

[54] HYDROGEN GENERATOR

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204/DIG. 3[51] Int. Cl. **B01k 3/00**; H01m 17/02[58] Field of Search 204/248, 129, 237, 238,
204/239, DIG. 3, 228; 136/160, 86 A, 100 R,
100 M

[56]

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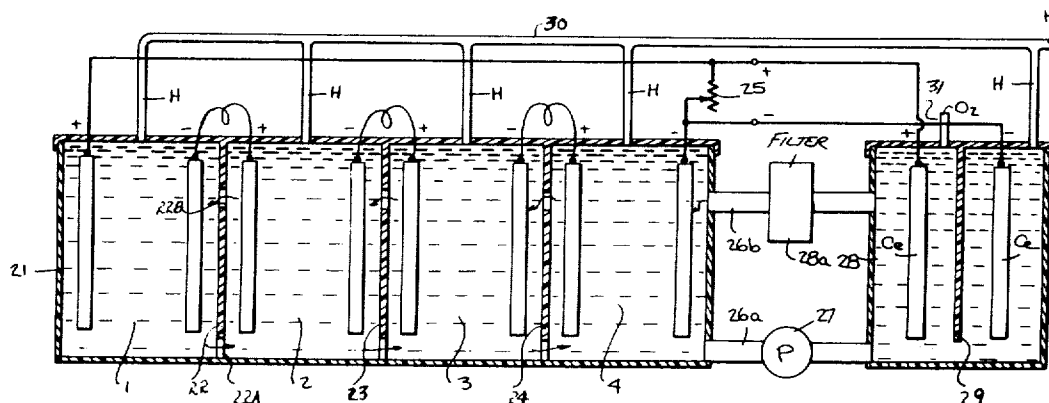
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ABSTRACT

A hydrogen generator constituted by a voltaic cell having a reactive magnesium electrode and a non-reactive electrode immersed in a salt-water electrolytic bath, a load being connected between the electrodes to cause a current flow in the cell resulting in an electrochemical reaction in which the magnesium is decomposed to produce hydrogen and in electrolysis in which the water is decomposed to produce hydrogen. In order to minimize polarization and other factors which diminish the production of hydrogen, the solution is circulated through an external flow loop having a pump interposed therein to draw the electrolyte from the bottom of the bath and to return it to the top thereof, the pump being powered by voltage derived from the cell.

10 Claims, 2 Drawing Figures

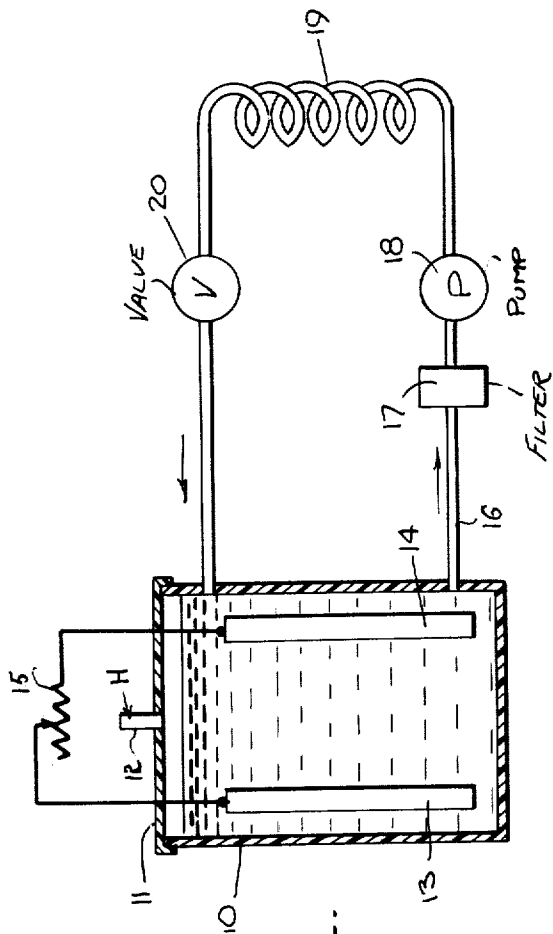


Fig. 1.

