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(54) HYDROGEN GENERATOR

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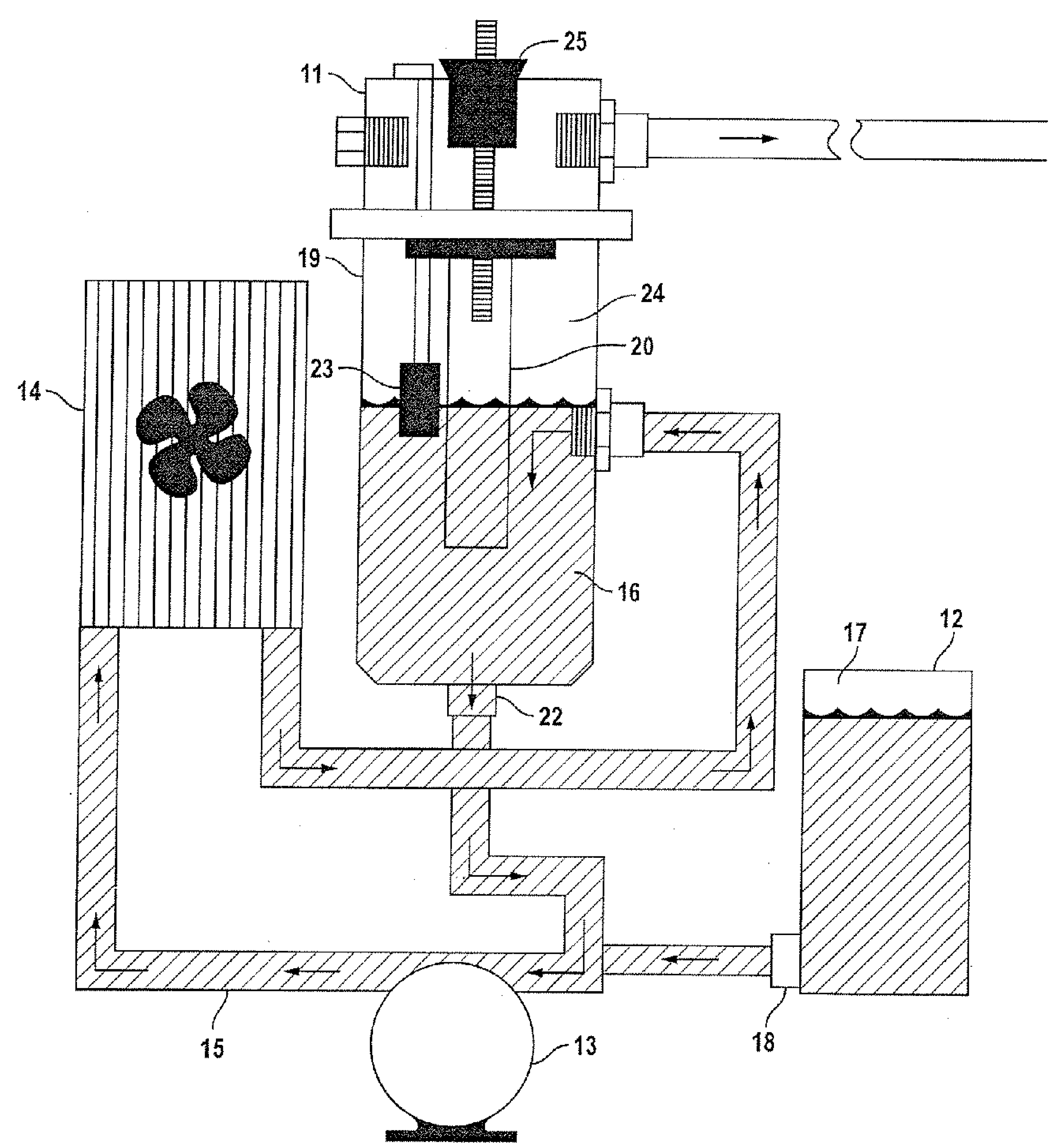
(57) ABSTRACT

A generator produces variable output of hydrogen and oxygen from electrolysis of water as a fuel supplement for combustion of hydrocarbon fuel. The generator includes an electrolytic reactor having a sealed cathode chamber partially filled with an electrolyte solution, and an anode immersed within the solution and electrically isolated from the chamber. A level sensor and reservoir maintain solution levels in one or more reactors configured in electrolyte communication. A source of electrical power energizes reactors responsive to changing combustion demand. A cooling system cools the reactors to allow the generator to operate at high amperage. An optional controller shifts reactor duty cycles to equalize reactor service over time. Gases produced in reactor air space above solution level are drawn or pumped to a combustion chamber to combine with hydrocarbon fuel and air. The combination results in greater combustion efficiency and reduces harmful emissions.

