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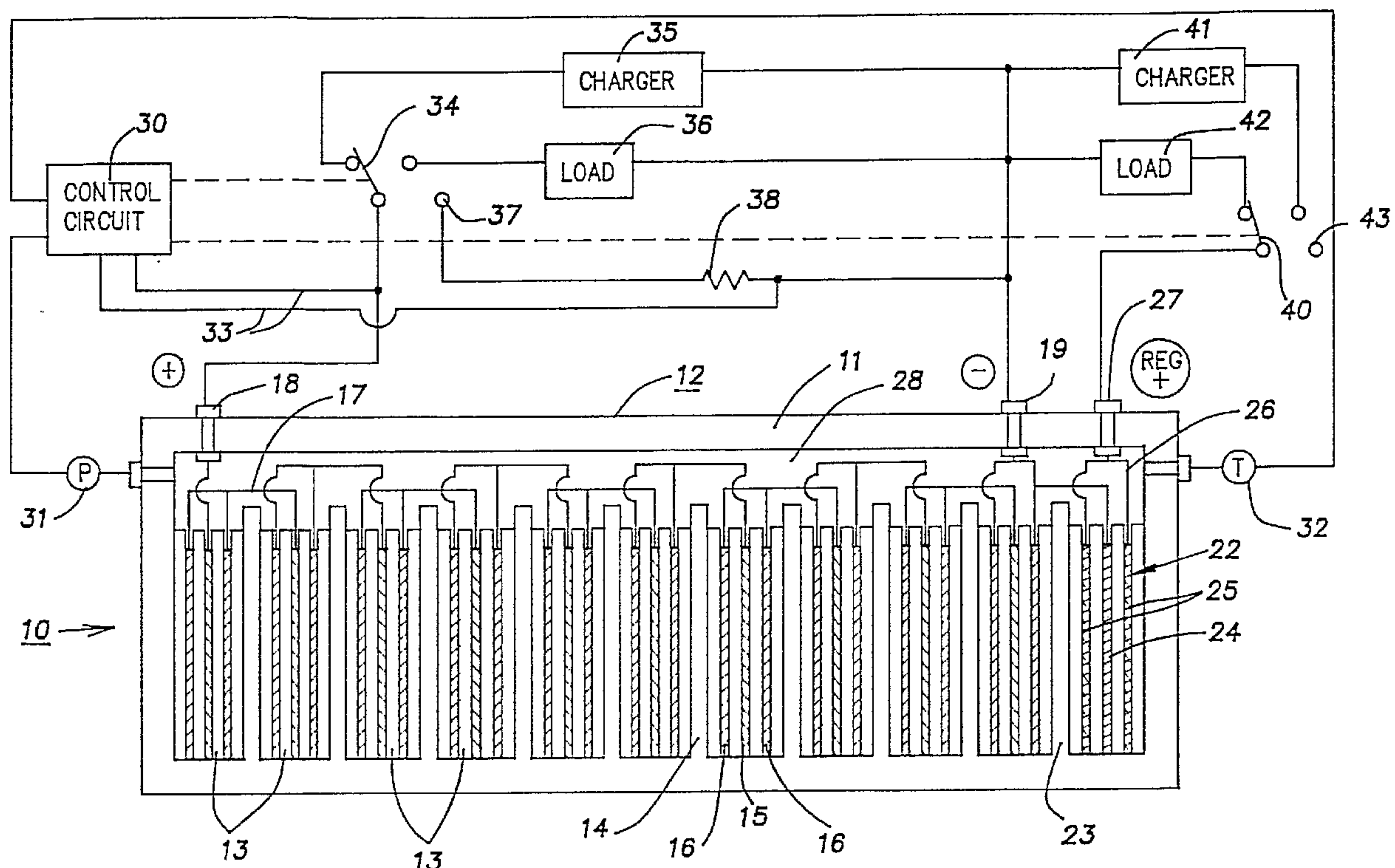
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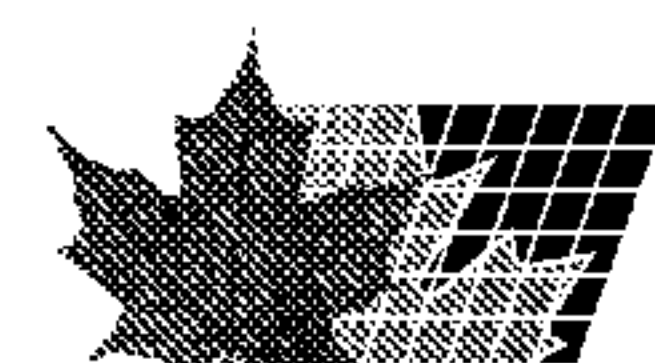
(54) Titre : BATTERIE ETANCHE RECHARGEABLE

