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(54) **CHLORINATOR FOR PORTABLE SPAS**

(75) Inventor: **Michael McCague**, Escondido, CA (US)

Correspondence Address:
**Masco Corporation**
**c/o Greenberg Traurig LLP**
**2450 Colorado Avenue, Suite 400E**
**Santa Monica, CA 90404 (US)**

(73) Assignee: **Watkins Manufacturing Corporation**

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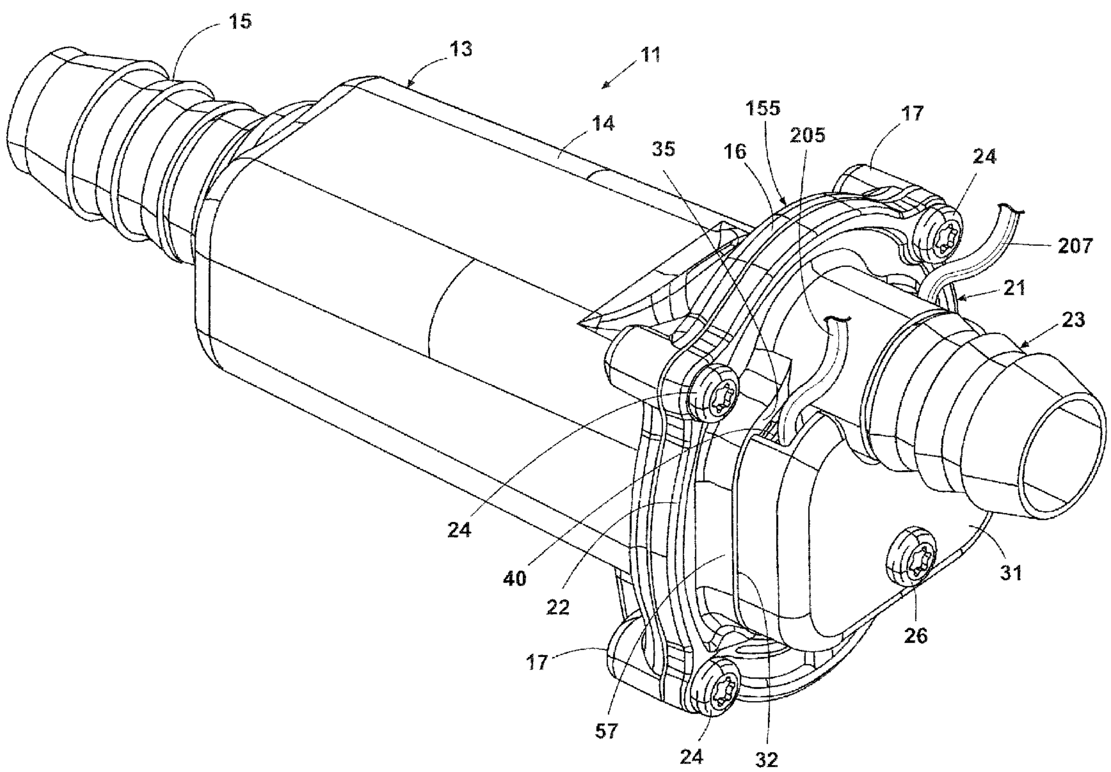
(57) **ABSTRACT**

An oxidizer generating apparatus having a housing with a fluid inlet at a first end, the inlet leading to a chamber, and a lid attachable to a second end of the housing for closing the chamber. First and second pairs of electrodes are attached to the lid so as to suspend them within the chamber in position to generate chlorine and/or other oxidants from fluid pumped through the housing.