100



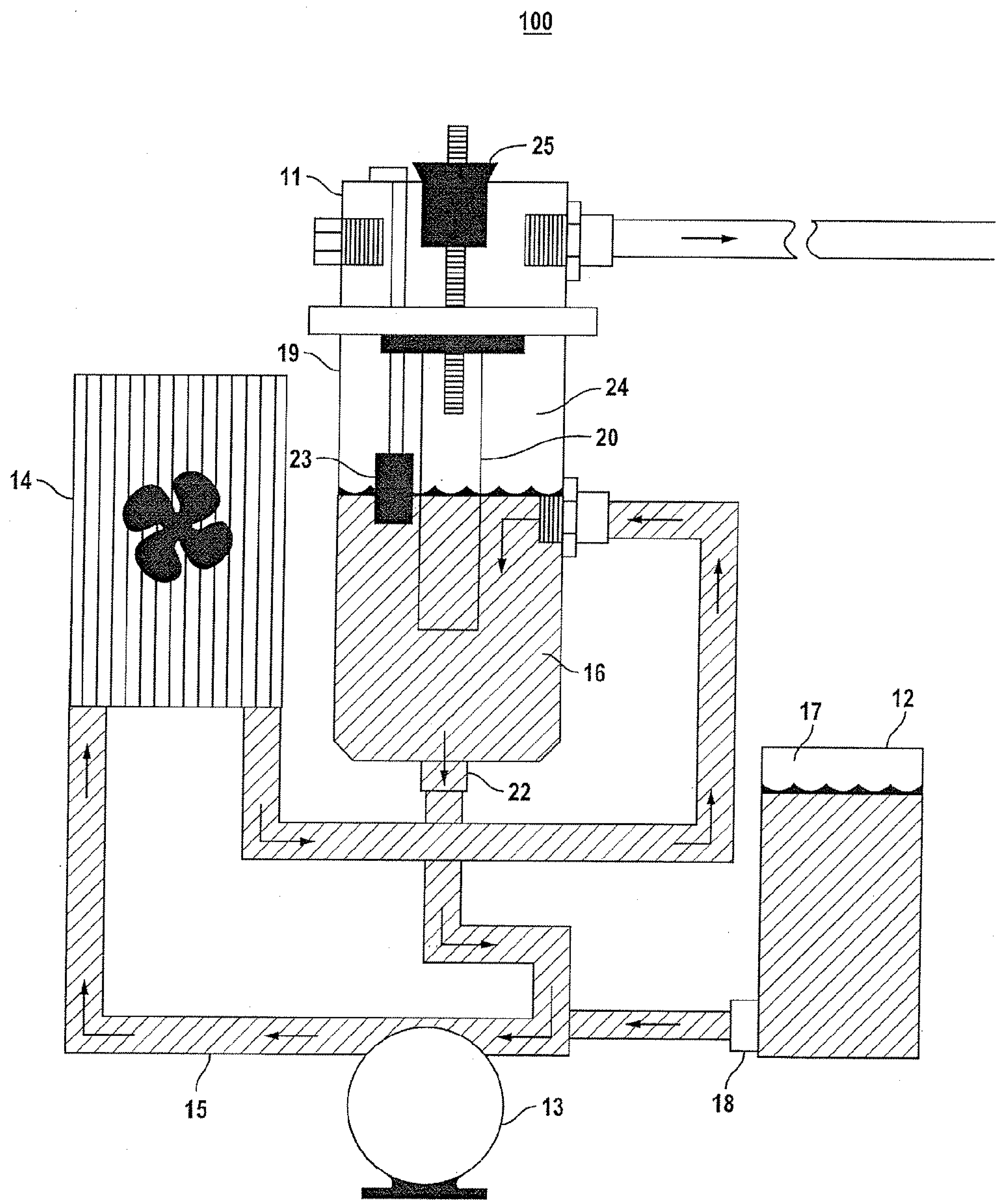


FIG. 1

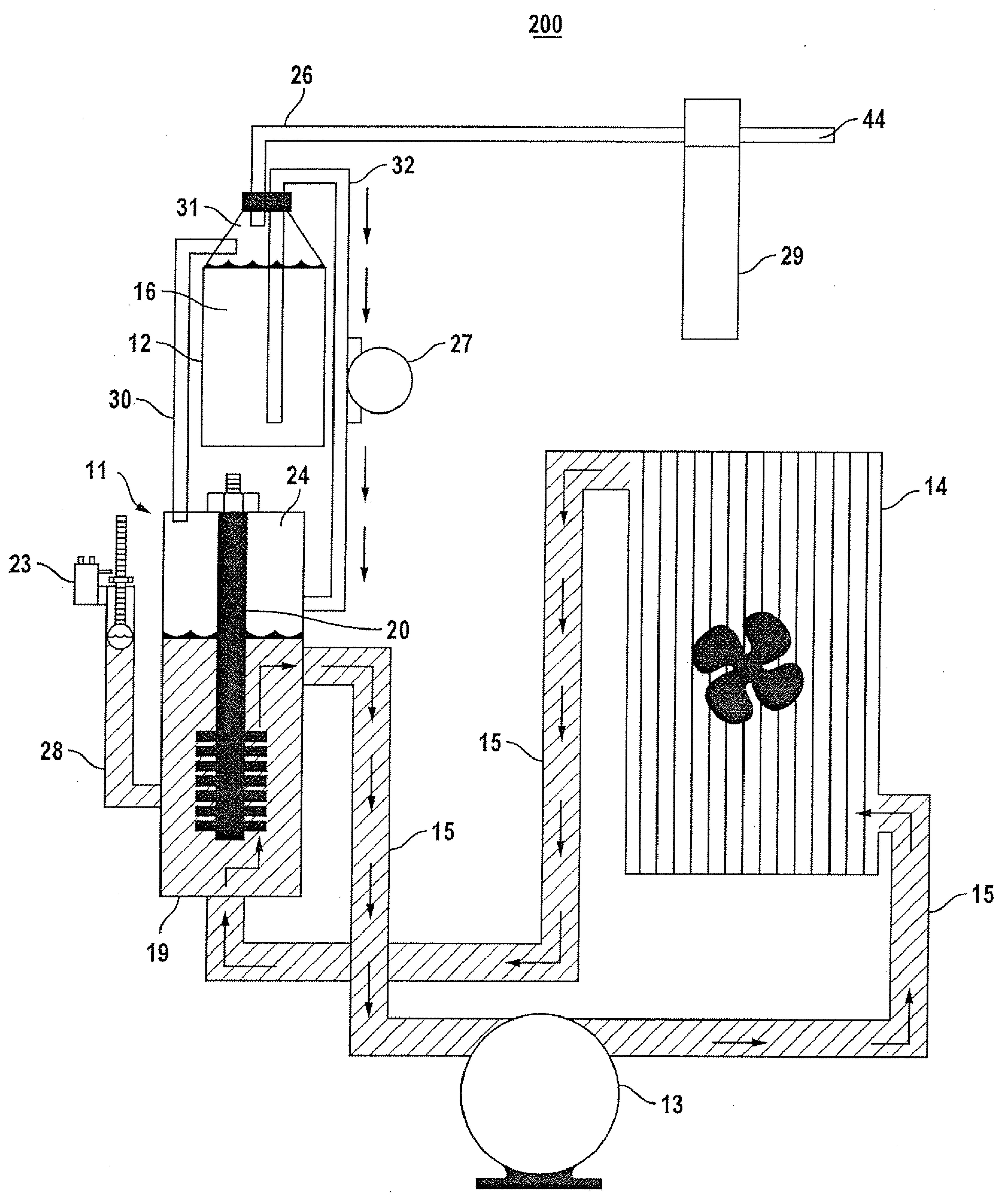


FIG. 2

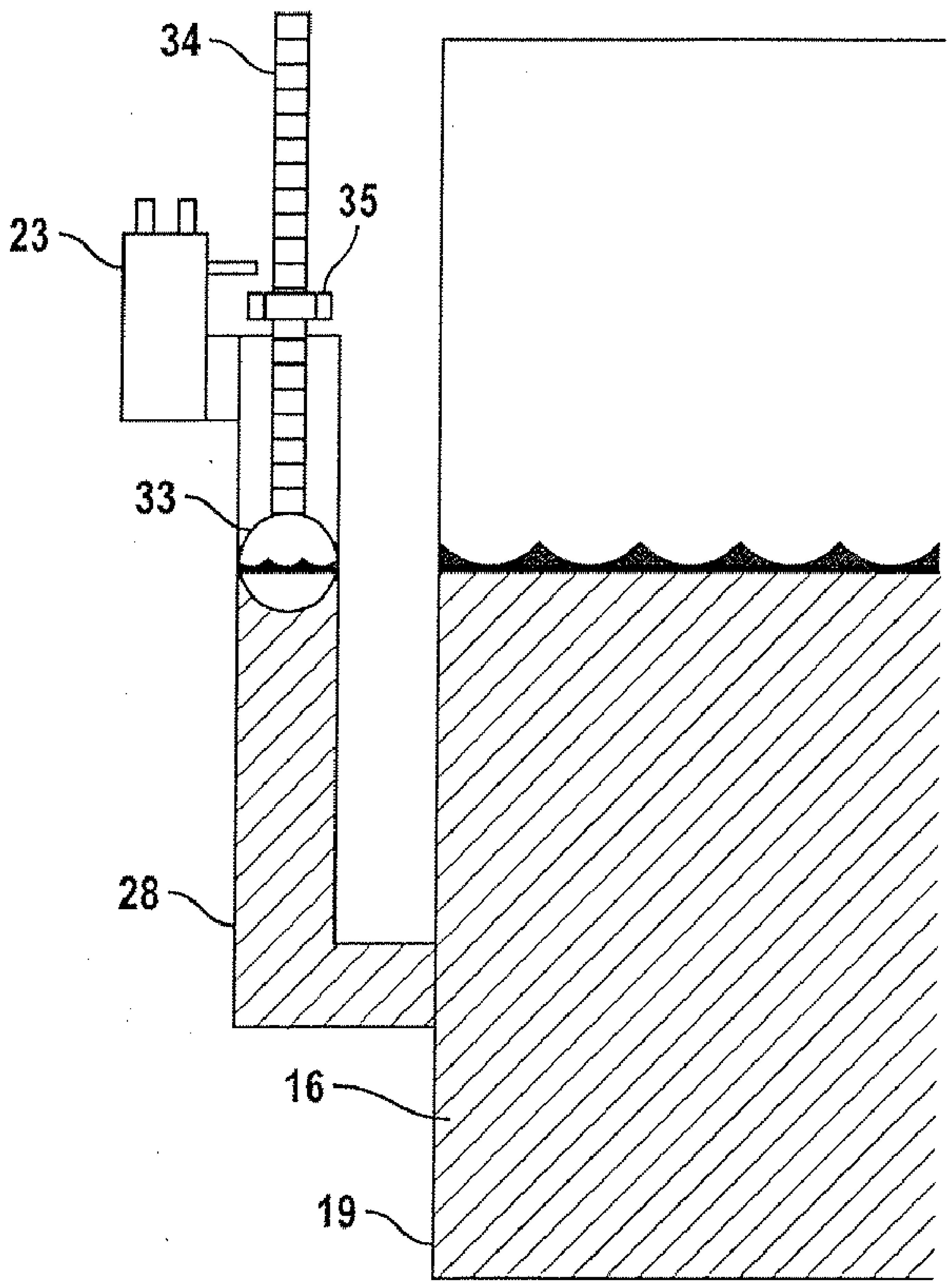


FIG. 3

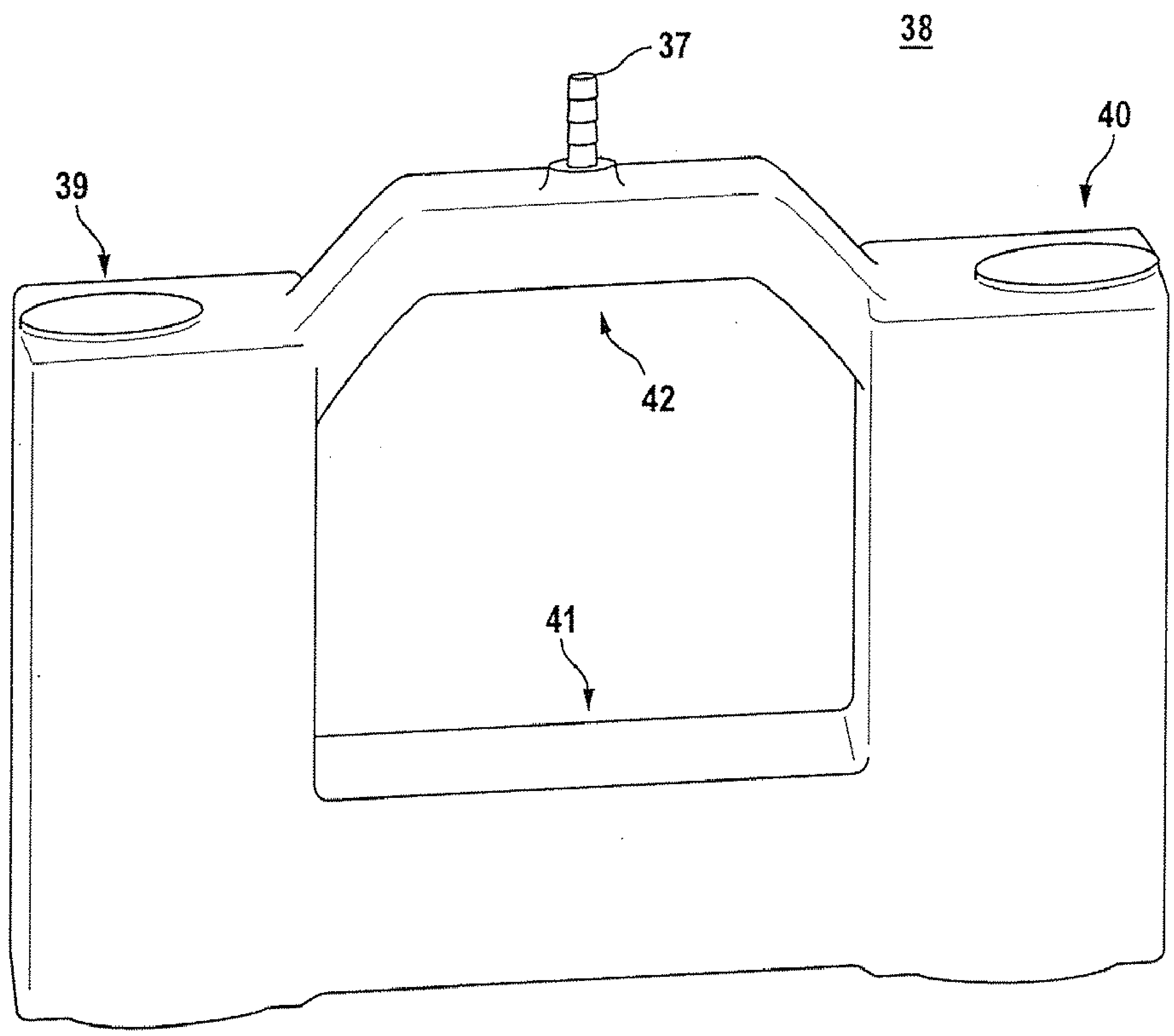


FIG. 5