(54) Title: SEALED RECHARGEABLE BATTERY



(57) Abrégé/Abstract:

A sealed rechargeable storage battery containing one or more rechargeable working cells and at least one regulator cell. The working cells are capable of generating gas in a gas space within the sealed battery during charging of the working cells. The regulator cell is in gaseous communication with the gas space, the regulator cell being chargeable and dischargeable by a control circuit to regulate the amount of gas in the gas space.



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ABSTRACT OF THE DISCLOSURE

1
2 A sealed rechargeable storage battery containing
3 one or more rechargeable working cells and at least one
4 regulator cell. The working cells are capable of
5 generating gas in a gas space within the sealed battery
6 during charging of the working cells. The regulator cell
7 is in gaseous communication with the gas space, the
8 regulator cell being chargeable and dischargeable by a
9 control circuit to regulate the amount of gas in the gas
10 space.

1 SEALED RECHARGEABLE BATTERY

2 BACKGROUND OF THE INVENTION

3 Rechargeable battery cells with solid electrodes
4 are of two general types: (1) open or vented, sometimes re-
5 ferred to as "flooded"; and (2) sealed, commonly referred
6 to as "starved". Generally, in a flooded cell, the
7 electrodes are immersed in electrolyte, while in a starved
8 cell, the electrodes are not immersed in electrolyte.
9 These two types of batteries differ primarily in the way in
10 which they deal with gases, namely oxygen and/or hydrogen,
11 which are generated in the battery cells toward the end of
12 the charging operation and during overcharging.

13 Type 1 allows the gases to vent to the
14 atmosphere; in Type 2 the gases (primarily oxygen) are
15 recombined back into water inside the sealed battery cell.
16 Type 2 is preferred from the user's point of view because
17 the sealed cell requires no periodic maintenance, maintains
18 charge balance between the plates, can operate in any
19 position, releases no explosive gases and does not leak
20 corrosive chemicals into the environment.

21 Two different kinds of sealed cells (Type 2) are
22 known in the industry. One is a standard design common in
23 consumer cylindrical and small prismatic or rectangular
24 cells up to about 50 Ah capacity for Ni-Cd, and about 500
25 Ah for Pb-Acid. The other (which has been commercialized
26 for Ni-Cd batteries only) employs recombination plates and
27 uses a split negative plate and is available in up to about
28 100 Ah capacity. Although different in construction and
29 performance, both of these sealed cells share some
30 fundamental principles, as follows.

31 1. They attempt to minimize hydrogen evolution by
32 using an excess of discharged negative material and rely on

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1 the oxygen cycle to maintain discharged negative material
2 in the cell at all times.

3 2. They are limited to individual vessel designs,
4 that is, individual cells each hermetically sealed to
5 ensure that all oxygen generated in a particular cell will
6 recombine in the same cell (with some exception for
7 monoblock Pb-Acid that sometimes use common gas space).

8 3. They use starved electrolyte in the stack of elec-
9 trodes and separators to permit oxygen transport to the
10 negative electrode. This dictates tight stacking of
11 electrodes, small interelectrode distance and close control
12 of the electrolyte level in the cell.

13 4. If placed in a multiple cell battery, they require
14 close matching of cell capacities, charge efficiencies and
15 temperatures to guarantee long life and avoid cell
16 reversal, hydrogen evolution, overpressure and overheating.

17 Vented cells, on the other hand, are more robust.
18 They do not require as tight a control in manufacturing,
19 they are less sensitive to overcharge and overdischarge or
20 deep discharge, and there is less concern with cell
21 temperature and pressure. They are generally less
22 expensive to build and more applicable to large cells as
23 well as large batteries, yet they pose considerable
24 difficulties to the user who is concerned with periodic
25 maintenance, explosive gas releases into the environment,
26 electrolyte splashing, and loss of plate balance in the
27 cells.

28 The above discussion indicates the need for a
29 battery that is sealed and requires no maintenance, yet is
30 more robust in design, manufacturing and use, more applica-
31 ble to large cells and large multi-cell batteries, easy to
32 produce at economical costs and offers advantages in energy
33 density.