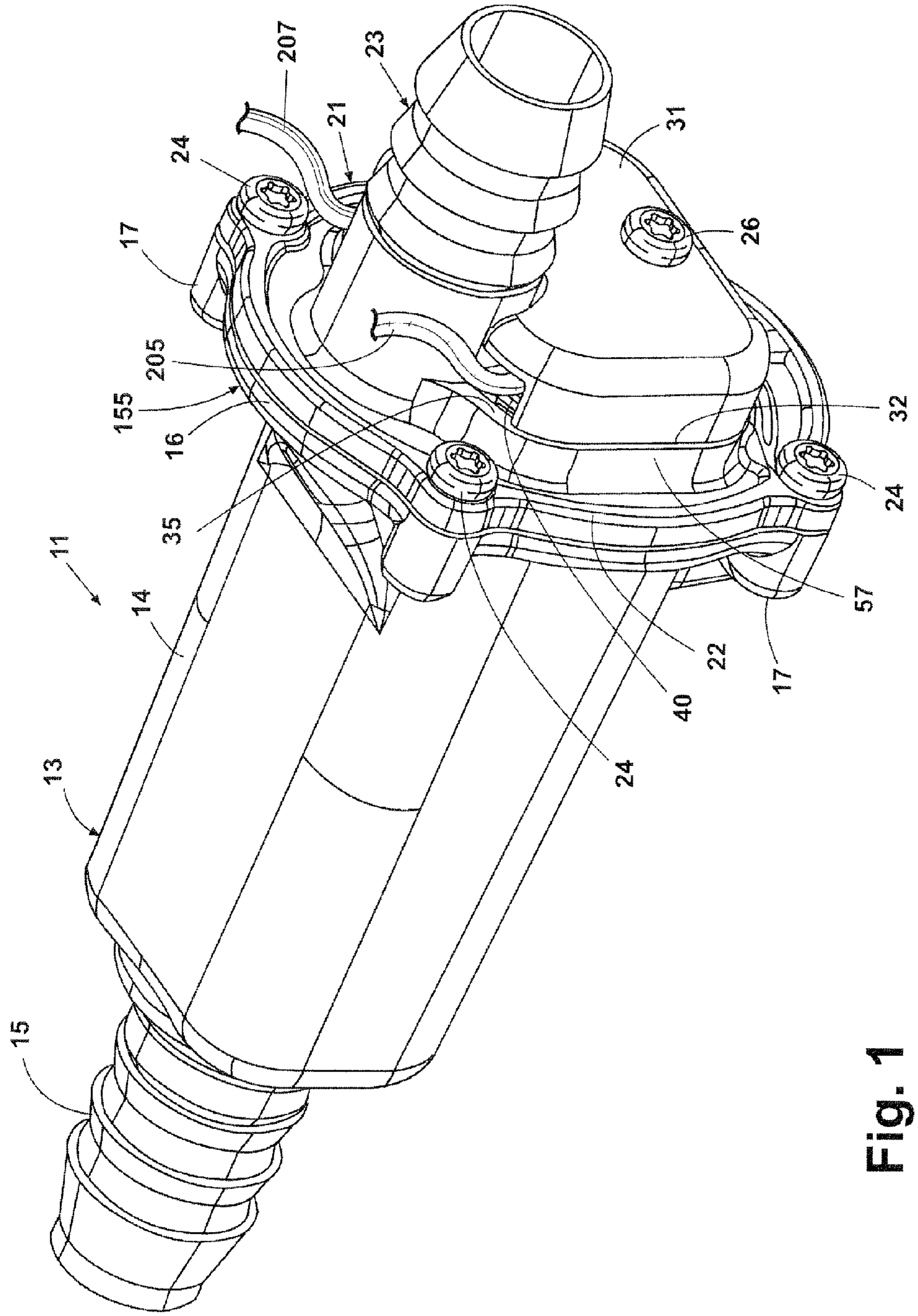



Fig. 1

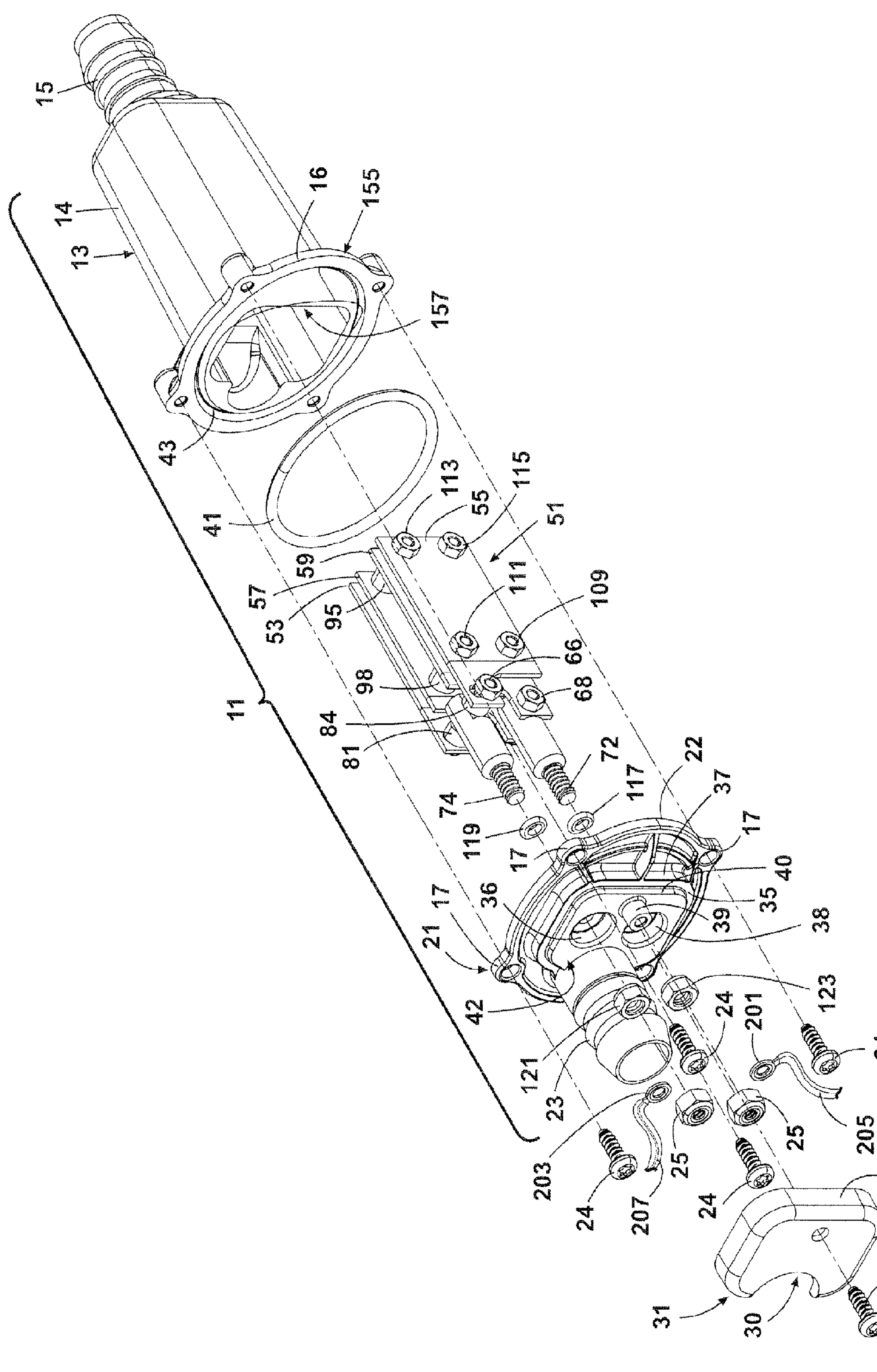

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