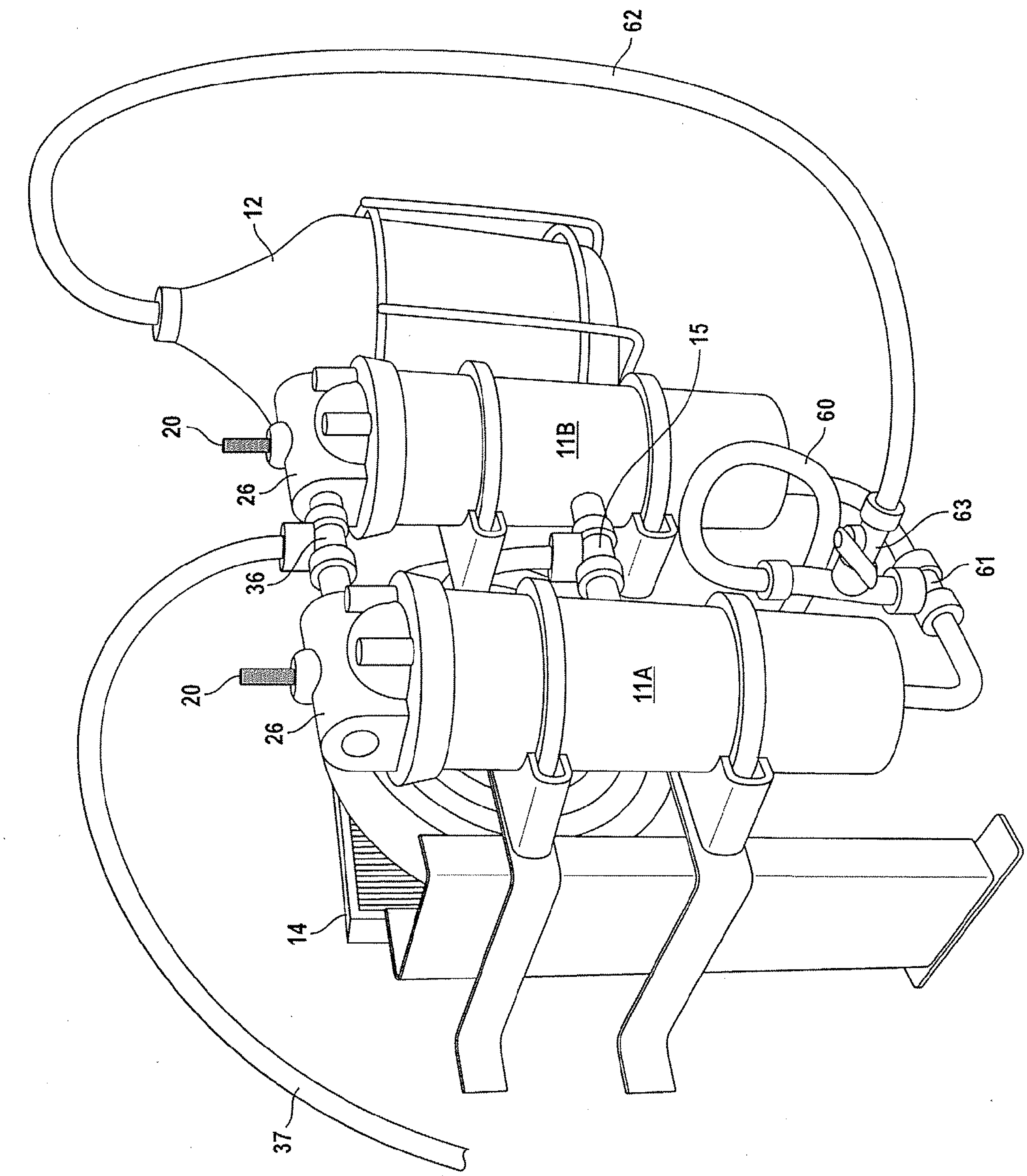


FIG. 4

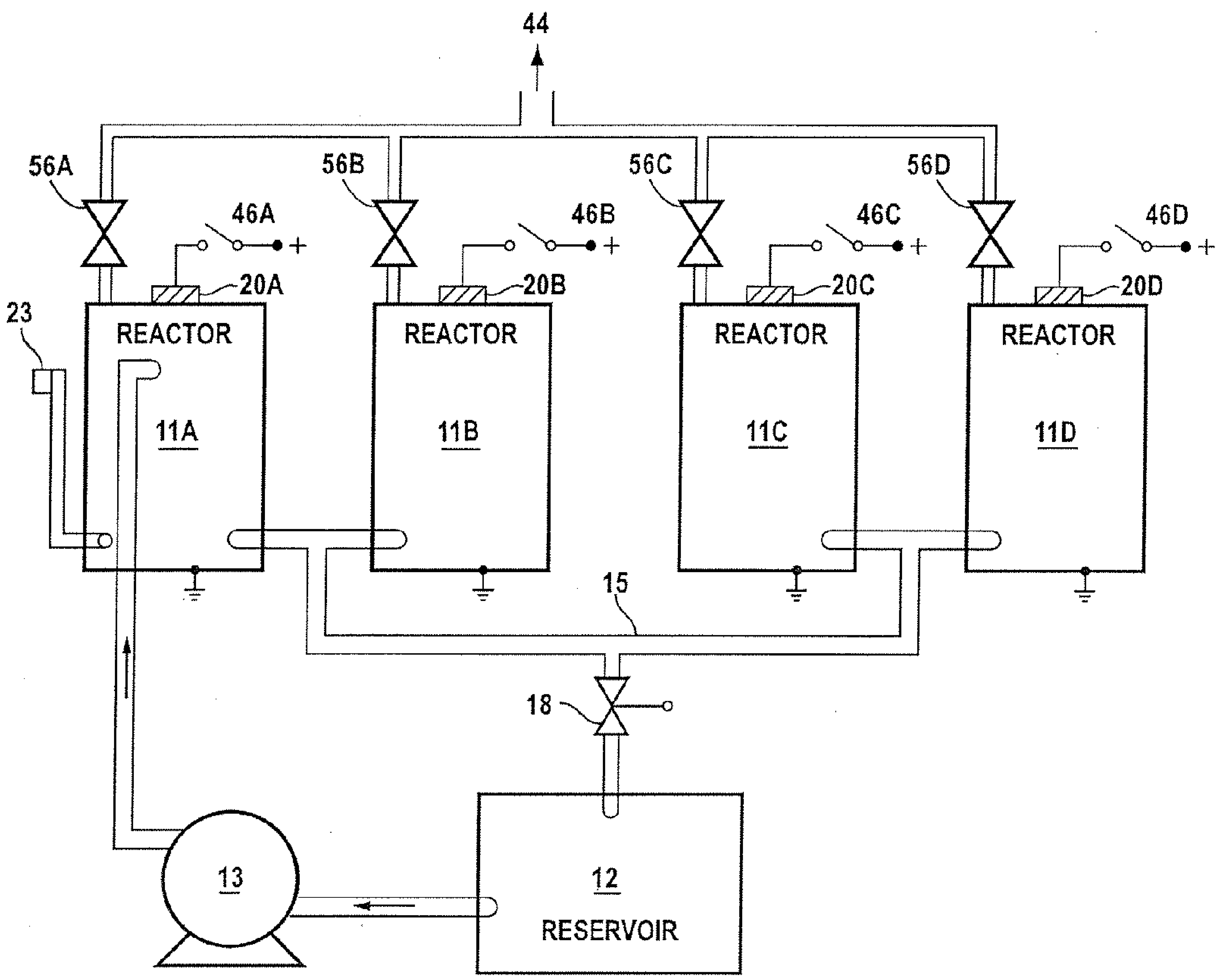

44
56A
56B
56C
56D
46A
46B
46C
46D
20A
20B
20C
20D
23
REACTOR
11A
REACTOR
11B
REACTOR
11C
REACTOR
11D
15
18
13
12
RESERVOIR