34 A prior US Patent which tried to address some of
35 these problems was US Patent No. 5,143,799. This

1 patent disclosed a sealed rechargeable nickel zinc or
2 silver zinc cell which was divided into two compartments,
3 one having a zinc electrode and a first hydrogen electrode
4 and a second having a nickel or silver electrode and a
5 second hydrogen electrode electrically connected to the
6 first hydrogen electrode. A common gas space was provided
7 for the two compartments so that the hydrogen and oxygen
8 gases could recombine to water and the container could be
9 sealed. Among other expensive features, this battery
10 requires a hydrogen electrode in each cell, which is very
11 costly, and the cells need to be starved.

12 SUMMARY OF THE INVENTION

13 The invention is directed to a sealed
14 rechargeable storage battery containing one or more
15 rechargeable working cells which are capable of generating
16 gas in a gas space within the sealed battery during
17 charging of the rechargeable working cells. At least one
18 regulator cell is provided within the battery and it is in
19 gaseous communication with the gas space. The regulator
20 cell is chargeable and dischargeable by a control circuit
21 to regulate the amount of the gas in the gas space. The
22 control circuit is preferably external to said battery.
23 Excessive gas is an amount or concentration or
24 pressure of gas above a desired or preselected amount or
25 concentration or pressure of gas. Typically, excessive gas
26 pressure is more than about 1.5 atm absolute (ata).

27 The invention is further directed towards a
28 rechargeable sealed battery of common vessel construction.
29 Such a battery may have a nickel oxide, silver oxide, or
30 manganese dioxide positive electrode as well as a cadmium,
31 iron, metal hydride, or zinc negative electrode. The
32 discussion will focus on that which is most commonly used
33 in rechargeable alkaline batteries with solid electrodes,

1 nickel oxide positive electrode in combination with cadmium
2 negative electrodes. This combination is known by the
3 common name Ni-Cd battery, often pronounced Nicad.
4 Nevertheless, in most cases, in this discussion nickel
5 oxide could be replaced with silver oxide (AgO) and
6 manganese dioxide (MnO₂), and cadmium could be replaced with
7 zinc (Zn), metal hydride (MHx), or Iron (Fe). Accordingly,
8 other battery combinations to which this invention could
9 apply include Ni-Zn, Ni-Fe, Ni-MHx, Ag-MHx, Ag-Cd, Ag-Zn,
10 Ag-Fe, and MnO₂-Zn. Also the basic principles could apply
11 to non-alkaline rechargeable battery systems such as PbO₂-Pb
12 (known as lead acid).

13 The invention may comprise a common vessel sealed
14 rechargeable battery which comprises in combination a
15 sealed housing, a plurality of a first type of cells within
16 the sealed housing, means for connecting all cells in
17 series, positive and negative terminals connected through a
18 wall of the sealed housing to positive and negative ends of
19 the series connected cells, one or more cells of a second
20 type, connected in parallel with each other, within said
21 sealed compartment and having a common gas space filled or
22 charged with hydrogen with cells of said first type, at
23 least one metal electrode and at least one hydrogen
24 electrode in said second cell type, a hydrogen terminal
25 connected through a wall of the sealed housing to the
26 hydrogen electrodes in said second cell type, and means to
27 make external connection to said negative electrode of said
28 second cell type. Preferably, positive hydrogen gas
29 pressure, generally less than 1 atm absolute, is maintained
30 in the battery at all times.

31 Further, the invention may be summarized as a
32 sealed rechargeable storage battery having a sealed
33 container filled or charged with hydrogen, at least one
34 rechargeable cell inside the sealed container, a regulator
35 of pressure inside the container, a pressure sensor mounted
36 to sense pressure inside the sealed container, a common gas

1 space inside said container for said at least one
2 rechargeable cell and said pressure regulator, and at least
3 three terminals extending in a sealed manner through the
4 container and connected to said at least one rechargeable
5 cell and to said pressure regulator.

6 The invention may further be summarized as a
7 rechargeable battery comprising in combination, a sealed
8 container having a wall, a plurality of working cells in
9 said container, negative and positive electrodes in each of
10 said working cells, means connecting cells of said working
11 cells in series between positive and negative terminals
12 extending through a container wall for external connection
13 to said series connected cells, one or more regulator cells
14 in said sealed container, a common gas space filled or
15 charged with hydrogen for all said cells in said sealed
16 container, hydrogen electrodes and a metal electrode in
17 said regulator cell, and means providing external
18 connection to said electrodes in said regulator cell.