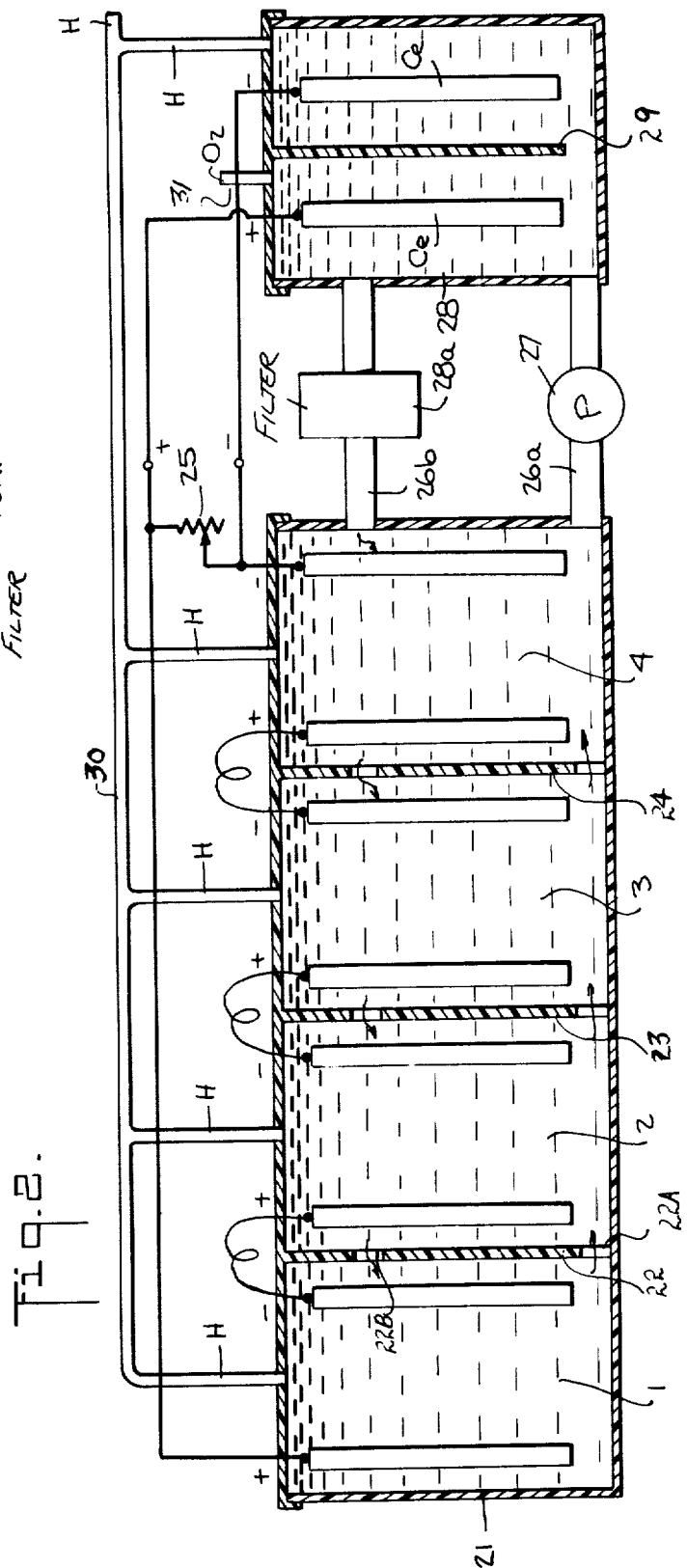


Fig. 2.

HYDROGEN GENERATOR

BACKGROUND OF THE INVENTION

This invention relates generally to the production of hydrogen, and more particularly to a hybrid technique for this purpose involving both an electrochemical action and electrolysis.

Substantial amounts of hydrogen are used industrially in oxy-hydrogen and atomic hydrogen flames for high-temperature welding, in the fixation of nitrogen as ammonia, in the hydrogenation of fatty oils and unsaturated hydrocarbons, and in the formation of methyl alcohol. In recent years it has been recognized that hydrogen may well be the ideal fuel for internal combustion and other engines, rather than gasoline or other hydrocarbons, for when a mixture of hydrogen and air is ignited in a combustion chamber to produce motive power, the combustion product is pure steam, rather than noxious pollutants such as carbon monoxide and unburned hydrocarbons. Moreover, with hydrogen as the fuel, it becomes possible to operate the engine at lower temperatures and thereby to minimize the emission of oxides of nitrogen.