FIG. 6

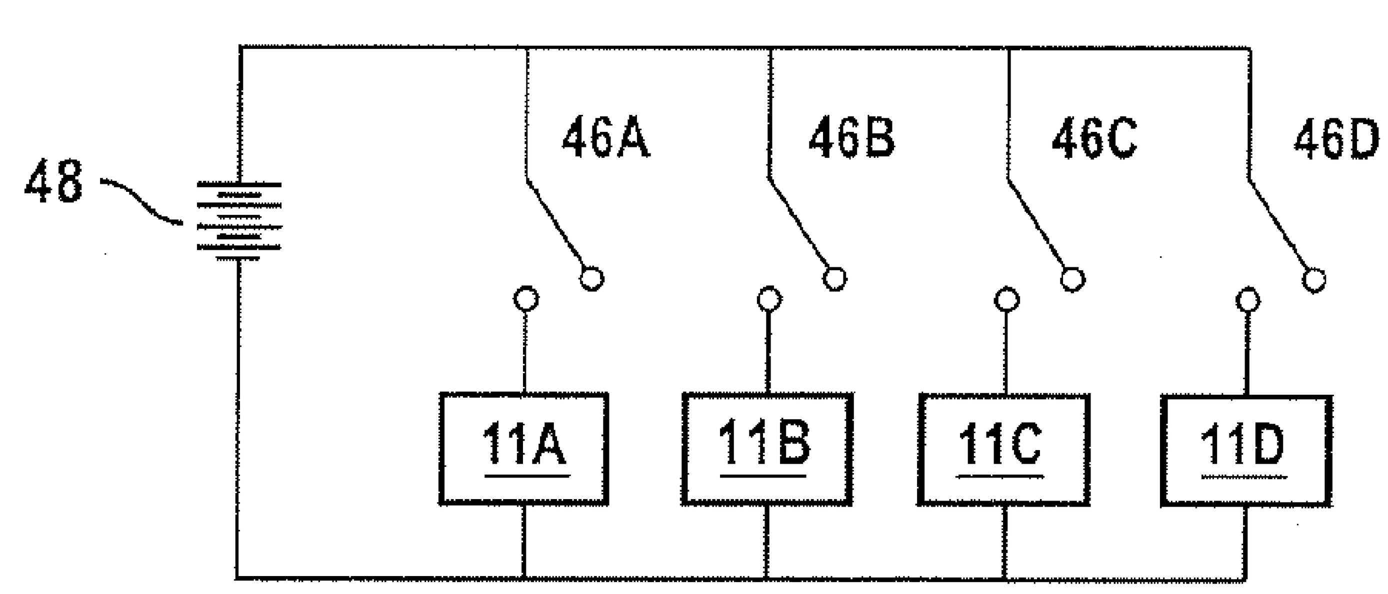

48
46A
46B
46C
46D
11A
11B
11C
11D

FIG. 7

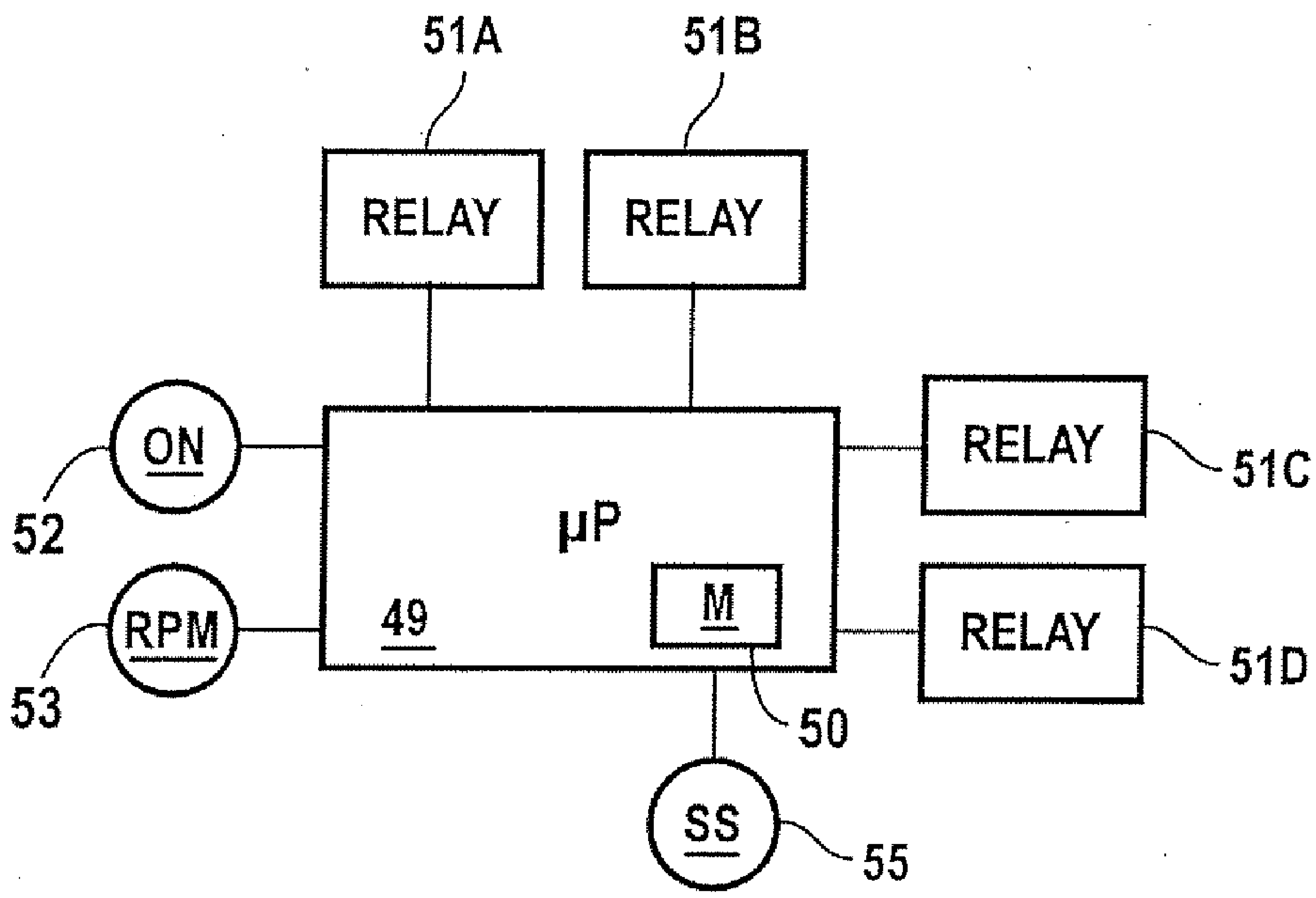

51A
51B
RELAY
RELAY
ON
52
μP
RELAY
51C
RPM
53
49
M
50
RELAY
51D
SS
55

FIG. 8

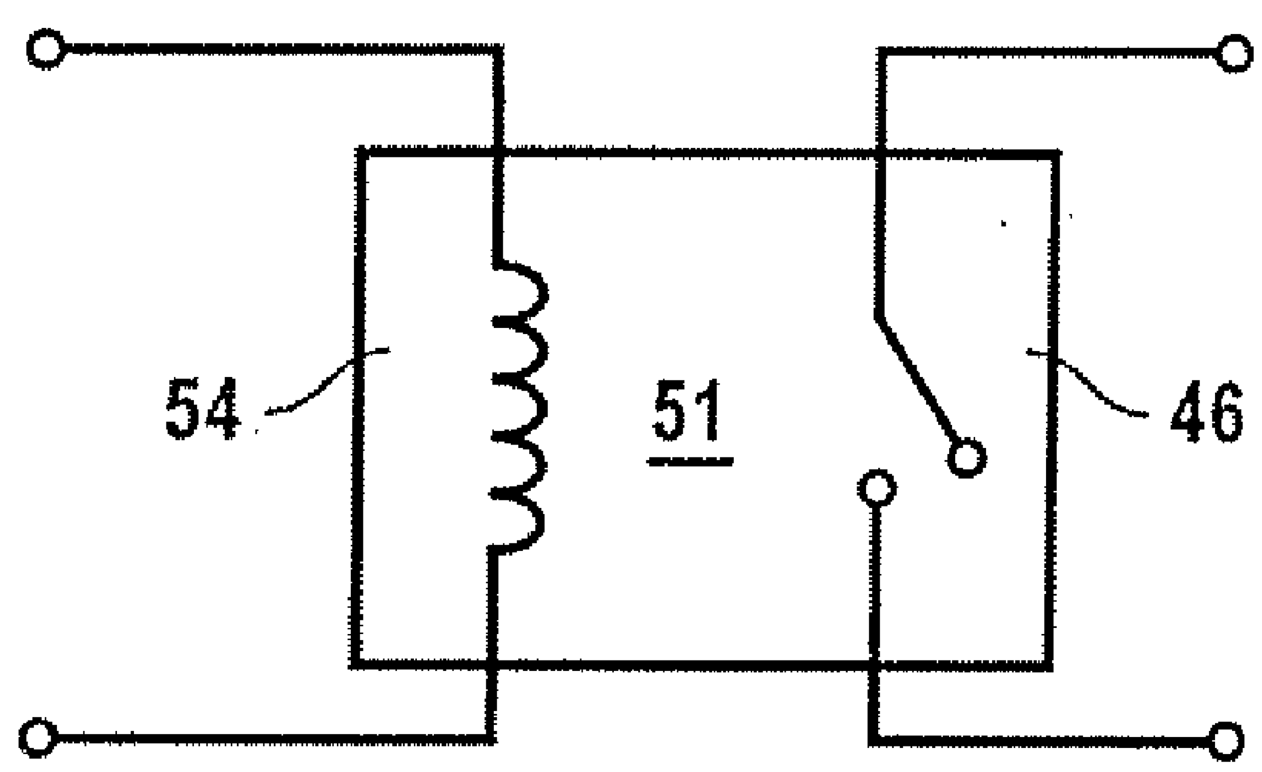

54
51
46

FIG. 9

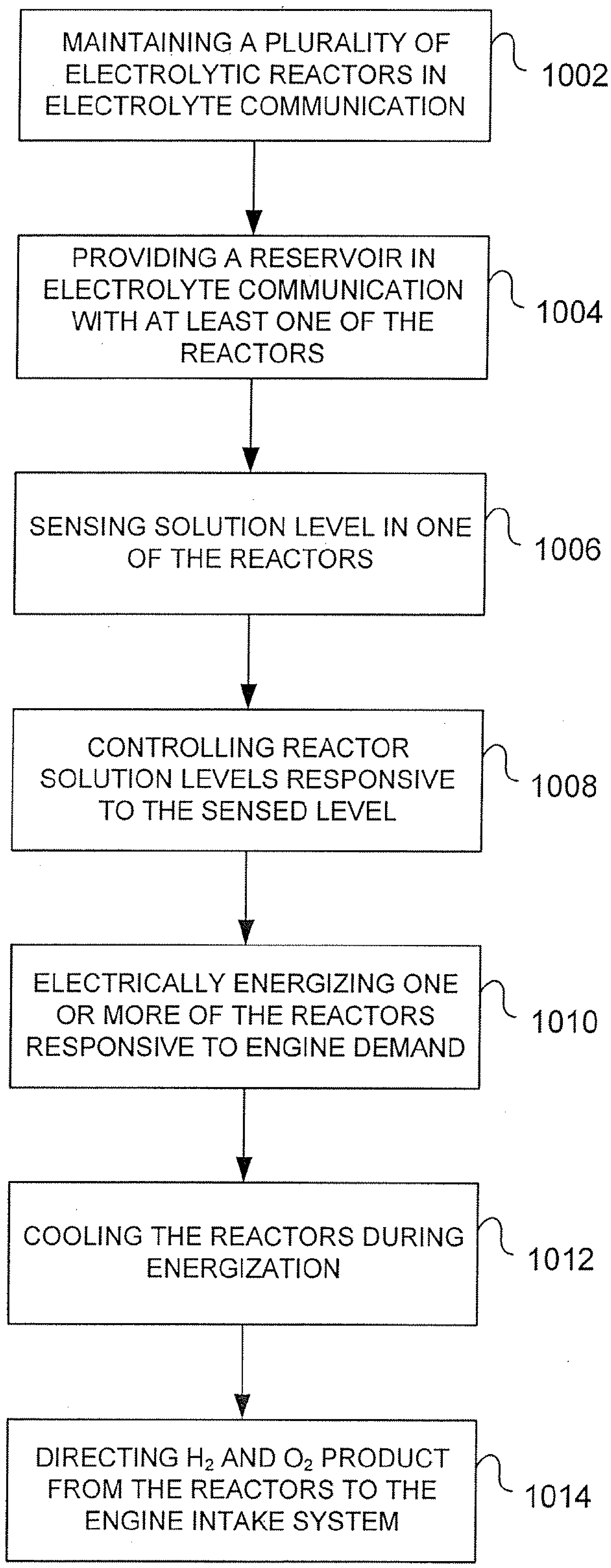

MAINTAINING A PLURALITY OF ELECTROLYTIC REACTORS IN ELECTROLYTE COMMUNICATION
1002
PROVIDING A RESERVOIR IN ELECTROLYTE COMMUNICATION WITH AT LEAST ONE OF THE REACTORS
1004
SENSING SOLUTION LEVEL IN ONE OF THE REACTORS
1006
CONTROLLING REACTOR SOLUTION LEVELS RESPONSIVE TO THE SENSED LEVEL
1008
ELECTRICALLY ENERGIZING ONE OR MORE OF THE REACTORS RESPONSIVE TO ENGINE DEMAND
1010
COOLING THE REACTORS DURING ENERGIZATION
1012
DIRECTING H_2 AND O_2 PRODUCT FROM THE REACTORS TO THE ENGINE INTAKE SYSTEM
1014

Fig. 10

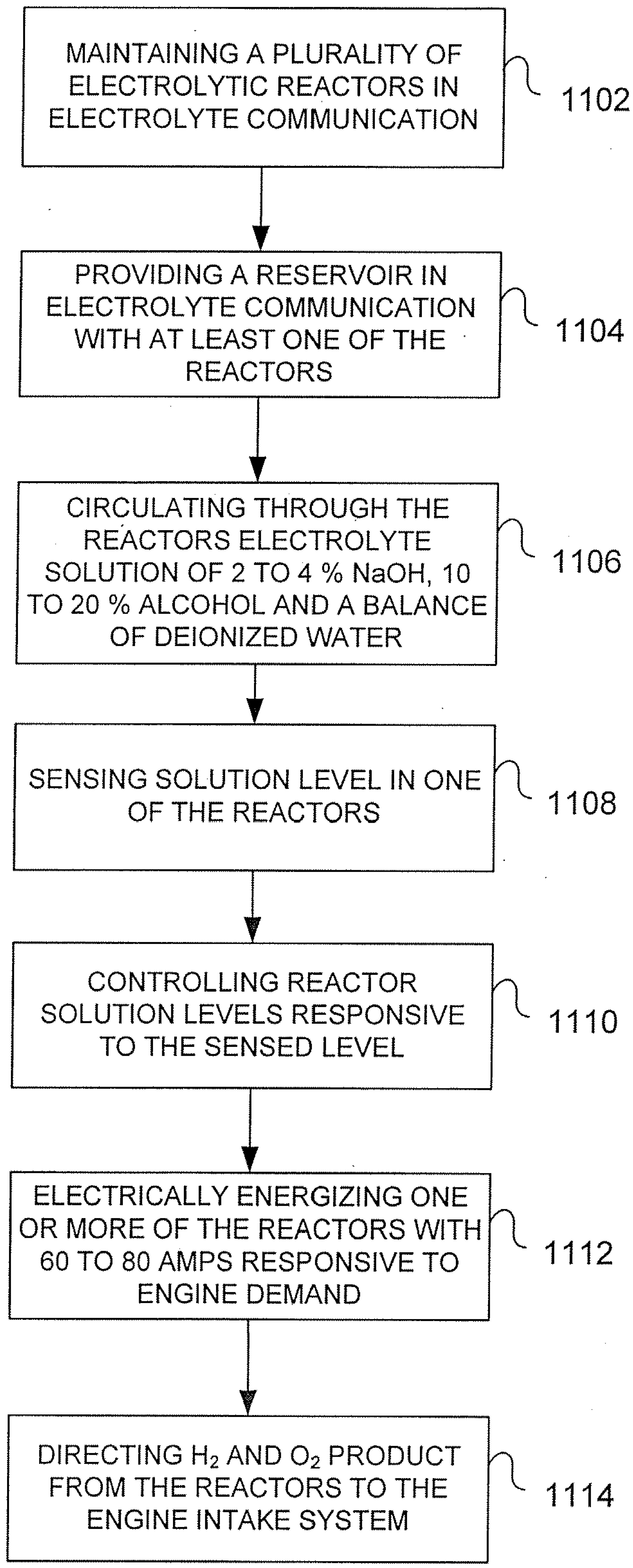

MAINTAINING A PLURALITY OF ELECTROLYTIC REACTORS IN ELECTROLYTE COMMUNICATION
1102
PROVIDING A RESERVOIR IN ELECTROLYTE COMMUNICATION WITH AT LEAST ONE OF THE REACTORS
1104
CIRCULATING THROUGH THE REACTORS ELECTROLYTE SOLUTION OF 2 TO 4 % NaOH, 10 TO 20 % ALCOHOL AND A BALANCE OF DEIONIZED WATER
1106
SENSING SOLUTION LEVEL IN ONE OF THE REACTORS
1108
CONTROLLING REACTOR SOLUTION LEVELS RESPONSIVE TO THE SENSED LEVEL
1110
ELECTRICALLY ENERGIZING ONE OR MORE OF THE REACTORS WITH 60 TO 80 AMPS RESPONSIVE TO ENGINE DEMAND
1112
DIRECTING H_2 AND O_2 PRODUCT FROM THE REACTORS TO THE ENGINE INTAKE SYSTEM
1114

Fig. 11

HYDROGEN GENERATOR

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to hydrogen generators for improving the efficiency of hydrocarbon fuel combustion. More specifically, the invention relates to hydrogen generators used with internal combustion engines to reduce harmful emissions from the internal combustion engines.

[0003] 2. Description of Related Art

[0004] An internal combustion engine produces power by burning a fuel within the combustion chambers of the engine. The fuel is mixed with air (which contains about twenty percent oxygen) and fed into the combustion chambers. The burning produces explosion and gases that move one or more pistons or rotors. The moving pistons or rotors are connected to an output shaft. Internal combustion engines are used to power automobiles, trucks, boats, tools, generators, and many other devices. The three main types of internal combustion engines are the conventional piston engine, the rotary engine, and the diesel engine.