19 An object of the invention, therefor, is to
20 provide a rechargeable sealed battery which has the
21 advantages of a vented battery and of a sealed battery.

22 Another object of the invention is to provide a
23 sealed battery which requires no periodical maintenance,
24 maintains charge balance between the plates, releases no
25 explosive gases, and does not leak corrosive chemicals into
26 the environment.

27 Another object of the invention is to provide a
28 rechargeable battery which may be sealed as distinct from
29 having to seal individual cells.

30 Another object of the invention is to provide a
31 sealed rechargeable battery which includes a rechargeable
32 regulator wherein discharging the regulator generates
33 hydrogen; charging the regulator consumes hydrogen, and in
34 open circuit stoichiometric amounts of hydrogen and oxygen
35 are consumed. This gives the unique possibility of
36 operating a sealed battery with individual cells that are

1 of vented design (flooded) with capability of dealing with
2 both oxygen and hydrogen evolution.

3 Other objections and a fuller understanding of
4 the invention may be had by referring to the following
5 description and claims, taken in conjunction with the
6 accompanying drawings.

7 BRIEF DESCRIPTION OF THE DRAWINGS

8 FIG. 1 illustrates a sealed rechargeable battery
9 according to the invention.

10 FIG. 2 is a graph which shows variations in
11 battery voltage and pressure during charge and discharge.

12 FIG. 3 is also a graph which shows variations in
13 battery voltage and pressure during charge and discharge.

14 FIG. 4 illustrates battery capacity of a test
15 battery over 140 cycles.

16 FIG. 5 is a graph which shows variations in
17 regulator voltage and battery pressure during charging and
18 discharging of the regulator.

19 DESCRIPTION OF THE PREFERRED EMBODIMENT

20 FIG. 1 shows diagrammatically a sealed
21 rechargeable battery 10 which has a wall 11 forming a
22 hermetically sealed container or caselike housing 12. At
23 least one working cell 13 of a first type is provided in
24 the battery. Usually the battery will contain a plurality
25 of such cells 13 and in this case ten of such cells 13 have
26 been shown. Fluid impermeable barriers 14 separate each of

1 the cells, and each cell includes at least one positive
2 electrode 15 and at least one negative electrode 16. In
3 the illustrated battery, two negative electrodes 16 are
4 shown with a single positive electrode 15 for each cell.
5 The invention will be described in terms of Ni-Cd cells and
6 a Cd-H₂ regulator, but it will be noted that in principle it
7 is possible to use in conjunction with a working Ni-Cd
8 battery (Ni-Fe, Ni-Zn, Ag-Zn, Pb-PbO₂, Ni-MHx, etc.) several
9 types of M-H₂ regulator cells, where M represents any stable
10 reversible metal electrode such as Cd, Zn, Fe, Pb, etc.

11 The working cells 13 are a string of several
12 vented, slightly flooded, Ni-Cd cells which are connected
13 in series by conductors 17 with one end of the series being
14 connected in a sealed manner through the wall of the
15 container 12 to an external positive terminal 18. The
16 other end of the series is connected through the wall of
17 the container 12 to an external negative terminal 19.

18 A regulator for the working cells is provided
19 inside the sealed case 12 in accordance with the present
20 invention. This regulator is capable of generating and
21 consuming hydrogen and consuming oxygen and in this
22 preferred embodiment is a regulator or auxiliary cell 22.
23 It is within the sealed case 12 but it is electrochemically
24 separated from the working cells by a fluid impermeable
25 barrier 23. The regulator cell 22 includes at least one
26 metal electrode 24 and at least one hydrogen electrode 25.
27 The hydrogen electrodes 25 may be connected by a conductor
28 26 to pass through the wall of the container 12 to an
29 external hydrogen terminal 27. The terminal 27 is termed a
30 "hydrogen" terminal because a principle function of the
31 regulator cell 22 is to produce hydrogen or conversely to
32 consume hydrogen in order to effect a balance with the
33 working cells 13. The regulator cell 22 and the working
34 cells 13 share a common gas space 28 so that hydrogen and
35 oxygen are free to intermingle and combine. Alternatively,
36 each cell could have an individual gas space above it, with