A number of experimental vehicles using hydrogen as a fuel have been demonstrated and widely publicized. Thus in the Sept. 17, 1973 issue of the New York Times is an article entitled "NASA Testing Hydrogen in Gasoline to Cut Fumes", it is noted that "Over the years, there has been much speculation and some work on the idea of using hydrogen, with its enormous power and ready availability, to power autos. In fact, hydrogen has been increasingly looked upon as the most promising long-term answer to the world's power needs as fossil fuels become exhausted". But while the use of hydrogen for this purpose has been the subject of many technical papers, there has been no significant commercialization of this concept.

A major factor which has heretofore precluded a commercially-feasible hydrogen-fueled automobile or other engine is the cost of producing hydrogen, for with known techniques the cost of hydrogen in an amount whose energy content in terms of BTU's is equivalent to the amount of gasoline required to fuel a car for a given number of miles, greatly exceeds the gasoline cost.

Hydrogen is prepared commercially by the electrolysis of aqueous salt solutions, by the reaction of dilute sulfuric acid and a metal such as zinc, by the reaction of iron with steam and by various other techniques, all of which are relatively expensive.

In order to reduce the cost of manufacturing hydrogen, particularly for use in operating automotive engines, there is disclosed in my prior U.S. Pat. No. 3,648,668, a hydrogen gas generator including a magnesium electrode and a carbon electrode immersed in a salt-water electrolyte, a variable load resistance being connected between the electrodes to control the rate at which hydrogen is generated. The entire disclosure in U.S. Pat. No. 3,648,668 is hereby incorporated by reference.

With the electrodes open-circuited, there is a chemical reaction between the magnesium electrode and the salt-water electrolyte which acts slowly to evolve hydrogen gas. When the circuit between the electrodes is closed by the variable load resistance, an electric current is caused to flow to a degree depending on the resistance of the load. The rate of hydrogen production

varies in proportion to the current flow which is inversely related to the value of load resistance.

The combination of a magnesium and carbon or steel electrode in a salt-water electrolyte acts as a voltaic cell and when current flows therein, the reaction in such that the magnesium electrode is decomposed to form magnesium hydroxide, this reaction continuing until the magnesium electrode is entirely decomposed. And because the electrochemical reaction gives rise to a galvanic voltage between the electrodes, this results in electrolysis of the water whereby hydrogen is liberated at the cathodic electrode (magnesium) and oxygen at the anode electrode (carbon or steel). Thus two molecules of hydrogen are formed for each molecule of oxygen.

Inasmuch as hydrogen is yielded by the cell both as a consequence of the decomposition of magnesium and because of electrolysis in which the decomposing magnesium serves concurrently as a cathode electrode, the overall amount of hydrogen produced by this hybrid system is far greater than that produced by the known reactions of magnesium in a salt solution.

It has been found, however, that with a hydrogen generator of the type disclosed in my prior patent, the volume of hydrogen generated at the outset of operation is large, but with continued operation this volume tends to diminish because of polarization and other factors, thereby making the generator less efficient. It has been found, for example, that the salt water solution which is initially neutral becomes increasingly base and that when this happens, the production of hydrogen is reduced. Also, with continued operation, the solution becomes heated, and while this is beneficial up to about 90° to 100° F, at higher temperatures it gives rise to a reduction in hydrogen output.

SUMMARY OF THE INVENTION

In view of the foregoing it is the main object of this invention to provide a galvanic hydrogen generator making use of a magnesium electrode in a salt-water solution to produce hydrogen both by electrochemical reaction and by electrolysis, the hydrogen output of the generator being undiminished throughout its useful life.

More particularly it is an object of this invention to provide a hydrogen cell of the above-identified type capable of producing hydrogen in large quantities and at relatively low cost, the salt-water electrolyte being circulated continuously to minimize polarization and other factors tending to diminish the output.

Also an object of the invention is to provide a hydrogen generator for the above-identified type wherein the voltage generated by the cell is exploited to operate a pump for circulating the electrolyte.

Still another object of the invention is to provide a hydrogen generating system in which the voltage generated in one or more magnesium cells wherein hydrogen is produced electrochemically also serves to effect electrolysis in these cells and in an external electrolysis cell.