[0005] Most internal combustion engines burn a fuel that is refined from petroleum. These fuels include gasoline, diesel fuel, and aviation fuel. Petroleum is a non-renewable resource. Most countries have to import petroleum and/or its refined products to meet their needs. The costs and the political consequences are enormous. Many steps have been taken to improve the efficiency of internal combustion engines and to supplement hydrocarbon fuels with renewable fuels such as ethanol and vegetable oils. However, the cost of hydrocarbon fuels continues to rise and the dependence on imported petroleum continues to increase for most industrialized countries.

[0006] Petroleum-based fuels contain a variety of hydrocarbons that, when burned in an engine, produce water and carbon dioxide and lesser amounts of carbon monoxide and unburned hydrocarbons. The hydrocarbon fuels generally contain small quantities of nitrogen and sulfur compounds which result in the formation of nitrogen oxides and sulfur oxides. Carbon monoxide, unburned hydrocarbons, nitrogen oxides, and sulfur oxides are all harmful to the environment. A variety of steps have been taken to reduce the air pollution caused by emissions from internal combustion engines. Clean-air legislation is one such step. However, when engine emissions fail to meet an environmental standard, the consequences can be economically troublesome to a business, especially those that rely on large-scale engine operations. Management may have no alternative but to shut down essential plant equipment until it can be repaired or replaced.

[0007] Accordingly, there has been a great incentive to reduce harmful emissions from internal combustion engines and to supplement the hydrocarbon fuels that are burned in them. It is widely believed that the fuel of the future is hydrogen. Hydrogen burns cleanly and produces water as a by-product. Hydrogen can be produced by electrolysis of water. Water is, of course, an abundant resource. However, modifications to the internal combustion engine must be made to burn solely hydrogen and an entire manufacturing and distributing network for hydrogen must be created. Many experts believe it will be many decades before hydrogen replaces petroleum-derived hydrocarbon fuels.

[0008] In the meantime, it is known that hydrogen produced by the electrolysis of water can be used to supplement hydrocarbon fuels in existing internal combustion engines. From the standpoint of thermodynamics, the energy required to generate hydrogen and oxygen from water by electrolysis is greater than the energy produced when the hydrogen and oxygen burn to regenerate water. However, it has been discovered that adding supplemental hydrogen and oxygen to an internal combustion engine enables the engine to burn the hydrocarbon fuel more efficiently, resulting in a net increase in efficiency and a reduction in emissions.

[0009] For example, U.S. Pat. No. 4,271,793 issued to Valdespino on Jun. 9, 1981 (incorporated herein by reference) discloses a hydrogen generator for an internal combustion engine. The generator comprises an electrolytic reactor that creates hydrogen and oxygen from water. The hydrogen and oxygen are fed to the intake of the engine. Another example, is U.S. Pat. No. 5,231,954 issued to Stowe on Aug. 3, 1993 (incorporated herein by reference), which also discloses a hydrogen generator for an internal combustion engine. The electrolytic reactor contains a pop-off lid to reduce the danger of explosions and the hydrogen and oxygen are fed into the positive crankcase ventilation system rather than directly into the intake manifold. A third example is U.S. Pat. No. 6,817,320 issued to Balan et al. on Nov. 16, 2004 (incorporated herein by reference). Balan et al. discloses a plurality of electrolysis cells for providing hydrogen to an internal combustion engine, and a control system for cell operation and safety assurance.

[0010] The electrolytic hydrogen generators of Valdespino, Stowe, and Balan et al., as well as many other such generators that have been discussed or built, suffer from a variety of problems that have prevented them from achieving widespread use. One problem is the risk of explosion inherent in any system that accumulates a volume of pressurized hydrogen gas. Another problem is controlling the generator of hydrogen gas in response to engine demand. Another problem is maintaining electrolyte level and temperature within desired limits during long term engine operation. Another problem is developing a cost-effective system with uncomplicated controls. Accordingly, a demand still exists for a safe and practical electrolytic hydrogen generator for an internal combustion engine.

SUMMARY OF THE INVENTION

[0011] The present invention provides a safe and practical hydrogen generator for supplementing hydrocarbon fuel burned in a combustion chamber. The invention improves combustion efficiency and reduces harmful emissions by generating hydrogen according to combustion demand.

[0012] In one embodiment, a hydrogen generator according to the present invention comprises a reactor having a sealed cathode chamber partially filled with an electrolyte solution, and an anode partially immersed in the solution and electrically isolated from the cathode chamber. The system includes a reservoir and level sensor form maintaining a desired level of reactor solution. An electric power source is configured to energize the reactor across its anode and cathode terminals to liberate hydrogen and oxygen gas from the solution by electrolysis. The power source may comprise an independent power supply or an engine electrical system. A cooling system, such as a heat sink, transfers heat from the reactor to counteract electrolyte heating and allows the reactor to operate at higher amperage. In the reactor, the gases rise to an air space above solution level and from there are drawn or pumped through conduit to combine in the combustion chamber with hydrocarbon fuel and air. The generator may include a plurality of electrolytic reactors maintained in electrolyte communication.

[0013] In one aspect of the invention, the components of the hydrogen generator are mounted on a portable skid to facilitate connection as an auxiliary system to stationary engines such as those used to power gantry cranes, mining drills, diesel generators, and other large horsepower industrial machines and equipment. In another aspect of the invention, the components of the hydrogen generator are permanently installed as an auxiliary system for an internal combustion engine mounted on a stationary apparatus or on a vehicle.

[0014] In another aspect of the invention, the electric power source is configured to energize a single reactor or any combination of reactors to effect production of hydrogen and oxygen responsive to engine demand. An engine demand signal derived from an RPM sensor or throttle position sensor causes the source to energize one or more reactors commensurate with the demand. In this aspect the source may be configured with a programmable logic controller and power relays to switch reactors between energized and non-energized states. In another aspect, the logic controller is programmed to shift reactor duty cycles with each engine start, such that reactor service times are substantially equalized over time. Shifting duty cycles in this manner advantageously maximizes system service time before maintenance. The logic controller may also be programmed to energize initially a plurality of reactors for boosting hydrogen and oxygen supplementation during cold-start conditions, and to de-energize one or more reactors when the engine achieves steady state operation.

[0015] In another embodiment, the invention provides a level control subsystem comprising a sensor for sensing electrolyte solution level in one of the reactors. Responsive to sensing a low level of solution in one reactor, the subsystem actuates a pump to draw solution from the reservoir for refilling the reactor. Responsive to sensing a high level of solution, the subsystem actuates a drain valve located between one of the reactors and the reservoir. Thus configured, the reservoir may receive excess solution from reactors in case of overflow, and also provide a source of make-up solution to rectify low electrolyte levels. Maintaining the reactors in electrolyte communication according to the invention advantageously allows the entire system to operate with level sensing and reservoir connections limited to a single reactor.

[0016] In another embodiment of the invention, the electrolyte solution comprises about two to four percent dissolved electrolyte, about ten to twenty percent alcohol, and a balance of deionized water. In one aspect, the electrolyte comprises sodium hydroxide and the alcohol comprises methanol. The methanol advantageously lowers the freezing point of the solution, and reacts in water with free sodium ions to produce hydrogen.

[0017] The present invention provides an environmental advantage by reducing harmful emissions from the exhaust of internal combustion engines. Experimental tests on engines equipped with a prototype of the invention show a significant reduction in pollutants such as carbon monoxide, unburned hydrocarbon, and nitrous oxide. The invention also provides a means for cleaning engine internals, by removing or reducing carbon build-up.

[0018] Another notable advantage of the invention is that it minimizes the risk of explosion. It does this by limiting hydrogen and oxygen production according to engine demand, and also by preventing these gases from accumulating under pressure. Another advantage is the extended service life realized by shifting reactor duty cycles. Another advantage is the simplicity of the design. Thus, hydrogen generation according to this invention is practical, safe, and requires little maintenance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Other systems, methods, features and advantages of the invention will be or will become apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description, be within the scope of the invention, and be protected by the accompanying claims. The invention will better understood upon consideration of the specification and the accompanying drawings, in which like reference numerals designate like parts throughout the figures, and wherein:

[0020] FIG. **1** is a schematic illustration of a preferred embodiment of the invention showing a single reactor and associated components.

[0021] FIG. **2** is a schematic illustration of another embodiment of the invention.

[0022] FIG. **3** is a schematic illustration of a preferred embodiment of a reactor level control system according to the invention.

[0023] FIG. **4** is a perspective illustration of the invention, showing two reactors in electrolyte communication.

[0024] FIG. **5** is a perspective illustration of a preferred embodiment comprising two reactors encased within an insulated enclosure.

[0025] FIG. **6** is a schematic illustration of a controller according to the invention for energizing one or more reactors according to engine demand.

[0026] FIG. **7** is an electrical schematic of a starting circuit for a hydrogen generator in a preferred embodiment of the invention.

[0027] FIG. **8** is a block diagram of a control circuit for a hydrogen generator in a preferred embodiment of the invention.

[0028] FIG. **9** is an electrical schematic of a typical relay connected across reactor starting and control circuits in a preferred embodiment of the invention.

[0029] FIG. **10** is a flow chart illustrating a method according to the invention for reducing harmful emissions in an internal combustion engine.

[0030] FIG. **11** is a flow chart illustrating an alternate method according to the invention for reducing harmful emissions in an internal combustion engine.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] FIG. **1** illustrates a system **100** according to the present invention. In this embodiment, the system comprises an electrolytic reactor **11**, a refillable reservoir **12**, a pump **13**, a heat exchanger **14**, and conduit **15** connecting the foregoing components as shown. System **100** produces hydrogen and oxygen by electrolysis of water within reactor **11**. The hydrogen and oxygen are produced to supplement hydrocarbon fuel burned in a combustion chamber, such as a wood or oil burning stove, a coal furnace, or cylinders of an internal combustion engine. Electrical power for energizing reactor **11** may originate from an independent source, or it may be derived from the electrical system of an engine. To simplify the disclosure, no combustion chambers or engines are shown in any of the figures.

[0032] Refillable reservoir **12** is configured to hold up to about two gallons of ionized water, although this volume may vary according to the particular application. Reservoir **12** may be constructed of a lightweight material such as plastic, but any other non-reactive material such as stainless steel is also suitable. Reservoir **12** holds an electrolyte solution **16** that contains a sufficient concentration of ions to conduct electricity and to carry out electrolysis in electrolytic reactor **11**. The electrolyte in solution **16** may comprise any acid, base or salt that disassociates in water into cations and anions, provided that the disassociated cation has less standard electrode potential than a hydrogen ion to ensure production of hydrogen gas during electrolysis.

[0033] In one embodiment, electrolyte solution **16** comprises salt water. The salt water may be formulated, or it may be taken directly from a large body of naturally occurring salt water. In the latter case, an ocean or saltwater lake may function as reservoir **16**. This configuration may be applied in gasoline or diesel engines located on offshore platforms or on boats or other seagoing vessels.

[0034] In another embodiment, solution **16** comprises an electrolyte such as lye dissolved in pure (deionized) water. Sodium hydroxide or potassium hydroxide may be used as the electrolyte.

[0035] Reservoir **12** is further configured with a port **17** for adding additional solution, and an outlet **18** that communicates, directly or indirectly, with electrolytic reactor **11**. In one embodiment, outlet **18** connects via conduit **15** directly to reactor **11**. In another embodiment, outlet **18** connects via conduit **15** indirectly to reactor **11** through pump **13** and heat exchanger **14**. Either way, reservoir **12** is maintained in electrolyte communication with reactor **11**.