1 all these gas spaces in gaseous communication with each
2 other. The hydrogen electrode 25 is a catalytic electrode
3 known in the art from fuel cells or nickel-hydrogen cells.
4 This electrode must have good activity to hydrogen, must
5 operate at low pressures, and must be stable in an alkaline
6 electrolyte. The preferred alkaline electrolyte will
7 feature potassium hydroxide with possibly some lithium
8 hydroxide and/or sodium hydroxide as well known in the art.
9 The electrolyte in the working cells could be different
10 from the one in the regulator, but the total electrolyte
11 activity of the two electrolytes should preferably be the
12 same since all cells are under common vapor pressure. The
13 regulator cell is "starved", with only enough electrolyte
14 to wet the plates and separators to guarantee effective gas
15 diffusion to the hydrogen electrode.

16 The sealed container 12 may have a fourth
17 terminal connected to the metal electrode of the regulator.
18 However, for better economy, the negative terminal of the
19 battery and of the regulator cell may be common as shown in
20 FIG. 1.

21 OPERATION

22 When the battery is discharging, the battery
23 operates as a regular vented battery, with all the
24 advantages of a vented flooded electrolyte battery while
25 still being sealed from the environment.

26 In a charging condition, the battery operates as
27 a regular vented battery until the onset of gas evolution.

1 Reactions at Regulator

2 Case 1: Preferential oxygen evolution on
 3 nickel-oxide electrode. Oxygen is generated on the nickel
 4 electrode and is chemically recombined in the regulator
 5 cells with the H₂ that is in the battery to produce water.

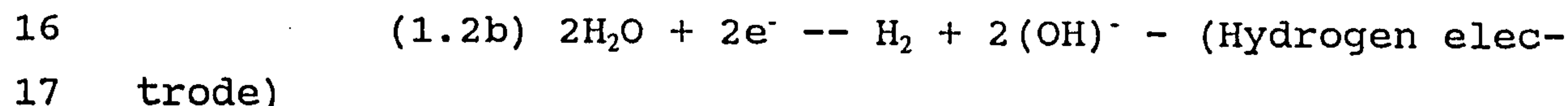
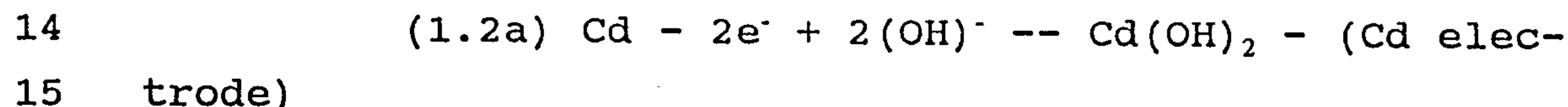
6 1.1 Chemical reaction at hydrogen electrode:



8 This will reduce pressure in the battery and
 9 cause rapid temperature rise because of the exothermal
 10 nature of the recombination reaction. To restore hydrogen
 11 pressure we activate the regulator according to reaction

12 1.2

13 1.2 Electrochemical discharge of regulator:



18 The sum of 1.2a and 1.2b is (1.2c):



20 If all hydrogen in the battery is consumed by
 21 reaction (1.1) and reaction (1.2) is not activated, then
 22 reaction (1.3) will occur.

23 1.3 Chemical reaction at cadmium electrode:



1 Case 2: Cadmium electrodes in preferential over-
 2 charge. In this case, the H_2 pressure in the cell increases
 3 as well as the battery voltage. To maintain hydrogen
 4 pressure, hydrogen is consumed in the regulator according
 5 to reaction 2.a.

6 2.a Charge regulator cell:

7 (2.a) $Cd(OH)_2 + H_2 \rightarrow Cd + 2H_2O$ (Reduce hydrogen
 8 pressure)

9 Which is equivalent to reverse reaction(1.2.c)

10 Case 3: Nickel and cadmium in overcharge. In this
 11 case, oxygen and hydrogen are produced and chemically
 12 recombined on the hydrogen electrode in the regulator cell
 13 to produce water and a large amount of heat (Reaction 1.1)
 14 and the regulator is in passive (open circuit) mode.

