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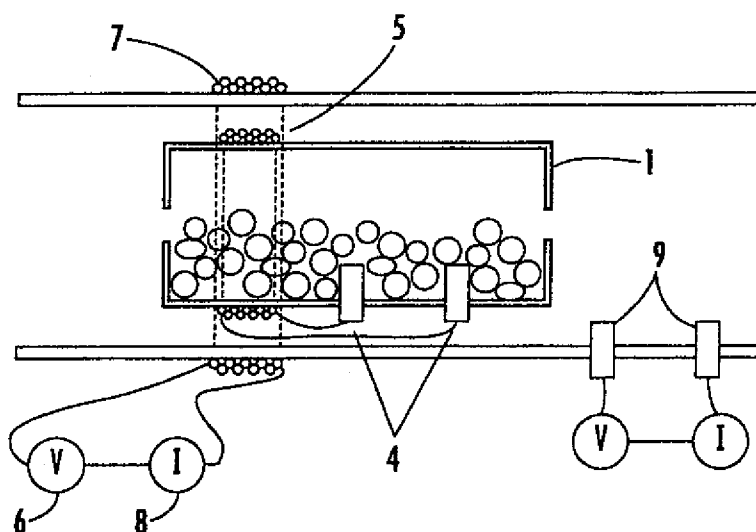
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: CONDUCTIVITY SENSOR FOR DETERMINING THE LEVEL OF GRANULES IN A WATER-FILLED CAPSULE



(57) Abstract: The present invention relates to a system for measuring the level of granular material in a container immersed in an aqueous medium, particularly, but not exclusively, for use as a measure of sanitizer level in spa and whirlpool halogenation systems. Electrodes fixed in the container wall are used to measure the electrical conductance along a path which is part filled with the granular material. Coils of wire are arranged such that the interrogating signal is coupled inductively to the sensor head. In this way the granule container can be made demountable, with no bare conductor material exposed to the aqueous medium. A separate reference circuit is used to measure the conductivity of the water in the system, and this signal is used to normalize the signal obtained from inside the container.

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CONDUCTIVITY SENSOR FOR DETERMINING THE LEVEL
OF GRANULES IN A WATER-FILLED CAPSULE

FIELD OF THE INVENTION

This invention relates to the field of measurement of granule fill level in
5 submerged capsules in an aqueous environment, particularly but not exclusively for
use as a measure of sanitizer level in spa and whirlpool halogenation systems.

BACKGROUND

A low-cost robust and reliable technical solution is required to address the
10 need for monitoring spa and whirlpool halogenation systems. Owing to the
comparatively heavy organic loading of whirlpool tubs, and the potential for foul
water to sit in the suction line for extended periods in between usage, there is a need
to disinfect the water as it re-circulates. Cartridge-based systems release controlled
amounts of sanitizer directly in to the water flow system. Since the cartridge has a
15 finite source of sanitizer, indication is needed to confirm that the cartridge contains a
significant amount of sanitizer. Eventually the cartridge will become depleted,
necessitating replacement. In the case of the sanitizing agent being a product of slow
decomposition of an insoluble solid, it is possible to monitor the level of sanitizing
agent by measuring the remaining level of solid matter within the cartridge. There
20 are many techniques for measuring fill level within a container. These include
paddle switches, ultrasonic, electromagnetic wave and capacitive measurements.
Invariably these measurements assume that the space not filled is occupied by air or
vacuum, such that the conductivity is zero and the relative dielectric constant is unity.

Of particular relevance is, for example, US Patent No. 6,237,412, which
25 describes a capacitive sensing technique for liquid level measurement. This is
extended by US Patent No. 6,269,694 to include powder level measurement. US
Patent No. 4,188,826 describes a resistance measurement for the level of a
conductive liquid. Additionally, WO 95/12704 A1 describes sensors for dosing
washing machines with detergent by way of measuring the conductivity of the soap
30 solution.

In the field of geophysics the well-known Archie equation describes the
relationship between porosity and resistivity in reservoir rocks, and measurement of

rock sample resistivity is a standard analytical technique. A method has been developed as described in US Patent No. 4,158,165 using inductive coupling of radio frequency signals to produce a non-contact sensor which can be used in a bore hole. This teaching has been extended in US Patent No. 5,811,973 to measure both real
5 and imaginary parts of the sample impedance.

This invention is an improvement over the existing techniques because it uses a well established method for characterizing porous rock samples to determine the fill level of man-made granular, insulating material in an aqueous environment. Additionally, the electrical signal may be extracted from the cartridge by a two-part
10 inductive link. In this way, the simplicity and sensitivity of the direct connection to the porous medium is maintained whilst no conductive elements apart from the measurement electrodes are exposed to the potentially corrosive aqueous environment, leading to long and reliable operation.