Fig. 2

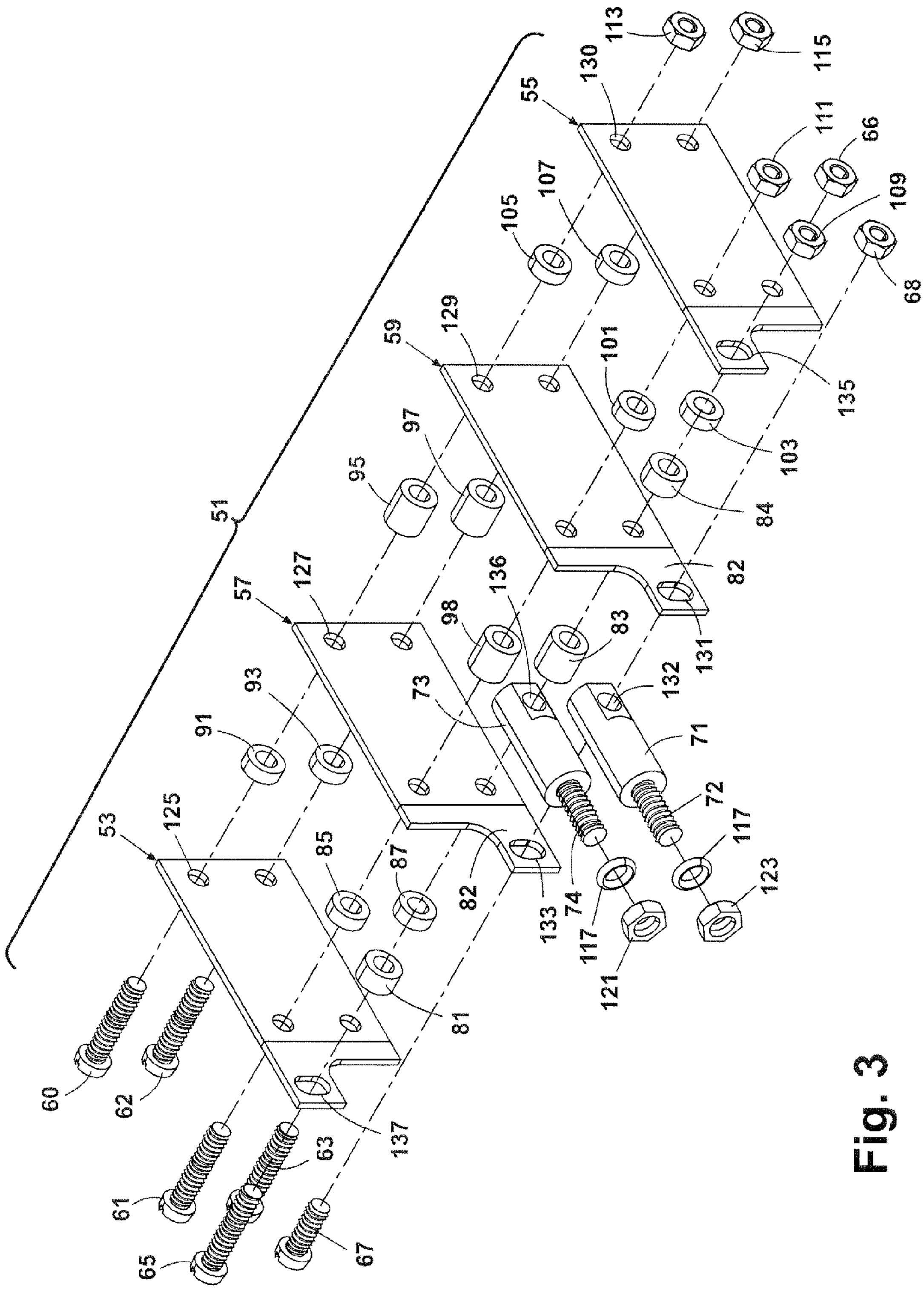
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Fig. 3