[0036] Electrolytic reactor **11** comprises a cathode **19** and an anode **20**. Cathode **19** is a sealed chamber adapted to hold a smaller quantity of solution **16** relative to the volume of reservoir **12**. In one embodiment, the volume of the chamber of cathode **19** is about one quarter gallon. During system operation, the amount of solution **16** contained in reactor **11** fills about 50 to 75 percent of the chamber such that an air space **24** exists above the level of solution for receiving gaseous reaction products. The chamber is made of an electrically conductive material, preferably stainless steel, chosen for its corrosion-resistant properties. A sufficiently heavy gauge of stainless steel is used so that the chamber can withstand any explosion that might occur. Anode **20** comprises an electrically conductive rod or tube disposed within the chamber and electrically isolated from the chamber by means of a dielectric plug **25**. In one embodiment, plug **25** comprises a synthetic rubber plug with a porcelain insert. Plug **25** insulates anode **20** from cathode **19** and also provides an environmental seal to prevent leakage. Anode **20** may be made from a graphite, aluminum, or copper rod enclosed in a stainless steel tube, or it may be a solid steel electrode. In a preferred embodiment, cathode **19** and anode **20** are made from 316L stainless steel. Alternatively, both cathode **19** and anode **20** may be made of nickel-plated steel.

[0037] Reactor **11** contains an inlet **21** and outlet **22** that communicate with reservoir **12**. Inlet **21** and outlet **22** allow solution **16** to be circulated through reactor **11** in a cooling loop to counteract the effects of electrical heating. Heated fluid is drawn from reactor **11** through outlet **22** to the inlet of pump **13**. The fluid is then pumped through heat exchanger **14** where it is cooled before returning to reactor **11** via inlet **21**. Various sections of conduit **15** provide flow paths to complete the cooling loop. Conduit **15** may consist of any material suitable for the purpose, such as ⅜ inch braided hose or stainless steel tubing.

[0038] Heat exchanger **14** is preferably a finned water-to-air heat exchanger similar to a conventional radiator. Heat exchanger **14** may include a fan to increase the air flow across the fins. Heat generated within reactor **11** by electrolysis can cause solution **16** to expand and boil. As the solution heats excessively, it begins to lose its ability to conduct electric current, thereby limiting the production of hydrogen and oxygen by electrolysis. Thus, heat exchanger **14** enables higher electrical currents to be used which, in turn, create greater quantities of hydrogen and oxygen. In one embodiment, system **100** is configured to operate for extended periods at 60 to 80 amperes.

[0039] In another embodiment, heat exchanger **14** is eliminated from the flow path, and reactor cooling is accomplished by using a heat sink. The heat sink is positioned in direct thermal contact with the reactor, and is configured to maximize heat transfer from cathode chamber **19**. The heat sink may be made from any metal suitable for the purpose, such as copper or aluminum, and may be configured with fins or other protrusions to increase surface area exposure to ambient air.

[0040] Reactor **11** preferably contains a level control mechanism for maintaining the level of solution **16** in reactor **12** at a desired level. In one embodiment, the level control mechanism includes a water level detector **23** (such as a float switch) located within the reactor, and a solenoid valve (not shown) located at reservoir outlet **18**. Level detector **23** is configured to close an electrical contact upon detecting a low level of solution **16**. Closure of the electrical contact energizes the solenoid valve, allowing pump **13** to draw additional solution **16** into the circuit, thereby increasing the solution in reactor **11**. When solution **16** achieves a desired level, detector **23** opens the electrical contact, de-energizing the solenoid valve to isolate reservoir **12** and maintain the desired level. Many other level control methods may be used without departing from the spirit of the present invention.

[0041] The level control system will allow the level of solution **16** to fluctuate between high and low setpoints. In one embodiment, the low setpoint corresponds to about 50% of chamber capacity, and the high setpoint corresponds to about 75% of chamber capacity. Thus, the volume of air space **24** within chamber **19** fluctuates with changes in the solution level while maintaining adequate space for the accumulation of hydrogen gas, oxygen gas, and water vapors. A gas outlet **26** of cathode chamber **19** connects to an appropriate location of the engine intake system **44** to direct the gas products to the cylinders of the engine. For example, the hydrogen and oxygen gases can be directed to the intake manifold, to the turbo charger (if the engine contains one), or to a line that communicates with the intake manifold.

[0042] Electrical power may be provided to the reactor from the electrical system of the engine (not shown). However, external power may also be used. In one embodiment, the terminals of the engine battery are connected across cathode **19** and anode **20**. A starting circuit may be added with appropriate interlocks to ensure that reactor **11** operates only when the engine is running. For example, interlocks (not shown) may be linked to the ignition switch and to an engine output to prevent energization of reactor **11** unless the ignition switch is on and the engine is running. A suitable engine output indicative of a running engine is oil pressure, which may be detected by means of an oil sending unit.

[0043] Before operation of the system can begin, reservoir **12** is completely filled with electrolyte solution **16** and reactor **11** is filled to a desired level between high and low setpoints. Then, the engine is turned on and the ignition switch is placed in the on position. The oil pressure sending unit closes a relay contact to connect the positive terminal of the engine battery to anode **20**. Another relay set starts pump **13** and a fan (if any) in heat exchanger **14** to cool and circulate solution **16** through reactor **11**. The electric potential between the cathode and the anode causes electrons to flow through the electrolyte solution. As the electrons flow, electrolysis occurs and water molecules disassociate according to the well-known equation:

$$2H_2O_{(aq)} \rightarrow 2H_{2(g)} + O_{2(g)}$$

with hydrogen gas collecting at the walls of the cathode and oxygen gas collecting along the surface of the anode. The hydrogen and oxygen gases form bubbles that rise through the surface of solution **16** to accumulate in air space **24**. These gases are drawn through outlet **26** by vacuum pressure to the intake system of the engine. There, the hydrogen and oxygen are combined with a mixture of hydrocarbon fuel and air, and burn during the combustion cycle in the engine cylinders. The hydrogen and the oxygen improve the speed of combustion and/or combustion efficiency in the engine. As a result, the emissions of carbon monoxide, unburned hydrocarbons, nitrogen oxides, and sulfur oxides are reduced. Another result is the mileage of the vehicle (the energy produced per unit of hydrocarbon fuel) increases. This is achieved while minimizing the risk of accidental explosion because the gaseous reaction products are not allowed to accumulate under pressure.

[0044] In certain applications, an engine may present a positive pressure to reactor outlet **26**. This may occur, for example, in engines equipped with turbo chargers. In that case, a positive displacement pump (not shown) such as a diaphragm pump may be installed between outlet **26** and the engine intake manifold to force reaction products into the engine cylinders.

[0045] In a single reactor, the rate of hydrogen and oxygen production may be increased by increasing the electrolyzing current. In practice, this current will be limited by a variety of factors, including the concentration of ions in solution, the output rating of the power supply, electrical cable gauge, and the ability of the cooling system or heat sink to prevent the solution from boiling within the reactor.

[0046] In one embodiment of the invention, an alcohol such as methanol or ethanol is added to the electrolyte solution to enhance hydrogen production. For example, methanol or ethanol can be added to a solution of lye or sodium hydroxide dissolved in deionized water. During electrolysis, methanol reacts with water to liberate hydrogen according to the following equation:

$$CH_3OH + H_2O \rightarrow CO_2 + 3H_{2(g)}$$

In a preferred embodiment, a system according to the invention is operated using a solution **16** comprising about 2 to 4 percent sodium hydroxide, about 10 to 20 percent alcohol, and a balance of deionized water.

[0047] FIG. **2** illustrates an alternate embodiment of a system **200** according to the invention. The principles of reactor operation are the same as described in the previous embodiment. However, system **200** demonstrates that alternative configurations of mechanical components are possible without departing from the scope of the invention. System **200** includes a reactor **11** comprising cathode chamber **19** and an anode **20** maintained in electrolyte communication with circulating pump **13** and heat exchanger **14** through conduits **15**. In this embodiment, reservoir **12** is located at a higher elevation than reactor **11**. A gas line **30** connects air space **24** of reactor **11** to an air space **31** maintained within reservoir **12** above the level of solution **16**. A refill pump **27** is provided to supply make-up solution to reactor **11** from reservoir **12** through refill line **32**, which is configured to draw solution from the bottom portion of reservoir **12**. Reservoir **12** also includes an outlet **26** which passes gaseous reaction product to the engine intake system. System **200** is further configured with a level controller comprising a level switch **23** and vertical tube **28**.

[0048] System **200** also depicts a finned anode **20**. In a finned anode, a portion of the anode rod includes fins that extend radially outward from the axis of the rod to increase the surface area of the anode that is exposed to solution **16**. One advantage of this variation is that it provides a means for adjusting the resistivity of the reactor. Fins may be added or subtracted, or the diameter of the fins may be selected to achieve higher or lower currents or current densities.

[0049] FIG. **3** shows the level controller in greater detail. In this embodiment the controller is located external to reactor **11** in a lower temperature area that facilitates electrical connections and calibration. Tube **28** is connected to cathode chamber **19** such that hydrostatic pressure causes an amount of solution **16** to rise within tube **28** to a level analogous to the level of solution **16** within cathode chamber **19**. A plastic float **33** connected to a threaded shaft **34** is suspended from the top of tube **28**, as shown. A contact nut **35** is fixed or welded to shaft **34**. Level switch **23** is positioned such that vertical movement of nut **35** in response to action of float **33** will open a contact on switch **23** when the level of solution **16** within tube **28** reaches a high setpoint. Opening the contact de-energizes refill pump **27** to shut off the flow of make-up solution to reactor **11**. Those skilled in the relevant art will recognize that other configurations of a level control circuit are possible. For example, switch **23** may be configured as a magnetic reed switch with multiple contacts corresponding to high and low setpoints for turning pump **27** off or on, thereby maintaining reactor solution level within desired limits.

[0050] Referring again to FIG. **2**, system **200** provides a further advantage by locating reservoir **12** in an elevated location relative to reactor **11**. The top portion of reservoir **12** may be configured in the shape of a cone, as shown, to form a first water trap. This configuration causes some amount of water vapor rising from reactor **11** to condense and collect on the inner walls of the cone, and eventually return by gravity to the body of solution **16** maintained within the reservoir. An optional second water trap **29** may be provided to capture any water vapor that passes through outlet **26** toward the engine intake.

[0051] In an embodiment of the invention that uses seawater as the electrolyte solution, the body of seawater serves as a reservoir for the hydrogen generator. Seawater may be received into the reactor vessel through an inlet **21** having an open end immersed in the sea, and discharged from the reactor back into the sea through an outlet **22**. The reactor includes a cathodic vessel configured to maintain a minimum level of seawater to allow an anode to remain at least partially submerged in the seawater during electrolysis. As in previous embodiments, when a power source energizes the reactor, gaseous products accumulate in an air space above the water level, to be drawn from the reactor through conduit to an intake manifold.

[0052] In this embodiment, a pump **13** can be used to circulate the seawater through the reactor. Or, in a hydrogen generator installed on a boat, seawater can be directed through the inlet by force of the boat in motion on the water without the need of a pump. Furthermore, because the saltwater circulation loop is open to the sea, cooling system components such as the fan and heat exchanger may be also eliminated from the system. In one aspect, the generator provides fuel supplements to an engine that provides the motive force for circulating seawater through the reactor.

[0053] In another embodiment using seawater as electrolyte, the system may include a means for adding alcohol into the cathode chamber to mix with seawater. The alcohol may be stored in a tank or reservoir, and transferred at a controlled rate into the chamber through conduit connections. A flow control valve, such as a globe valve, may be placed in the flow path to regulate the transfer rate of alcohol. The flow control valve may be configured to regulate flow in response to engine demand. For example, the position of the globe valve may be function of engine rpm or throttle position.