15 SUMMARY OF THE INVENTION

This invention describes a system for monitoring the fill level of a granular, insulating material in an aqueous environment. Two electrodes are placed in the volume where the granular material is contained by the cartridge, such that the total electrical conductance through the water which fills the inter-granular space will vary
20 depending on the amount of material present. When the conductivity of the water in the system is known, the volume fraction of insulating material can be estimated.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example,
25 with reference to the accompanying drawings, in which:

Figure 1 illustrates a cartridge, made from an insulating material, fitted with two graphite electrodes penetrating into the cartridge interior, and part filled with granular sanitizing agent;

Figure 2 illustrates a graph of resistance readings for an example cartridge as
30 a function of weight of a particular sanitizing agent added to the cartridge;

Figure 3 illustrates the inductive coupling arrangement to the cartridge. This is a cross-sectional view of the cartridge inserted in to a section of pipe which forms part of the water recirculating system of the spa; and

Figure 4 shows a graph of the variation of the ratio of measured cartridge to reference resistances as a function of time after the pumping system is started, following a period of stagnation.

DETAILED DESCRIPTION

Figure 1 illustrates the cartridge 1, made from an insulating material and filled with sanitizing agent granules 2. Holes 3 are formed in the end walls of the cartridge 1, such that when the sanitizing agent decomposes, the decomposition products can diffuse or flow out into the main body of the pipe work, and hence into the spa or whirlpool. Two graphite electrodes 4 are fitted through the bottom wall of the cartridge 1, and secured in place by a waterproof sealant. An electrical measurement, preferentially an alternating current signal, is made between the two electrodes 4, to determine the conductance or resistance. The granule fill level can be related to this measurement, as shown in Figure 2, where the resistance in the cartridge 1 has been measured for a number of weights of sanitizer leaded in to the cartridge 1. In the case of gradually decomposing sanitizer, the granules 2 will tend to settle on the bottom of the cartridge 1, as indicated in Figure 1. The conductance measured inside the cartridge 1 will be the sum of numerous percolation paths around the insulating granules 2. The exact nature and value of these will not be absolutely predictable, but if the granules 2 are manufactured in a consistent manner, then the variation in the resulting ensemble will be sufficiently small that the conductance measurement will be adequate to determine when the cartridge 1 is close to exhaustion. The reliability of the resistance measurement as an indication of fill level will also depend on the conductivity of the water. It is likely that the conductivity of the water will vary over time. To compensate for this, a reference measurement is made of the conductivity of the water outside the cartridge 1. The fill level is then determined from the ratio of the signal measured at the cartridge electrodes 4 to signal measured at the reference electrodes 9. This, however, assumes that the conductivity of the water in the vicinity of the reference electrodes 9 is the

same as that inside the cartridge 1. This is evidently not true when the cartridge 1 has been left stagnant for a while, so that the decomposition products of the granules have locally enhanced the water conductivity, and a diffusion gradient exists between inside and outside the cartridge 1. This gradient is rapidly washed away when
5 substantial flow past the cartridge 1 exists, as shown in Figure 4, when the pumping system is started. By monitoring the time variation of the resistance ratio after initiation of pumping, it is possible to establish whether the entrance and exit holes 3 are clear or blocked.

In the case of a replaceable cartridge 1, it is advantageous to have non-contact
10 signal coupling to the electrodes 4. In our preferred embodiment, shown in Figure 3, this is done inductively. An insulated wire is wound around the body of the cartridge 1 to form a coil 5 and the ends connected to the electrodes 4. The outer part of the electrodes 4 and the bare ends of the coil 5 are coated with insulating material, so that only the part of the electrodes 4 inside the cartridge 1 is in electrical contact with
15 water. An alternating current signal 6 is applied to an outer coil 7, which couples inductively to the inner coil 5. By analyzing the real and imaginary parts of the current signal 8, the real part of current flowing through the inner coil 5, and hence the conductance between the electrodes 4, can be deduced. By use of inductive coupling, the cartridge 1 can be made demountable, with no bare conductor material
20 exposed to the aqueous medium.

The reference electrodes 9 do not need to be replaced on a regular basis and so can be mounted on the wall of spa or whirlpool, adjacent to the cartridge 1. There is no particular advantage in making the connection to these electrodes 9 non-contact, and so are connected directly to their measurement circuit, for simplicity.