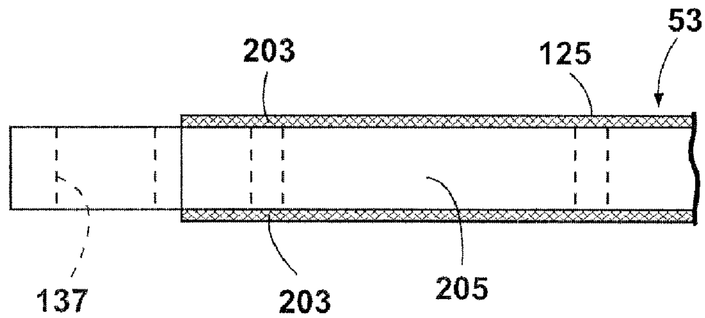


Fig. 4

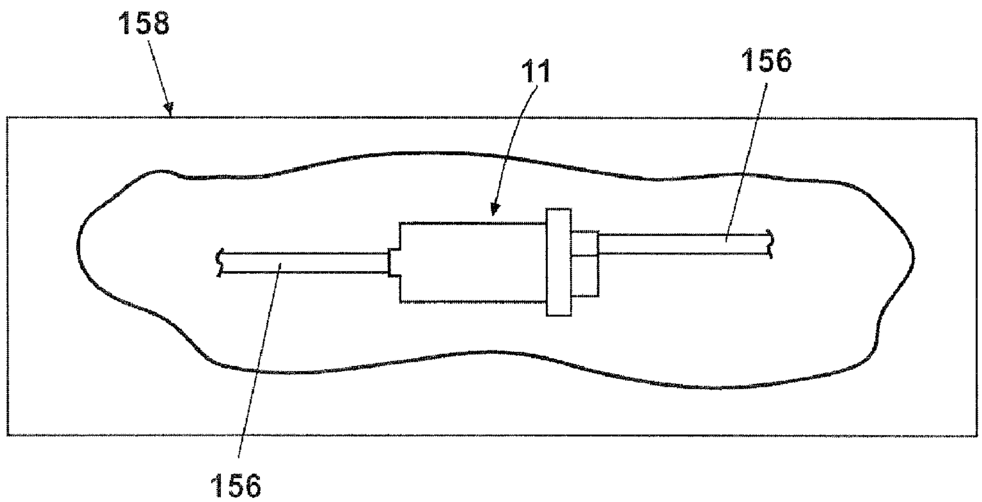


Fig. 5

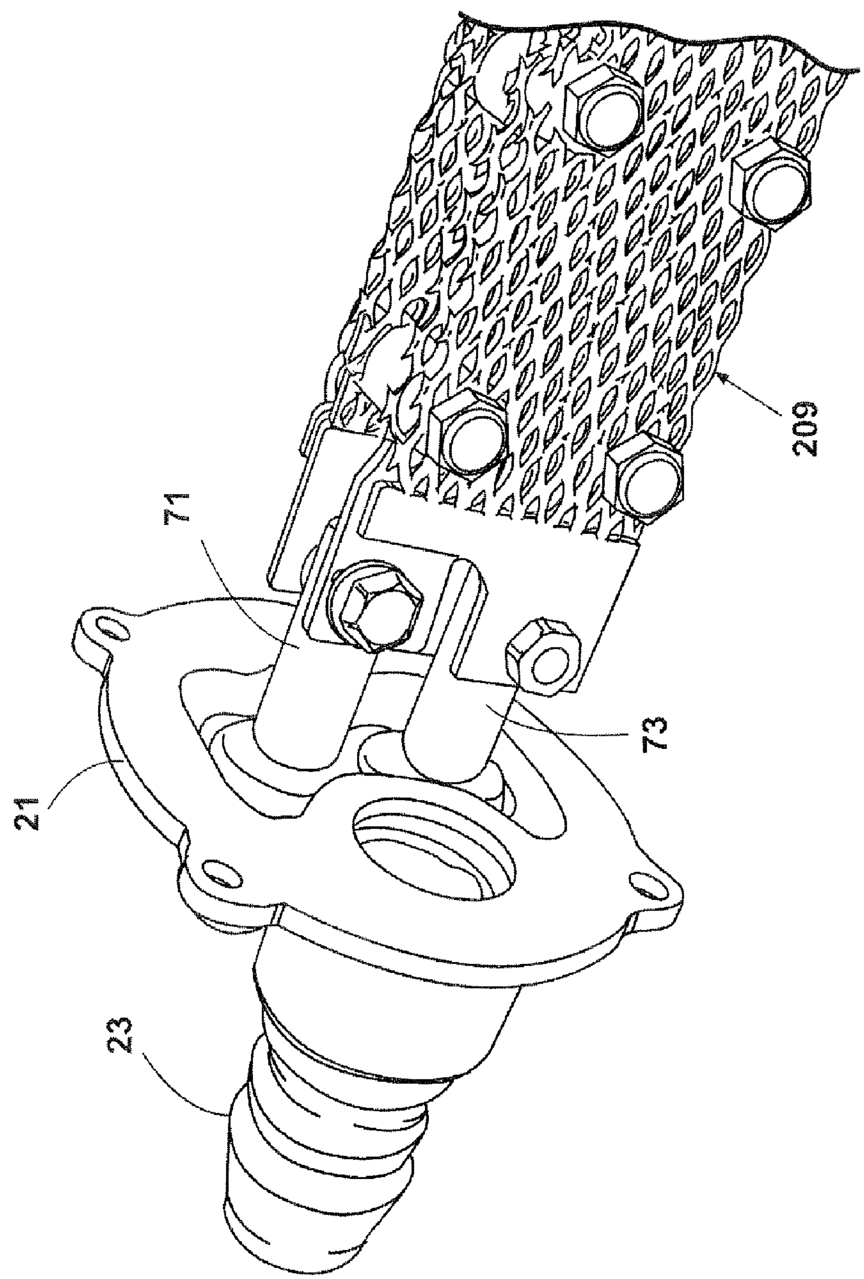


Fig. 6

# CHLORINATOR FOR PORTABLE SPAS

## FIELD OF INVENTION

**[0001]** This disclosure relates to water purification particularly with respect to water containing vessels such as spas, hot tubs, whirlpools, pools and the like and to a chlorinator or oxidizer generator suitable for such purpose.

## RELATED ART

**[0002]** Portable spas have become quite popular as a result of their ease of use and multiplicity of features such as varied jet and seating configurations. Maintaining appropriate water chemistry and sanitation is of course important to enhancing the spa user experience.

## SUMMARY

**[0003]** The following is a summary of various features, aspects, and advantages realizable according to various illustrative embodiments of the invention. It is provided as an introduction to assist those skilled in the art to more rapidly assimilate the detailed discussion which ensues and does not and is not intended in any way to limit the scope of the claims which are appended hereto in order to particularly point out the invention.

**[0004]** An illustrative embodiment of a portable spa chlorinator includes a housing having a fluid inlet at a first end, which leads to a chamber within the housing. A lid is attachable to a second end of the housing to close the chamber. First and second pairs of electrodes are attached to the lid so as to be suspended within the chamber when the lid is attached to the housing. When an appropriate voltage is applied, the electrodes interact with the fluid pumped through the chamber to generate various oxidizing agents.

**[0005]** In one embodiment, each electrode of the first and second pairs comprises a doped diamond surface, wherein the dopant may be, for example, boron. In one illustrative embodiment, the doped diamond surface resides on a substrate, while in another the doped diamond surface comprises the surface of a whole diamond electrode. In the former illustrative embodiment, the substrate may be selected from one of the group including titanium, niobium, silicon, platinum, or stainless steel. The electrodes may be solid metal plates or a mesh, the latter providing increased surface area.