Briefly stated, these objects are attained in one preferred embodiment of the invention wherein a voltaic cell constituted by a magnesium electrode and a carbon or steel electrode immersed in a salt-water bath such as sea water, is provided with an external flow loop having a pump interposed therein, preferably powered by the cell voltage, the loop drawing electrolyte from the bottom of the bath and returning it to the top of the bath

whereby the electrolyte is continuously circulated. The loop may include a heat exchange coil to reduce the temperature of the electrolyte.

In another embodiment of the invention, the loop includes an electrolysis cell having a pair of like electrodes therein to which a voltage derived from the magnesium cell is applied, whereby the hydrogen liberated in the electrolysis cell is added to the hydrogen generated in the voltaic cell and the liberated oxygen is fed to a separate output.

OUTLINE OF THE DRAWING

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawing, wherein:

FIG. 1 is a schematic diagram of one preferred embodiment of the invention, and

FIG. 2 is a schematic diagram of another preferred embodiment of the invention.

DESCRIPTION OF THE INVENTION

First Embodiment

Referring now to FIG. 1, there is shown a hydrogen-generating voltaic cell in accordance with the invention in which a salt or sea water electrolyte is contained in a tank 10, preferably fabricated of a non-corrosive metal provided with an insulating liner, or of a high-strength synthetic non-reactive plastic material. The cover 11 of tank 10 includes a gas-discharge outlet 12.

Supported within tank 10 and immersed in the electrolyte is an active magnesium electrode 13 and an inactive electrode 14, preferably composed of carbon, steel or other conductive material which is non-reactive. The tank is hermetically sealed except for the outlet provided for the escape of hydrogen gas. Electrodes 13 and 14 are interconnected by a variable load resistor 15. This load may also include other electrical devices such as lamps and motors.

When the electrodes are interconnected by the load resistor, a current flows in the cell with an intensity determined by the resistance of the load - the higher the resistance, the smaller the current. The rate of hydrogen production is proportional to current flow, this rate being greatest where the load is effectively a short circuit. In practice, in order to limit the amount of hydrogen generated to the demand therefor, a control circuit may be provided which is responsive to the level of demand and functions to vary the load resistor to meet but not exceed the demand.

The electrochemical reaction which accompanies the decomposition of the magnesium electrode results in the formation of magnesium hydroxide which is deposited in the bottom of the tank. When the magnesium electrode is consumed, it must be replaced. The magnesium hydroxide may be processed to recover its magnesium content. Concurrent with the electrochemical activity is electrolysis which liberates hydrogen. No significant amount of liberated oxygen passes out of the cell, for the oxygen becomes involved in the electrochemical reaction and also forms hydrogen peroxide. Inasmuch as the cell itself generates the voltage for electrolysis, the cell operates as an auto-electrolysis device requiring no external voltage source.

As previously noted, the electrolyte is initially neutral. However, in the course of operation, the electro-

lyte becomes base in character, its temperature rises and polarization occurs, all of which act to reduce the hydrogen output. These adverse effects are minimized by means of an external flow loop 16 which communicates at its input end with the bottom of the electrolyte bath in tank 10 and at its return end with the top of the bath.

Interposed in loop 16 is a strainer or filter 17 to collect the magnesium hydroxide sediment, a pump 18, a heat exchange coil 19 and a control valve 20. Pump 18 is powered by voltage derived from cell 10, and since this voltage in a single cell is less than 1.5 volts, a suitable D-C voltage multiplier may, in practice, be used to step up this voltage to a higher operating voltage, such as 24 volts.

When the pump is operative, the electrolyte is drawn from the bottom of the bath by the pump and carried through the filter 17 to remove sediment therefrom, the electrolyte then passing through cooling coil 19 before it is returned to the top of the bath. Thus the electrolyte is continuously circulated, in the course of which it is purified and cooled to maintain operation of the cell at optimum efficiency.

Second Embodiment

In the arrangement shown in FIG. 2, a group of identical voltaic cells 1, 2, 3 and 4 is provided. This group is formed in a common tank 21 divided into four cells by partitions 22, 23 and 24. Each cell is equipped with a magnesium electrode Mg and a carbon electrode C. The cells are serially connected to an adjustable load resistor 25, so that the voltage applied to the load is 4 times the voltage of a single cell. Obviously, in practice the arrangement may be scaled to define a greater number of voltaic cells.