[0054] FIG. **4** shows a working prototype of the present invention, which comprises a preferred configuration of multiple reactors maintained in electrolyte communication. In this embodiment, cathode chambers of two reactors **11**A and **11**B are linked by an inverted T-shaped conduit **15**. Horizontal legs of conduit **15** connect to either chamber at a position below a desired level of electrolyte solution. Electrolyte solution circulates out of the chambers through the vertical leg of conduit **15**, through a heat exchanger **14**, and back to the chambers through conduit **60**. A second T-shaped conduit **61** directs solution from conduit **60** into the chambers through the base of each reactor, as shown. A reservoir **12** is configured to supply make-up solution to the reactors through conduit **62**. Conduit **62** connects through isolation valve **63** to conduit **60**. Outlet ports **26** extend from the top of each reactor **11**A and **11**B and are linked by T-shaped connector **36**. From there, hydrogen and oxygen products are directed to the engine intake system through conduit **37**. Each cathode chamber is electrically grounded, and positive DC voltage is applied to each anode terminal **20**. A pump (not shown) circulates the solution. In operation, the dual-reactor prototype typically draws between 60 and 80 amps.

[0055] Experimental tests were run using the prototype generator of FIG. **4**. In the tests, the electrolyte solution consisted of about 3% sodium hydroxide and about 10% methanol in deionized water. Emission levels were measured on three separate diesel engines. These particular engines were in service as prime movers on gantry cranes.

[0056] First, emission levels were measured on a two-cycle engine running without the prototype installed. The two-cycle engine had been in service for some time. Second, emissions levels were measured on a new four-cycle engine without the prototype installed, using the same test equipment and fuel as in the first test. The new four-cycle engine was equipped with factory installed twin catalytic converters. Third, emission levels were measured on another two-cycle engine of similar design as the engine used in the first test. The third engine had also seen significant service, and was tested under the same conditions as in the first two tests, but with the prototype installed. With the engine running, electrical current in the generator set was maintained between 60 and 80 amps. The following table shows the test results:

	2-cycle engine w/o H_2 generator	4-cycle engine w/o H_2 generator	2-cycle engine w/H_2 generator
CO:	0.022	0.014	0.003
HC:	7	5	2
CO_2:	2.90	2.39	1.43
O_2:	16.86	17.48	18.73
NO*x*:	490	84	55

[0057] A comparison of the tabulated results reveals that levels of harmful emissions were significantly lowest with the prototype generator installed. In particular, nitrous oxide emissions from the two-cycle engines dropped from 490 ppm to 55 ppm. In many jurisdictions, a reading of 490 ppm NOx would clearly fail an emissions test, while a reading of 84 ppm NOx would clearly pass. Note also that the used engine equipped with the prototype generator outperformed the new four-cycle engine in all categories.

[0058] In another experiment, opacity tests were performed on a four-cycle, six-cylinder diesel engine equipped with twin catalytic converters. This engine was also in service on a gantry crane. The first test was run without the prototype installed. Opacity levels were measures from cold start over the first hour of running time. Opacity is the degree, expressed in a percentage, to which emissions reduce the transmission of light and obscure the view of the background. In the second test, the prototype hydrogen generator was installed on the same engine and opacity was again measured from cold start over the first hour of running time. In the third test with the prototype still installed, the same engine was allowed to continue running for three days, and opacity measurements were taken over the final hour of running time. The results of these three tests are tabulated below:

	4-cyc. 6-cyl., first hour w/o H_2 generator	4-cyc. 6-cyl., first hour w/H_2 generator	4-cyc. 6-cyl., after 3 days w/H_2 generator
% opacity:	4.5	2.4	1.3

These results indicate that the prototype hydrogen generator significantly reduced overall emissions from the diesel engine.

[0059] Many advantages arise from configuring multiple reactors in electrolyte communication. First, the size of each reactor is restricted to limit the volume of volatile gases that can accumulate within reactor air space. This minimizes the risk of explosion, and also minimizes the reactor vessel thickness required to ensure explosion-proof properties of the reactor vessel. Second, by combining multiple relatively small reactors, the size of the system may be scaled to meet the demands of any size engine without the need to customize reactor components. Manufacturing costs are minimized because standardized components reduce overall tooling requirements. A further advantage of multiple smaller-sized reactors is that high current densities can be achieved in each reactor while maintaining electrolyzing currents at manageable levels. Another advantage is the ability to vary system output according to changing engine demand by selectively energizing and de-energizing one or more of the reactors in response to engine demand. By maintaining the reactors in electrolyte communication, only a single reactor is required for monitoring electrolyte levels in order to maintain solution levels in all reactors. In another embodiment where the heat exchanger comprises a passive heat sink (i.e. a radiator without fan or cooling pump), multiple reactors advantageously expose greater total surface area for better heat transfer.

[0060] FIG. **5** illustrates another embodiment of a system according to the invention comprising dual reactors enclosed within an insulated housing **38**. Housing **38** is preferably manufactured from a thermoplastic such as cross-linked polyethylene. Housing **38** encloses a first reactor within a first portion **39**, and a second reactor within a second portion **40**, as shown. A bottom portion **41** encloses conduit for maintaining the reactors in electrolyte communication and for refilling the reactors, and electrical cable and other components required for operating the reactors. The cable and conduit connect to sources outside enclosure **38** through various ports (not shown).

[0061] A connecting portion **42** encloses reactor outlet conduits to a common port **37** configured for connection to an engine intake system. Port **37** may also connect to the outlet port of a similar set of dual reactors in a three-way connection that combines the output of four reactors for delivery to the engine. An unlimited number of reactor sets can be combined in similar fashion. Connecting portion **42** may also be configured as shown to form a convenient handle for carrying the system by hand. This facilitates set-up in remote locations, such as mining operations, where engine access may be difficult, and where multiple reactor sets are required to meet engine demand. Enclosure **38** has a depth of about 6 inches, a width of about 2 to 3 feet, and a height of about 1.5 to 2.5 feet. The thickness of enclosure **38** is about 1/16 to 1/8 inches.

[0062] FIGS. **6** through **9** illustrate a control system according to the invention for energizing one or more reactors according to engine demand. As shown in FIG. **6**, a system of four reactors **11**A, **11**B, **11**C and **11**D are configured to deliver hydrogen and oxygen product to a single engine intake manifold **44**. Reactors **11**A, **11**B, **11**C and **11**D are all maintained in electrolyte communication through conduits **15** that connect below the electrolyte solution level in each reactor. The conduits combine to connect to a reservoir **12** through solenoid valve **18**. Reactor **11**A is configured with a level sensor **23**. In response to sensor **23** sensing a low level condition, a pump **13** pumps electrolyte solution from reservoir **12** into reactors **11**A, **11**B, **11**C and **11**D through a single inlet provided in reactor **11**A. Because the reactors are maintained in electrolyte communication, hydrostatic pressure acts to equalize the solution levels in all four reactors. In response to sensor **23** sensing a high level condition, solenoid valve **18** opens to drain electrolyte from the reactors into reservoir **12**.

[0063] The cathode chamber of each reactor **11**A, **11**B, **11**C and **11**D is electrically grounded, or electrically connected to the negative terminal of an electrical DC power source **48**. Each reactor **11**A, **11**B, **11**C and **11**D is configured with an anode **20**A, **20**B, **20**C and **20**D, respectively, as in previously described embodiments. Each anode is connected to the positive terminal of power source **48** through a relay contact **46**A, **46**B, **46**C, or **46**D, as shown. The electrical circuit for the relay contacts is shown in FIG. **7**.

[0064] In one embodiment shown in FIG. **8**, the control system comprises a programmable logic controller **49** coupled to, or having an integral memory **50**. In this embodiment, the control system components are considered an integral part of the electrical power source that supplies power to the reactors. These components may be physically located within the vehicle that house the engine, or they may be located within a control module external to the vehicle, for example, within a module mounted on a portable skid that includes the reactor and its components.

[0065] Controller **49** may be any microprocessor known in the art and suitable for accepting digital input signals and outputting digital control signals in response to the input signals according to one or more control algorithms maintained in memory **50**. In the present example, controller **49** is coupled to relays **51**A, **51**B, **51**C and **51**D, each operatively connected to actuate (or close) its corresponding contact **46**A, **46**B, **46**C or **46**D in response to receiving an actuation signal from controller **49**.

[0066] A schematic for a relay **51** is shown in FIG. **9**. An actuation signal presented across input terminals **54** closes contact **46**. Contact **46** is electrically isolated from the actuating circuit. In the schematic, terminals **54** may be the terminals of a magnetic coil, or they may be the input gate of a transistor. Thus, relay **51** may comprise a magnetic relay, a solid state relay, or any suitable equivalent.

[0067] One example of a starting sequence for the system will now be described. Initially, the engine is off, contacts **46**A, **46**B, **46**C and **46**D are open, and none of the reactors are energized. When the engine ignition switch is turned on, an ignition sensor **52** sends a signal, such as a logical one, to controller **49** indicating that the ignition switch is on. Controller **49** inputs this signal and awaits a second input signal indicating that the engine is running. The second signal may be derived from a number of engine sensors, such as an oil pressure sensor or an RPM sensor **53**. When the engine achieves a desired RPM, sensor **53** sends an engine-running signal to controller **49**. Upon receipt of the second (engine-running) signal, controller **49** executes a starting algorithm stored in memory **50**, which directs controller **49** to actuate one or more relays **51**A, **51**B, **51**C and **51**D. As each relay closes, its corresponding reactor is energized to produce hydrogen and oxygen gas by electrolysis.

[0068] The number of reactors energized by controller **49** may vary according to the RPM value, or according to a particular algorithm. For example, during an engine cold-start condition, engine pollutants can be particularly high because the cold temperature inhibits combustion of hydrocarbons. To address this condition, a starting algorithm can be programmed to initially energize a plurality of reactors in order to produce an abundance of hydrogen and oxygen to assist with combustion. After the engine warms up to a steady-state condition, the algorithm may cause one or more of the reactors to de-energize, as necessary. An engine steady-state indicator **55** may be provided for this purpose, i.e. to transmit a steady-state status indication to controller **49**. Various parameters may be monitored to provide a source for the steady-state indication. For example, engine running time, engine oil pressure, engine oil temperature, engine coolant temperature, reactor solution temperature, or engine exhaust chemistry may be used to provide this indication.

[0069] In another embodiment, an algorithm may be provided to allow the controller to energize one or more of the reactors in response to engine demand. Engine demand may be represented by a signal such as engine RPM, and transmitted to controller **49** by RPM sensor **53**. For example, a single reactor may be energized for a low range of RPM (0 to 1000), a second reactor may be energized for a higher ranger of RPM (1000 to 1500), a third reactor may be energized for the next range (1500 to 2000), and so on. Reactors may then be de-energized as RPM decreases. In another aspect, engine demand may be represented by a signal transmitted from a throttle position sensor.

[0070] In another embodiment, controller **49** and/or memory **50** may be configured with one or more counters that keep track of the service time for each reactor to enable the controller to shift reactor duty cycles. For example, a count maintained in a counter may represent the total time (in minutes or hours) that a reactor has been energized. Algorithms may then instruct controller **49** to energize reactors according to a priority such that reactor service times are equalized over time. If, at a particular engine start, reactor **11**D has the lowest count among all reactors in a system, it is assigned a highest priority to ensure that it sees additional service time even when fewer than all reactors need to be energized to satisfy engine demand. In that instance, reactors with the highest counts (and lower priorities) may remain temporarily de-energized. At a subsequent engine start, if the service time of reactor **11**D has since exceeded the service time of another reactor, controller **49** may shift the duty from reactor **11**D to a reactor with higher priority.