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** FIG. **1** is a perspective view of a chlorinator according to an illustrative embodiment.

**[0007]** FIG. **2** is an exploded perspective view of the chlorinator of FIG. **1**.

**[0008]** FIG. **3** is an exploded perspective view of an electrode assembly illustrated in FIG. **2**.

**[0009]** FIG. **4** is a schematic side view of a diamond doped electrode according to an illustrative embodiment.

**[0010]** FIG. **5**. is a side schematic view of a chlorinator installed in the fluid circulation line of a portable spa.

**[0011]** FIG. **6** is a partial perspective view of an illustrative embodiment of a lid and mesh electrode assembly.

## DETAILED DESCRIPTION

**[0012]** A chlorinator **11** according to a illustrative embodiment is shown in FIGS. **1**-**3**. The chlorinator **11** includes a housing **13**, a lid **21**, and a cap **31**. The housing **13** is preferably a unitarily molded polyvinyl chloride (PVC) part with an integrally molded, barbed fluid outlet **15** at one end and an integrally molded flange **155** at the opposite end. In the illustrative embodiment, the housing **13** has a generally rectangular cross-section with rounded corners, e.g. **14**, arcing through ninety degrees, and is adapted to be plumbed into the circulation line of a portable spa.

**[0013]** The lid **21** is also preferably a unitarily molded PVC part having a rim **22** whose contour conforms in shape to that of the rim **16** of the housing flange **155**. Four self-threading screws **24** attach the lid **21** to the flange **155**. An integrally molded, barbed fluid inlet **23** protrudes from the base **24** of the lid **21** and provides a fluid inlet to the housing **13**. As seen in FIG. **2**, an o-ring **41** is inserted in a circular receiving channel **43** in the housing **13** to provide a watertight seal between the housing **13** and the lid **21**.