15 Increased pressure, reduced pressure, increased
 16 voltage, and a rise in temperature will all serve to
 17 indicate overcharge conditions and will trigger a signal to
 18 the charger to reduce the charge rate or terminate
 19 charging. The rise in battery voltage on charge is on the
 20 order of 300 millivolts per cell. The rise in temperature
 21 during charge is on the order of 5 - 10°C. Preferably, an
 22 overall gas pressure rise of about 0.1 atm will trigger a
 23 change in the rate of charging. Preferably, charging is
 24 terminated upon an overall gas pressure rise of about 1
 25 atm. The subject battery in accordance with the invention
 26 can be fast charged since overcharge conditions are
 27 promptly detected via change in gas pressure. Most of the
 28 heat generation takes place in the regulator cell upon
 29 recombination of hydrogen and oxygen to form water.

30 In FIG. 1, a control circuit 30 is shown having
 31 input from a pressure transducer 31, a temperature probe
 32 32, preferably at the location of the regulator cell 22,

1 and a voltage input via conductors 33 across the terminals
2 18 and 19. These inputs to the control circuit control the
3 output, such that the control circuit controls a selector
4 switch 34 which may be used to select a charger 35, a load
5 36 or, in effect, an open circuit 37 condition for the
6 working cells of the battery. The control circuit may also
7 control another selector switch 40 to selectively control a
8 charger 41, discharger or load 42, or an open circuit
9 terminal 43 for the regulator cell 22.

10 In open circuit, the battery will operate at
11 nominal hydrogen pressure in a preferred method of
12 operation. If nickel oxide electrodes evolve oxygen in
13 open circuit, the oxygen will react with the hydrogen in
14 the cell to produce water. This will reduce the pressure
15 in the cell. To counteract this effect it is possible to:
16 discharge the regulator (reaction 1.2c) and produce
17 hydrogen; or maintain the working cells at lower potential
18 for minimum oxygen evolution via an external load such as
19 high resistance 38. Preferably, oxygen gas in the gas
20 space is minimized because oxygen gas can passivate or
21 otherwise inactivate or adversely affect the hydrogen
22 electrode.

23 The Ni-Cd cell will thus operate as a standard
24 vented design. In principle, any type of nickel and Cd
25 electrode can be used, however, excessive electrolyte can
26 be very minimal. This would be a slightly flooded design
27 for the working cells.

28 The regulator cell 22 should contain enough
29 cadmium capacity to serve as an overcharge reserve for the
30 full battery. For example, if the battery is constructed
31 with ten Ni-Cd cells in series at 100 Ah each and one
32 regulator cell, and if one wishes to allow for a cumulative
33 10% of total positive electrode capacity to evolve oxygen
34 with no hydrogen evolution, the metallic Cd capacity of the
35 auxiliary cell should be at least: $100 \times 10 \times 10\% = 100$
36 Ah.

1 Balancing the battery is a part of the design
2 criteria. To obtain a chemical and pressure balance, the
3 regulator cell or cells serve as an overcharge buffer and
4 end of charge detector. It is desirable to return to the
5 nominal operating window that incorporates in the cell
6 partially charged cadmium electrodes and moderate hydrogen
7 pressure. The state of charge of the cadmium electrodes in
8 the regulator and the gas pressures in the cell can be
9 adjusted throughout the life of the battery by charging or
10 discharging the regulator.

11 Typically, batteries that are deep discharged
12 will become unbalanced after some time, and weak cells will
13 reverse and will generate H_2 gas. In the subject battery
14 this will be detectable because the gas pressure in the
15 common gas space will increase, which will be detectable by
16 the pressure sensor. Accordingly, deep discharge can be
17 detected and in an application such as an electrical
18 vehicle or other traction battery, a signal or indicator
19 can be activated, indicating to the operator that the
20 battery needs recharging. Additionally, the regulator cell
21 can be activated to consume the H_2 gas. Furthermore, the
22 regulator cell is capable of being charged or discharged
23 independently of the charging or discharging of the working
24 cells in the battery, and vice versa.

25 The electrolyte and water balance is also part of
26 balancing the battery. During overcharge gas will evolve
27 in the working electrodes and produce water in the auxilia-
28 ry cell. This will result in increasing the concentration
29 of electrolyte in the working cells and decreasing the
30 concentration of electrolyte in the auxiliary cell; howev-
31 er, all the cells share a common gas space 28. Since the
32 vapor pressure of dilute electrolyte is higher than that of
33 concentrated electrolyte, water will evaporate from the
34 auxiliary cell and condense in the working cells. This
35 will occur until electrolyte activity is equalized. In
36 effect, all the water that moves to the auxiliary cell

1 during overcharge will, over time, reverse or revert back
2 to the working cells, to result in zero net movement of
3 water or electrolyte. This results in a self balancing
4 situation.