The four cells formed in the tank have a common salt-water electrolyte, and in order to permit this electrolyte to circulate freely from cell to cell, each partition is provided with a lower port, such as port 22A, and an upper port 22B.

Coupled to the tank 21 is an external flow loop whose lower branch 26A has a pump 27 interposed therein and whose upper branch 26B has a filter 28a interposed therein. This loop passes through an electrolysis cell 28 having a pair of spaced carbon electrodes Ce immersed therein, which electrodes are isolated from each other by a divider 29 serving to segregate hydrogen gas evolved at the negatively-biased carbon electrode (cathode) and the oxygen evolved at the positively-biased carbon electrode (anode).

The voltage for operating the electrolysis cell is taken from across load resistor 25. This voltage is also used to operate pump 27. No electrochemical action takes place in the electrolysis cell, for in this cell it is only water which is decomposed. Since this water is derived from the voltaic cells where hydrogen peroxide is produced, this hydrogen peroxide is subjected to electrolysis.

In order to accumulate hydrogen from both the voltaic cells and the electrolysis cell, a manifold 30 is provided which is coupled to all of these cells. A separate outlet 31 is provided for the oxygen output.

It has been found that in the course of operation, the electrolyte in voltaic cells 1, 2, 3 and 4 which is initially neutral in character becomes base, whereas the electrolyte in the electrolysis cell 28 becomes acid. But because of the continuous circulation of the electrolyte

from the voltaic cells through the electrolysis cell and back to the voltaic cells, the intermingling of the acid electrolyte with the base electrolyte acts to maintain the electrolyte generally neutral, thereby optimizing the hydrogen output.

While there has been shown preferred embodiments of the invention, it will be appreciated that many changes and modifications may be made without, however, departing from the essential spirit of the invention. For example, while circulation of the electrolyte has been realized by means of an external loop incorporating a pump, one can by providing a cell whose electrodes are immersed in the open sea in an arrangement in which the saline sea water freely circulates, obtain a similar result.

I claim:

1. A hydrogen generator comprising:

A. at least one voltaic cell having an active magnesium electrode and a non-active electrode adapted to be immersed in a salt-water electrolyte contained in a tank having a hydrogen outlet above the level of said electrolyte,

B. a variable load resistor external to the cell and connected across the electrodes to produce a current in said cell resulting in the proportional production of hydrogen which is discharged through said outlet, a voltage being developed across said load resistor, and

C. an external flow loop communicating with said tank adjacent the lower and upper ends thereof to effect continuous circulation and cooling of said electrolyte to minimize polarization and other adverse effects, said loop including an electrically-operated pump connected to said load resistor and powered by said voltage, said pump functioning to draw the electrolyte from the lower end of the tank and to return it to the upper end thereof.

2. A generator as set forth in claim 1, wherein said loop further includes a heat-exchange coil to cool said electrolyte.

3. A generator as set forth in claim 1, wherein said loop further includes a filter to remove contaminants from the electrolyte.

4. A generator as set forth in claim 1, wherein said loop further includes an electrolysis cell having a pair of electrodes therein connected across said load resistor, the hydrogen evolved in said electrolysis cell being combined with that produced by said voltaic cell.

5. A generator as set forth in claim 1, wherein said non-active electrode is carbon.

6. A generator as set forth in claim 4, wherein said pair of electrodes are carbon electrodes.

7. A generator as set forth in claim 1, wherein said tank is divided into a plurality of voltaic cells by partitions having ports therein to permit the interflow of said electrolyte, said voltaic cells being serially-connected to said load resistor.

8. A generator as set forth in claim 4, wherein said electrolysis cell includes a divider between said pair of electrodes to separate evolved oxygen from evolved hydrogen.

9. A hydrogen generator as set forth in claim 1, wherein said cell electrodes are immersed in the open sea to provide a freely-circulating salt-water electrolyte.

10. A hydrogen generator as set forth in claim 1, wherein said external flow loop includes an electrolysis cell through which said electrolyte circulates whereby as the electrolyte in the voltaic cell becomes chemically base in character in the course of operation, the electrolyte in the electrolysis cell becomes acid in character to an extent maintaining the circulating electrolyte substantially neutral to optimize the hydrogen output.

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