25

FURTHER EMBODIMENTS

The electrodes 4 may be constructed of conductive material alternative to graphite. For example, stainless steel or chromium plated brass or other material commonly used for fixtures and fittings of sanitary ware. The electrodes 4 may be
30 coated with a think insulating protective layer of, for example, ceramic, such that the measuring signal couples capacitively to the contents of the cartridge 1.

The coils 5, 7 may be wound in other ways apart from around the body of the cartridge 1. For example, the inner coil 5 may be placed on the outer wall of the cartridge 1, with its axis normal to the cartridge 1 axis, such that when the cartridge 1 is inserted in to position the secondary and primary coils lie substantially adjacent to each other.

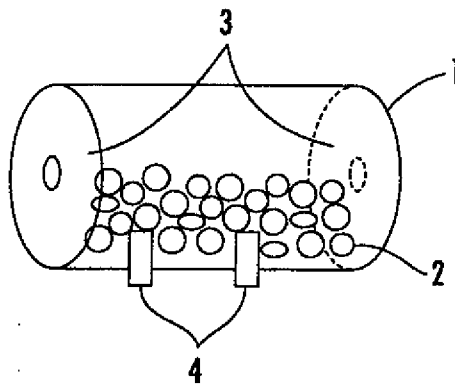
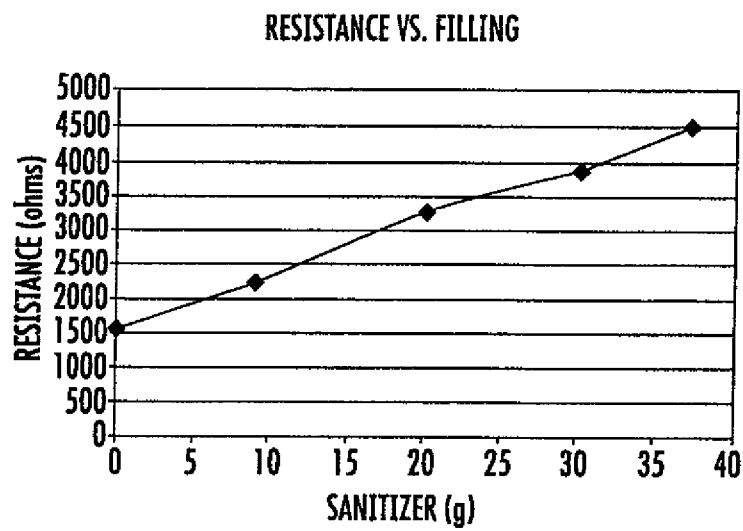
The addition of a capacitor to the inner coil 5 will make the circuit resonant, and with appropriate choice of stimulation frequency will make the system more sensitive to variations in conductance.

CLAIMS

1. An apparatus for measuring fill level of a cartridge containing granules or powder of a non-insulating material, in an aqueous environment, comprising:
5 a capsule;
a plurality of electrodes on the inside of the capsule;
an alternating current impedance measuring circuit attached to the electrodes for measuring the impedance of the capsule; and
a reference circuit for measuring the impedance of the water, such that the fill
10 level of the granules is determined from the ratio of capsule impedance to reference impedance.
2. The apparatus for measuring fill level of a cartridge as in Claim 1, wherein the alternating current impedance measuring circuit comprises an insulated wire that
15 is wrapped around the cartridge to form a coil and connected inductively to the electrodes.
3. The apparatus for measuring fill level of a cartridge as in Claim 2, wherein the coil has an axis that is substantially parallel to the trajectory of the capsule, as the
20 capsule is either inserted or extracted from the aqueous environment.
4. The apparatus for measuring fill level of a cartridge as in Claim 2, wherein the coil has an axis that is substantially perpendicular to the trajectory of the capsule, as the capsule is either inserted or extracted from the aqueous environment.
25
5. The apparatus for measuring fill level of a cartridge as in Claim 1, wherein the electrodes are stainless steel or other corrosion resistant metal.
6. The apparatus for measuring fill level of a cartridge as in Claim 1, wherein
30 the electrodes are coated with a thin insulating protective layer.

7. The apparatus for measuring fill level of a cartridge as in Claim 1, wherein the granules are a sanitizing agent for use in a spa or whirlpool halogenation system.
8. The apparatus for measuring fill level of a cartridge as in Claim 2, further
5 comprising a capacitor that is attached to the coil in order to make the circuit resonant.
9. A method for analyzing the signals derived from an apparatus for measuring fill level of a cartridge containing granules or powder of a non-insulating material, in
10 an aqueous environment, whereby the fill level of granules is determined from the ratio of capsule conductance to reference conductance.
10. A method for analyzing the signals derived from an apparatus for measuring fill level of a cartridge containing granules or powder of a non-insulating material, in
15 an aqueous environment, whereby the fill level of granules is determined from the ratio of real part of the inductively measured complex impedance signal to the reference conductance.