5 The advantages of these aspects of the invention are:

- 6 1. Savings in weight, volume and cost.
 - 7 a. No excess CdO
 - 8 b. No excess electrolyte (compared to vented design)
 - 9 c. Single low pressure container for 10 cells
 - 10 d. Only three or four terminals for 10 cells
- 11 2. Sensitive overcharge detection via change of pressure
12 and rapid rise in temperature.
- 13 3. More adaptable to large multi-cell battery. The first
14 cell that overcharges or goes into reverse will affect the
15 total pressure as well as temperature balance in the bat-
16 tery and will generate a signal to change the electrical
17 state.
- 18 4. Lower manufacturing tolerance requirements.
- 19 5. None of the disadvantages of a vented cell battery.
- 20 6. The hydrogen atmosphere in the battery is protective
21 of the electrodes and the separators and will enhance
22 component life compared to the oxygen atmosphere typical of
23 sealed Ni-Cd cells.

24 EXAMPLE AND TEST

25 The basic idea of the present invention has been
26 verified with a 5-cell Ni-Cd sealed rechargeable battery
27 with 0.4 Ah capacity.

28 Fibrous nickel and cadmium electrodes were
29 employed for the working cells 13 and cadmium and hydrogen
30 electrodes for the regulator 22. The capacity of the
31 cadmium electrode of the regulator was 0.40 Ah.

32 The hydrogen electrode was the same design as
33 used for nickel-hydrogen cells known in the art. The
34 active layer contained a mixture of platinum (4mg/cm²) and

1 tetrafluoroethylene polymer known as Teflon and available
2 from Du Pont pressed on a nickel screen and a diffusion
3 back layer which contained only tetrafluoroethylene polymer
4 to provide fast diffusion of hydrogen under low pressure.

5 The cells were connected in series and were
6 placed in a vessel with a single regulator cell. The vessel
7 was filled with 0.5 atm of hydrogen. The battery had three
8 terminals: one positive for the working cells, one positive
9 for the regulator, and a common negative for the working
10 cells and the regulator. The above-described battery was
11 used for the tests reported in FIGS. 2 - 5.

12 This design was tested, as shown in FIGS. 2 - 4,
13 by cycling at currents of 0.5A (1.25C₅) for both charge and
14 discharge modes at room temperature. The charge was
15 terminated by a change in pressure of 0.1 atm and the
16 discharge was down to 5 volts; these conditions applied to
17 FIGS. 2 - 4.

18 Fig. 2 shows variations in battery voltage and
19 pressure during charge and discharge at room temperature.
20 After some pressure increase caused by oxygen evolution,
21 pressure drops as a result of oxygen and hydrogen combining
22 on the hydrogen electrode to form water. The pressure drop
23 triggers a signal to the charger to reduce the charge rate
24 or terminate charge. Charging is terminated upon a rise of
25 a little more than 1.8 volts and a pressure drop of about
26 0.1 atm. Hydrogen pressure is restored by means of
27 discharging the regulator. The regulator would be active in
28 this event.

29 Fig. 3 also shows variations in battery voltage
30 and pressure during charge and discharge at room
31 temperature. Overcharging is occurring and O₂ and H₂ are
32 evolved, causing a pressure rise. The rise in pressure
33 during charge is the same as the drop in pressure during
34 discharge. The regulator is passive in this event and is
35 used for consumption of stoichiometric amounts of hydrogen
36 and oxygen. This indicates that the overall evolution of

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1 oxygen and hydrogen is stoichiometric. The regulator was
2 electrically passive in Fig. 3; it recombined oxygen and
3 hydrogen but was not charging or discharging.

4 Fig. 4 is based on the same test as FIG. 3 and
5 displays battery capacity of the above-described battery
6 over 140 cycles. The regulator was kept passive as the
7 overall gas evolution was stoichiometric. As can be seen,
8 the battery displayed stable performance.

9 Fig. 5 shows that, in accordance with the
10 invention, the regulator cell can be charged and discharged
11 at room temperature to effectively control the gas pressure
12 in the battery and to significantly change the gas pressure
13 in the battery with only a small amount of energy being
14 consumed.