**[0014]** The cap **31** is also preferably a unitarily molded PVC part and is attached to the lid **21** by a screw **26**. The edge **32** of the cap **31** fits flush against a mounting surface **35** of a raised (mesa) area **37** of the lid **21** and against an axially projecting perimeter edge or lip **40** of a second raised area **41**. The cap **31** is fastened into place against surface **35** by the screw **26**, which threads into a raised boss **39** portion of the lid **21**. Electrical leads **205**, **207** enter through apertures at each side of the cap **31**.

**[0015]** As noted above, in the illustrative embodiment, the housing **13**, lid **21** and caps **31** are unitarily molded plastic parts. It should be understood that, in other embodiments, these parts could be fabricated as an assembly of sub-components. Additionally, such parts could be fabricated of materials other than PVC, for example, such as ABS, Luran, Teflon, PTFE or Kynar.

**[0016]** FIGS. **2** and **3** depict an electrode or cell assembly **51**. The assembly **51** includes a first pair of electrodes **53**, **55** and a second pair of electrodes **57**, **59**. Each of the four electrodes **53**, **55**, **57**, **59** lie parallel to one another in respective horizontal planes in the illustrative embodiment.

**[0017]** As shown in FIGS. **2** and **3**, the two inner electrodes **57**, **59** and two outer electrodes **53**, **55** are held in position by four bolts **60**, **61**, **62**, **63**, which pass through respective sets of co-linear holes, one set being, for example, the four holes **125**, **127**, **129**, **130**. The four bolts **60**, **61**, **62**, **63** further pass through suitable spacers, respectively **91**, **95**, **105**; **85**, **98**, **101**; **93**, **97**, **107**; and **87**, **83**, **103** and thread into suitable respective nuts **113**, **111**, **115**, **109**. The bolts **60**, **61**, **62**, **63** and their associated spacers and nuts are preferably fabricated of a suitable plastic, such as, for example, PVDF (Kynar).

**[0018]** The two inner electrodes **57**, **59** are connected to a voltage of a first polarity by a first supply electrode **71**. The first supply electrode **71** is attached to the two inner plates **57**, **59** by a bolt **67**. The bolt **67** passes through respective oblong apertures **131**, **133** in L-shaped mounting sections **82** of the electrodes **57**, **59**, then through a hole **132** in the electrode **71**, and then threads into a nut **68**.

**[0019]** The two outer electrodes **53**, **55** are connected to a source of voltage opposite in polarity to that applied to the inner electrodes **57**, **59**. That voltage is supplied by a second supply electrode **73**, which is attached to the outer electrodes **57**, **59** by a bolt **65**. The bolt **65** passes through oblong apertures **135**, **137** in L-shaped mounting sections **82** of the electrodes **53**, **55**, then through a hole **136** in the second supply electrode **73** and then threads into a nut **109**. The bolts **65**, **67** and supply electrodes **71**, **73** are fabricated of conductive material such as, for example, titanium or platinum.

**[0020]** The projecting shafts **72**, **74** of the respective supply electrodes **71**, **73** pass through respective holes in the lid **21** leading to respective wells **38**, **36** and are fastened to the lid **21** by respective locking nuts **121**, **123** and sealed against respective O-rings **117**, **119**, which may be, for example, viton o-rings. The o-rings **117**, **119** provide a watertight seal and, together with o-ring **41** insure that fluid does not escape or leak out of the housing **13**.

**[0021]** Respective locking nuts **25** hold the ring terminals **201**, **203** of the respective supply leads **205**, **207** to the supply electrodes **71**, **73**. Attachment of the cap **31** then covers the wells **36**, **38**, the electrical leads **205**, **207** and the supply electrode shafts **72**, **74**.

**[0022]** Thus, the electrode assembly **51** is attached to the lid **21** and is suspended within the housing **13** when the lid **21** is attached to the housing by the screws **24**. The interior of the housing **13** forms a chamber **157** wherein hydroxyl radicals are generated when power is supplied to the electrodes **71**, **73** via the leads **205**, **207**.

**[0023]** In one embodiment, the electrodes **53**, **55**, **57**, **59** are rectangular in shape and each comprise a boron doped synthetic diamond electrode tailored to flow rate. As illustrated in FIG. **4**, such electrodes may be formed, for example, by chemical vapor deposition (CVD) of a very thin coating **203** of boron or nitrogen doped diamond onto a niobium substrate **205**. Such electrodes may be fabricated, for example, by Adamant, Chauxde-Fords, Switzerland. Other substrate materials may be used such as titanium, silicon, platinum or stainless steel. Embodiments may also be constructed of self-supporting diamond without using a substrate, such as may be obtained, for example, from Advanced Oxidation, Cornwall, U.K. In various embodiments, the substrates may either be solid plates or mesh, the latter providing increased surface area. FIG. **6** illustrates an embodiment employing mesh electrodes **209**.