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**FIG. 1****FIG. 2**

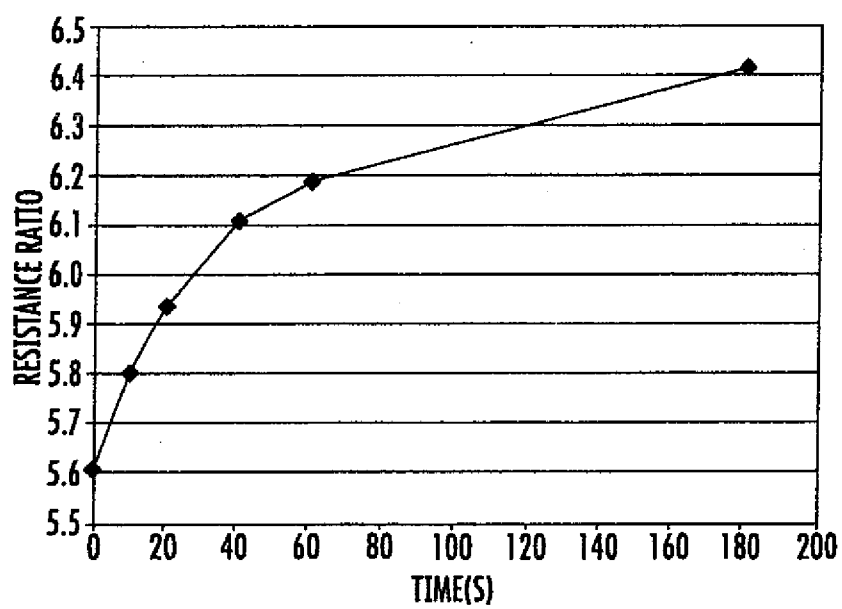
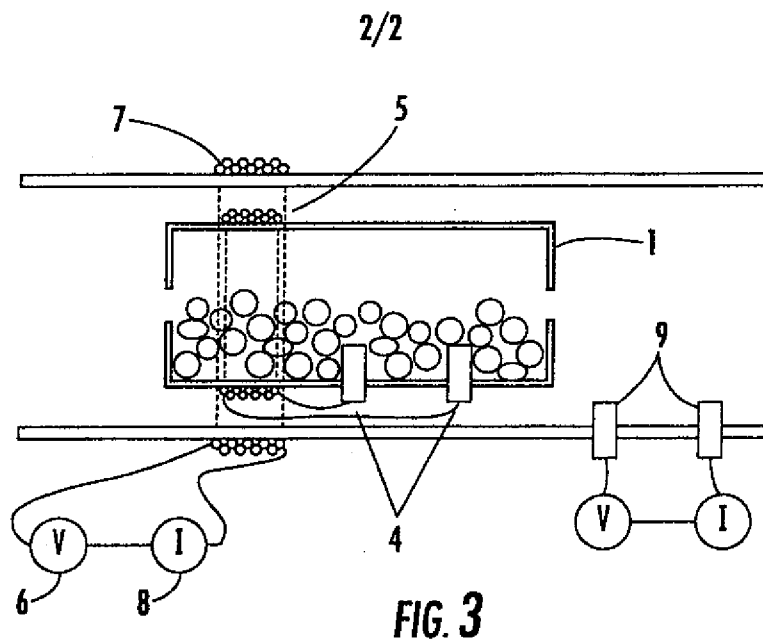


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2007/061262

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01F23/24

ADD. C02F103/42

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)

G01F E04H G01N G01R

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 772 872 A (SHELHAMER DONALD E [US]) 30 June 1998 (1998-06-30) column 4, line 50 - column 5, line 14; figures 2,3	1,9,10
A	WO 95/12704 A (UNILEVER NV [NL]; UNILEVER PLC [GB]; DER KINDEREN KLAAS [NL]) 11 May 1995 (1995-05-11) cited in the application the whole document	1,9,10
A	US 4 928 813 A (CASBERG JOHN M [US]) 29 May 1990 (1990-05-29) the whole document	1,9,10
A	WO 01/75459 A (ACCENT HYDROPONICS PTY LTD [AU]; CHAMBERLAIN CLIVE BARRON [AU]) 11 October 2001 (2001-10-11) page 3, line 19 - page 4, line 9; figure 1	1,9,10



Further documents are listed in the continuation of Box C.



See patent family annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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