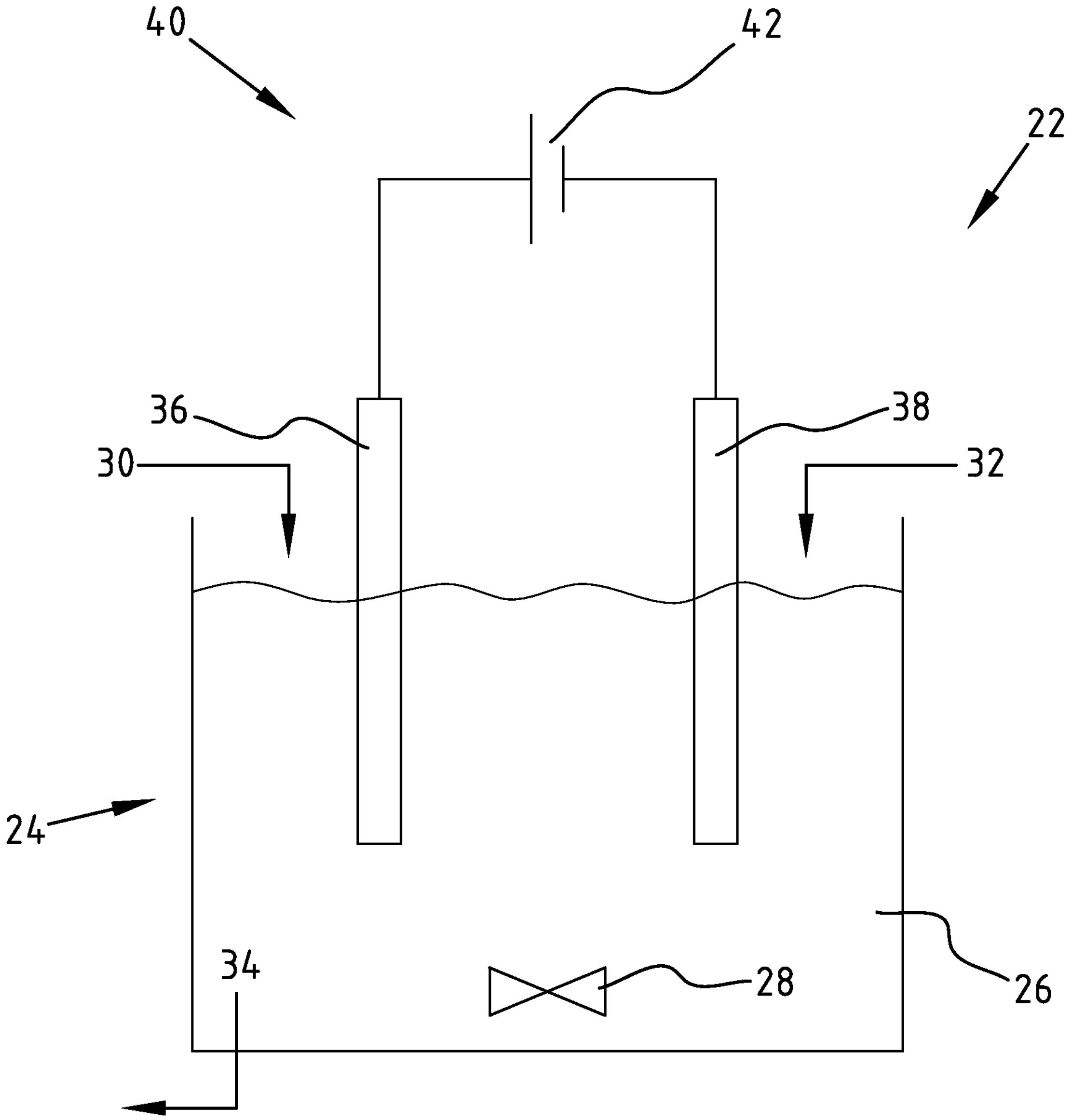

FIG. 2

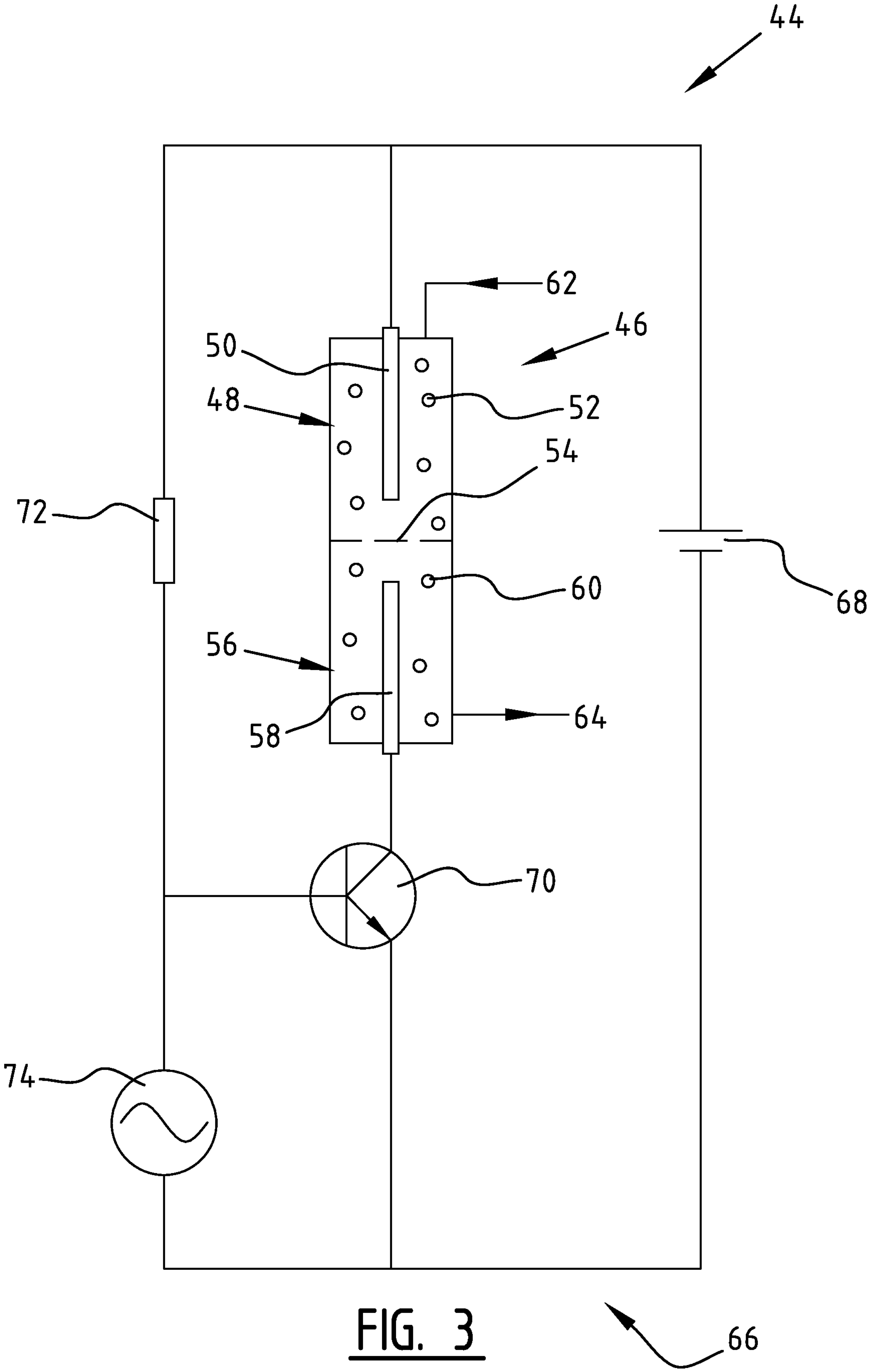

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2009/050555

A. CLASSIFICATION OF SUBJECT MATTER
INV. C02F1/467 C02F1/48 C02F1/28

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

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

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
7 December 2009	22/12/2009

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

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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