**[0024]** In operation of illustrative embodiments in an illustrative portable spa environment, a chlorinator **11** is installed in the circulation line **156** of a portable spa **158** as shown in FIG. **5**. A constant current mode of operation of the device **11** may be employed. In such case, a selected current flow through each electrode pair **57**, **59**; **53**, **55** in the range of 1-5 amps, for example, 2 amps, may be used with a floating voltage across each electrode pair of 5-24 volts. In such embodiments, flow rates through the cell **11** may range from ½ gallon to 5 gallons per minute with a salt (NaCl) level in the spa water of from 500 ppm to 3500 ppm (target 1,000 to 2,000 ppm). Electronically, a constant current AC/DC transformer supplying 1 to 4.5 amps at 5 to 24 volts D.C. may be used along with a microcontroller to control activation of the cell **11**.

**[0025]** In such embodiments, hydroxyl radicals are generated directly off the electrode plates **53**, **55**, **57**, **59**. The hydroxyl radicals then oxidize organic waste in the process water or react with water and dissolved salts to produce various oxidizers. These include but are not limited to, ozone (O3), hydrogen peroxide (H2O2), sodium hypochlorite (NaHOCI/OC1), chlorine dioxide (ClO2), sodium persulfates (NaHSO5) and sodium percarbonate ($Na_2CO_3$). This broad spectrum of oxidizers is capable of neutralizing organic and other contaminants which may be present.

**[0026]** The design of the housing **13** is preferably such as to provide adequate mixing and turbulence of the process stream and the generated hydroxyl radicals. Flow through the cell **11** is optimized to allow for the self cleaning of the cell generated by polarity reversing and sloughing of the formed scale layers. Vapor lock is prevented in the cell **11** though either maintaining flow when the cell **11** is mounted horizontally with inlet **23** located on the top as shown in FIG. **1** or by mounting the cell **11** vertically with water entering the inlet **23** from the bottom.

**[0027]** A chlorine generator system according to an illustrative embodiment may operate in an open-loop mode using scheduled and timed generation of chlorine. The length and interval of daily generation is typically a function of the spa size, bather load, and water salinity. In such a system, the cell **11** may produce a constant stream of 0.1 to 0.60 ppm (parts per million) chlorine in a 4 gpm flow (2 Amp & 1000 to 2000 ppm salt). To maintain the chlorine level in the water, the cell **11** must operate longer for a large spa than for a small spa. Additionally the cell **11** must run longer with a higher expected bather load. The salt level has a strong direct relationship to the quantity of chlorine produced.

**[0028]** In an illustrative open loop system the user inputs three variables to the system at start-up. The first is the spa size (SPA). A size code may be used (e.g. 1-8). The anticipated use level, (USE) (1-5) is the second variable. Use level "(1)" corresponds to minimal use and vacation mode. A higher level should be entered if more bathing is expected. The user preferably adjusts the use level over the course of use. The third start-up variable input is the water hardness (Hd). This parameter controls the polarity reversal cycle timing used to clean the electrodes.

**[0029]** As an additional input feature, a manual chlorine addition (Add) command may be implemented. This command instructs the system to generate enough chlorine to add 2 ppm to the spa. This chlorine Add temporarily overrides scheduled operation times.

**[0030]** The manual Add command dictates that the system run for a length of time sufficient to add 2 ppm Chlorine. The amount of time needed to bring the water to 2 ppm is highly dependent on the amount of bather load in the water. A standard 24 hour dose or longer may be needed to completely bring the water up. In one implementation of the Add command, the system switches from 2 amps to 4-4.5 amps to rapidly generate chlorine. One run cycle every six hours may be used to maintain uniform around the clock treatment.

**[0031]** In one embodiment, salt is measured each time the unit **11** generates chlorine as well as when requested by the user. The system measures the salt level of the water by means of measuring the voltage across the cell **11**. The voltage reading is then compared against allowable limits. The salt concentration is normalized, and displayed on the user interface. A voltage higher than specified returns a low salt error and a voltage less than specified returns a high salt error.

**[0032]** If there is a low salt condition, an error may be sent to the spa controls, triggering a "water care" icon to flash. The unit **11** may be allowed to continue to generate chlorine in this condition. The spa controls or controller will boost available voltage to a regulated limit to automatically compensate for low salt or conductivity situations. If there is a high salt condition, an error will be sent to the spa controls, again triggering the water care icon to flash. In this case, the unit **11** will not generate chlorine until the salt level has been corrected.

**[0033]** To prevent mineral scale on the electrodes **53**, **55**, **57**, **59**, polarity reversal may be used. The time period of the reversal is a function of water hardness and is preferably made adjustable to a user input hardness reading. Rapid cycling of the electrodes will cause premature electrode failure. Therefore a dead band in the cycle may be implemented to allow the electrodes to discharge prior to the polarity reversal. The dead band interval may be, for example, a minimum of 20 seconds.

**[0034]** At either initial start-up or at a maintenance event, the spa water should be manually balanced. Once the spa water has been balanced it should be super chlorinated (5 ppm). Super chlorination prepares the system for operation and immediate spa usage by cleaning the spa after a period of nonuse. After super chlorination, salt is added to the water. The spa control system may operate such that the water care icon is blinking to indicate that the salt level is low and/or the unit has not been initialized or programmed. Salt should be added slowly into the filter compartment while all of the jets are operating. The jets should operate an additional 10 minutes after the salt is fully added. An example of a target salt concentration is 1000 ppm. High demand users can add up to 2000 ppm salt, which will lower the hours required to generate chlorine and therefore lower the USE level. A salt level reading is preferably taken every time the unit begins a generation cycle to ensure proper salt levels at start-up and during the time between water changes.