[0071] In another embodiment, the electrical power source and its associated control system may be configured to energize initially a first set of one or more reactors when the engine starts, and upon a subsequent start, to energize initially a second set of one or more reactors. The second set of reactors may have some reactors in common with the first set of reactors, provided that there is at least one reactor in the second set that is absent from the first set. This provides another means for the control system to shift duty cycles among the reactors, since at least one reactor will remain idle. Over time, each reactor will see a substantially equal amount of service time. This advantageously maximizes the service time of the system between maintenance intervals.

[0072] In another embodiment of the invention, the outlet conduit of each reactor **11**A, **11**B, **11**C and **11**D may be configured with an isolation valve **56**A, **56**B, **56**C or **56**D, respectively. These may be manual valves, or they may be valves that can be closed automatically by the control system. In cases where engine demand requires one or more reactors to remain idle, it may be advantageous to isolate the air space of the idle reactors to reduce the load on the vacuum drawn by the intake manifold. Each solenoid valve may be energized and de-energized by a controller **49** and relay **51** in the same manner that the reactors are energized and de-energized. This provision for isolating a reactor also allows an inoperable, redundant reactor to be temporarily valved out of service.

[0073] In accordance with the foregoing disclosure, methods of the present invention will now be described. FIG. **10** illustrates one embodiment of a method **1000** for generating hydrogen and oxygen by electrolysis of water according to engine demand. The method begins at step **1002**, which comprises maintaining a plurality of electrolytic reactors in electrolyte communication. Electrolytic communication is achieved by connecting each reactor chamber to at least one other reactor chamber from among the plurality of reactors, such that all connections are made to allow electrolyte solution to flow from one reactor to another. The next step is step **1004**, which comprises providing a reservoir in electrolyte communication with at least one of the reactors.

[0074] Next, step **1006** comprises sensing the level of electrolyte solution in the reactors. Provided that the reactors are maintained in electrolyte communication, it is only necessary to sense the solution level in any one of the reactors, as its level will be substantially equal to the level in all others. The next step is step **1008**. This step comprises controlling the solution level in the reactors responsive to the level sensed in the previous step. As discussed in previous embodiments, a control circuit comprising the sensor, the reservoir, one or more pumps, one or more valves, and a power source may be used to effect this step. Next, in step **1010**, one or more of the reactors are electrically energized responsive to engine demand. Energization of the reactors begins the electrolysis process that produces hydrogen and oxygen gas. To counteract the resulting temperature rise within the reactors, step **1012** is performed. Step **1012** comprises cooling the reactors during energization, which may be accomplished by circulating the electrolyte solution though a heat exchanger, or by providing a passive heat sink for transferring heat from the reactor vessels. The final step is step **1014**, wherein hydrogen and oxygen reaction products are directed from the reactors to the intake system of the internal combustion engine.

[0075] Another method according to the invention is illustrated in FIG. **11**. This method begins at step **1102**. Steps **1102** and **1104** are identical to steps **1002** and **1004** of the previous embodiment. In the next step **1106**, an electrolyte solution is circulated through the reactors. This particular solution consists of 2 to 4% sodium hydroxide, 10 to 20% alcohol, and a balance of deionized water. In one example, the alcohol is methanol. In step **1108** a reactor solution level is sensed, and in step **1110** reactor solution levels are controlled responsive to the sensed level. The next step is 1112, wherein, responsive to engine demand, one or more of the reactors are energized with an energizing current of between about 60 and about 80 amps. In the final step **1114**, the gaseous hydrogen and oxygen reaction products are directed from the reactors to the engine intake system.

[0076] The invention has been presented in an illustrative style. The terminology employed throughout should be read in an exemplary rather than a limiting manner. While various exemplary embodiments have been shown and described, it should be apparent to one of ordinary skill in the art that there are many more embodiments that are within the scope of the subject invention. Accordingly, the invention is not to be restricted, except in light of the appended claims and their equivalents.

What is claimed is:

1. A system for generating hydrogen and oxygen by electrolysis of water for supplementing a hydrocarbon fuel burned in a combustion chamber, the system comprising:

an electrolytic reactor comprising:
- (i) a sealed cathode chamber partially filled with an electrolyte solution; and
- (ii) an anode at least partially immersed in the solution and electrically isolated from the chamber;

a reservoir in electrolyte communication with the reactor;

a level controller for maintaining reactor solution level;

a cooling system for cooling the reactor;

conduit for directing hydrogen and oxygen product from the reactor to the combustion chamber; and

a power source for energizing the reactor.

2. The system of claim 24 wherein the power source is configured to energize the reactor with a variable electrolyzing current in response to changing engine demand.

3. The system of claim 24 wherein the electrolyte solution comprises water, alcohol, and dissolved lye.

4. The system of claim 24 wherein the cooling system comprises a heat sink in direct thermal contact with the reactor.

5. A system for generating variable output of hydrogen and oxygen by electrolysis of water for supplementing a hydrocarbon fuel in an internal combustion engine, the system comprising:

a plurality of electrolytic reactors in electrolyte communication, each reactor comprising:

(i) a sealed cathode chamber partially filled with an electrolyte solution; and

(ii) an anode at least partially immersed in the solution and electrically isolated from the chamber;

a reservoir in electrolyte communication with at least one of the reactors;

level control means for maintaining solution level in the reactors;

a cooling system for transferring heat from the reactors;

conduit for directing hydrogen and oxygen product from the reactors to the engine; and

a source of electric potential for energizing one or more of the reactors in response to engine demand.

6. The system of claim 1 wherein the solution is an aqueous solution comprising about 2 to 4 percent sodium hydroxide and about 10 to 20 percent alcohol.

7. The system of claim 1 wherein the level control means comprises a level sensor coupled to a valve located between the reservoir and the at least one reactor, whereby, responsive to the sensor sensing a high level of solution, the valve opens to sink solution from the reactors to the reservoir.

8. The system of claim 1 wherein the level control means comprises a level sensor coupled to a pump located between the reservoir and one of the reactors, whereby, responsive to the sensor sensing a low level of solution, the pump turns on to supply solution from the reservoir to the reactors.

9. The system of claim 1 wherein the source further comprises a means for sensing changing engine demand and a means for coupling the source to one or more of the reactors responsive to changing engine demand to produce hydrogen and oxygen output that varies according to changing engine demand.

10. The system of claim 5 wherein the means for sensing changing engine demand comprises a throttle position sensor.

11. The system of claim 5 wherein the means for sensing changing engine demand comprises an RPM sensor.

12. The system of claim 1 wherein the source is configured to shift reactor duty cycles such that reactor service times are substantially equalized over time.

13. The system of claim 8 wherein the source is configured to energize initially a first set of one or more reactors when the engine starts, and upon a subsequent start, to energize initially a second set of one or more reactors, the second set comprising at least one reactor absent from the first set.

14. The system of claim 1 wherein the source is configured to energize initially a plurality of reactors, and responsive to sensing a steady-state operating condition, to de-energize one or more reactors.

15. The system of claim 10 wherein the steady-state operating condition is selected from the group consisting of engine running time, engine oil pressure, engine oil temperature, engine coolant temperature, reactor solution temperature, and engine exhaust chemistry.

16. A system for generating hydrogen and oxygen by electrolysis of water for supplementing a hydrocarbon fuel burned in a combustion chamber, the system comprising:

an electrolytic reactor comprising:

(i) a cathode chamber having an inlet for receiving saltwater flow and an outlet for discharging the flow; and

(ii) an anode at least partially immersed in the flow and electrically isolated from the chamber;

conduit for directing hydrogen and oxygen product from the reactor to the combustion chamber; and

a power source for energizing the reactor.

17. The system of claim 16 wherein an engine comprises the combustion chamber.

18. The system of claim 17 wherein the engine causes the saltwater flow.

19. The system of claim 16 further comprising a means for adding alcohol into the cathode chamber.

20. A method of generating variable output of hydrogen and oxygen for supplementing a hydrocarbon fuel in an internal combustion engine intake system by electrolyzing an electrolyte solution in a plurality of reactors, each reactor electrically coupled to an electrical power source and comprising a sealed cathode chamber partially filled with the solution and having an anode immersed therein, the method comprising:

maintaining the reactors in electrolyte communication;

providing a reservoir in electrolyte communication with at least one of the reactors;

sensing solution level in the reactors;

controlling solution level responsive to the sensed level;

energizing one or more of the reactors by means of the electrical power source responsive to engine demand;

cooling the reactors during energization; and

directing hydrogen and oxygen product from the reactors to the engine intake system.

21. The method of claim 20 wherein the electrolyte solution is an aqueous solution comprising about 2 to 4 percent sodium hydroxide and about 10 to 20 percent alcohol.

22. The method of claim 20 wherein the controlling step further comprises sinking solution from the reactors to the reservoir responsive to sensing a high level of solution.

23. The method of claim 20 wherein the controlling step comprises pumping solution from the reservoir to one of the reactors responsive to sensing a low level of solution.

24. The method of claim 20 wherein the energizing step further comprises sensing changing engine demand and responsive to changing engine demand, coupling the source to one or more of the reactors to produce hydrogen and oxygen output that varies according to changing engine demand.

25. The method of claim 24 wherein sensing changing engine demand further comprises sensing engine throttle position.

26. The method of claim 24 wherein sensing changing engine demand further comprises sensing engine RPM.

27. The method of claim 20 wherein the energizing step further comprises shifting reactor duty cycles such that reactor service times are substantially equalized over time.

28. The method of claim 27 further comprising energizing initially a first set of one or more reactors when the engine starts, and upon a subsequent start, energizing initially a

second set of one or more reactors, the second set comprising at least one reactor absent from the first set.

29. The method of claim **20** wherein the energizing step further comprises energizing initially a plurality of reactors, and responsive to sensing a steady-state operating condition, de-energizing one or more reactors.

30. The method of claim **29** wherein the steady-state operating condition is selected from the group consisting of engine running time, engine oil pressure, engine oil temperature, engine coolant temperature, reactor solution temperature, and engine exhaust chemistry.

31. A method of generating variable output of hydrogen and oxygen in a plurality of electrolytic reactors for supplementing a hydrocarbon fuel in an internal combustion engine intake system, each reactor electrically coupled to an electrical power source and comprising a sealed cathode chamber having an anode disposed therein, the method comprising:

maintaining the reactors in electrolyte communication;

providing a reservoir in electrolyte communication with at least one of the reactors;

circulating through the reactors an amount of electrolyte solution comprising about 2 to 4 percent sodium hydroxide, 10 to 20 percent alcohol, and a balance of deionized water;

sensing solution level in the reactors;

controlling reactor solution levels responsive to the sensed level;

energizing one or more of the reactors each with 60 to 80 amps by means of the electrical power source responsive to engine demand; and

directing hydrogen and oxygen product from the reactors to the engine intake system.

32. The method of claim **31** wherein the circulating step further comprises circulating the electrolyte solution through a heat exchanger.

33. An electrolyte solution for generating hydrogen and oxygen gas by electrolysis, the solution comprising water, alcohol, and dissolved lye.

34. The solution of claim **33** comprising between about 2 and about 4 percent dissolved lye, between about 10 and about 20 percent alcohol, and a balance of deionized water.

35. The solution of claim **33** wherein the lye comprises sodium hydroxide.

36. The solution of claim **33** wherein the alcohol comprises methanol.

37. An electrolyte solution for use in an electrolytic reactor for generating hydrogen and oxygen gas as a fuel supplement for an internal combustion engine, the solution comprising about 10 to about 20 percent methanol and a balance of sodium hydroxide dissolved in pure water.

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