**[0035]** Typical operation of an illustrative system preferably requires a weekly chlorine and water quality check to ensure that the system is working correctly. Although the user is not required to enter the chlorine concentration, the value is needed to determine the use level. Over the course of the first month, the user may determine their Use Level by taking a reading of the water before they enter the spa. If the chlorine level is low, e.g., "1" or less, the user will want to increase the use level by one to increase the output. If the user finds that the chlorine level is 5 or higher, the user will want to drop the use level by one and retest in a few days or a week. If the bather load is predictable, the use level may only need occasional adjustments.

**[0036]** If the bather load is sporadic, the user may want to perform a manual addition. In such case, the user may enter the spa control menu and confirm an addition (Add). The addition operation turns the system on immediately and operates the specified amount of time determined to elevate the chlorine level by 2 ppm (this depends on bather load and time and cannot be guaranteed). If the water is overly polluted such that the actual bather load far exceeded the anticipated bather load, a manual dichlor/MPS dose may be used and is compatible with the system.

**[0037]** Typically, the spa will require a monthly manual shock with MPS or dichlor to eliminate any accumulated waste. The oxidizer level should be brought to and held at 5 ppm while all jets configurations and pumps are operated for 30 minutes each. It is important to monitor pH at this time as well to ensure that the water remains balanced.

**[0038]** Over time the water level in spa typically drops from evaporation or splash out. When fresh water is added to the spa, it is important to rebalance the water and monitor the salt concentration. The system may employ a conductivity sensor to determine the amount of salt in the water and whether it is too high or too low. A water care icon may be arranged to blink to indicate that the salt is low and that more salt is needed. Salt should be added in 0.25 lb (100 g) increments to ensure that it is not over dosed.

**[0039]** While the apparatus and method have been described in terms of what are presently considered to be the most practical and preferred embodiments, it is to be understood that the disclosure is not limited to the disclosed embodiments. It is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims.

**1**. An oxidizer generating apparatus comprising:
a housing having a fluid inlet at a first end, said inlet leading to a chamber.
a lid attachable to a second end of said housing for closing said chamber; and
a first pair of electrodes and a second pair of electrodes, each pair being coupled to said lid so as to suspend the first and second pair of electrodes within said chamber.

**2**. The apparatus of claim **1** wherein each electrode of said first and second pair comprises a doped diamond surface.

**3**. The apparatus of claim **2** wherein said doped diamond surface resides on a substrate.

**4**. The apparatus of claim **2** wherein said doped diamond surface comprises the surface of a whole diamond electrode.

**5**. The apparatus of claim **3** wherein said substrate is selected from one of the group of titanium, niobium, silicon, platinum, or stainless steel.

**6**. The apparatus of claim **2** wherein said doped diamond surface comprises boron doped diamond.

**7**. The apparatus of claim **2** wherein said doped diamond surface comprises boron doped synthetic diamond.

**8**. The apparatus of claim **5** wherein said doped diamond surface comprises boron doped diamond.

**9**. The apparatus of claim **2** wherein said diamond doped surface comprises nitrogen doped diamond.

**10**. The apparatus of claim **2** wherein said doped diamond surface is formed on a mesh substrate.

**11**. The apparatus of claim **1** wherein said housing and electrodes contained therein are positioned in the circulation line of a portable spa.

**12**. The apparatus of claim **11** wherein said housing has a fluid outlet and wherein said first and second pairs of electrodes interact with fluid flowing from said inlet through said chamber to said outlet to generate hydroxyl radicals.

**13**. The apparatus of claim **1** wherein said first pair of electrodes comprises first and second inner electrodes positioned adjacent to one another and adapted to be connected to a voltage of a first polarity.

**14**. The apparatus of claim **13** wherein said second pair of electrodes comprise a first outer electrode positioned adjacent the first inner electrode and a second outer electrode positioned adjacent the second inner electrode, the first and second outer electrodes adapted to be connected to a voltage of a polarity opposite to that of said first polarity.

**15**. The apparatus of claim **14** further comprising a first supply electrode and a second supply electrode, the first supply electrode being electrically coupled to said first pair of electrodes and said second supply electrode being electrically coupled to said second pair of electrodes.

**16**. The apparatus of claim **15** wherein said first and second supply electrodes are each attached to said lid.

**17**. The apparatus of claim **16** when each of said first and second supply electrodes extend through said lid and are sealably attached thereto.

**18**. An oxidizer generating apparatus comprising:
a housing having a fluid inlet at a first end, said inlet leading to a chamber.
a lid attachable to a second end of said housing for closing said chamber;
a first pair of electrodes and a second pair of electrodes; and
means for coupling the first and second pair of electrodes to said lid so as to suspend the first and second pair of electrodes within said chamber.

* * * * *