15 As noted above, the present invention also
16 applies to non-Ni-Cd batteries. Characteristics and
17 features of some of these are discussed below.

18 1. Ni-Zn with Zn-H₂ regulator

19 a. This battery provides a means for
20 consuming both oxygen and hydrogen without the need to
21 split all individual cells. This is in contrast to the
22 battery disclosed in U.S. Patent No. 5,143,799.

23 b. For this system there may be a trade
24 off between using a flooded electrolyte design to provide a
25 better overcharge reservoir versus using starved
26 electrolyte to minimize zincate (ZnO₂⁻²) migration.

27 c. With this design it is possible to
28 generate hydrogen on the nickel electrodes at positive cell
29 voltage to restore hydrogen pressure.

30 2. Ag-Zn

1 The discussion in a, b, and c immediately above
2 also applies here. In addition, since both electrodes
3 require very little overcharge, the amount of usage of the
4 regulator and thus its capacity (overcharge reservoir) can
5 be much reduced.

6 3. Ni-MHx (Nickel Metal Hydride)

7 a. This system generally operates at
8 hydrogen pressure. However, the equilibrium pressure is
9 temperature dependent. Thus, charge adjustment and
10 termination will have to be triggered more by the
11 temperature signal than by the pressure signal.

12 b. The lifetime of the metal hydride elec-
13 trode should be drastically improved compared to standard
14 designed Ni-MHx cells, since the metal hydride electrodes
15 of the working cell will not have to support oxygen reduc-
16 tion. The latter reaction is known to degrade the metal
17 hydride.

18 c. The present invention will permit the
19 construction of large nickel metal hydride cells which are
20 impractical to operate in a standard sealed-cell design.

21 d. The operating pressure is likely to be
22 higher than that of Ni-Cd monoblock, probably a few
23 atmospheres.

24 e. It is believed that it is possible to
25 have a cylindrical vessel with little volume penalty. This
26 is advantageous since cylindrical vessels can withstand
27 higher pressures than prismatic ones.

28 4. Nickel Iron (Ni-Fe), with Cd-H₂ or Fe-H₂ regulator

1 a. This design allows for a sealed nickel
2 iron battery, which is currently unknown in the art.

3 b. The capacity of the regulator will have
4 to be bigger than that of a Ni-Cd battery regulator, due to
5 the poor charging efficiency of the iron electrode.

6 5. Lead Acid (Pb-Acid)

7 In this battery the reaction at the regulator is:



9 Pb-Acid batteries are available in a flooded, and
10 semi-sealed Valve Regulated Lead Acid construction, known
11 as VRLA.

12 The life of the VRLA battery is considerably
13 shorter than the life of a flooded battery. This is because
14 the valve of the VRLA battery occasionally opens to allow
15 excess gas to escape and causes the starved cell stack to
16 dry out. The present invention provides for a sealed
17 battery which uses flooded cells. Thus lifetime before
18 dryout will be greatly extended since the individual cells
19 feature excess electrolyte.

20 The present disclosure includes that contained in
21 the appended claims, as well as that of the foregoing
22 description. Although this invention has been described in
23 its preferred form with a certain degree of particularity,
24 it is understood that the present disclosure of the
25 preferred form has been made only by way of example, and
26 that numerous changes in the details of the circuit and the
27 combination and arrangement of circuit elements may be
28 resorted to without departing from the spirit and scope of
29 the invention as hereinafter claimed.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE
PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

-18-

1 1. In a sealed rechargeable storage battery
2 containing one or more rechargeable working cells capable
3 of generating gas in a gas space within said sealed battery
4 during charging of said rechargeable working cells, the
5 improvement comprising at least one regulator cell provided
6 within said battery and in gaseous communication with said
7 gas space, said regulator cell being chargeable and
8 dischargeable by a control circuit to regulate the amount
9 of said gas.

1 2. A battery according to claim 1, wherein the
2 regulator cell is a metal hydrogen cell capable of consum-
3 ing or generating hydrogen gas in said gas space to thereby
4 regulate the amount of gas in the gas space.

1 3. A battery according to claim 1, wherein said
2 gas space is common to all of said rechargeable working
3 cells and to said regulator cell and said gas space is
4 charged with hydrogen.

1 4. A battery according to claim 2, including at
2 least three electrical terminals for connecting the battery
3 into an electrical circuit, at least one of said terminals
4 being connected to a hydrogen electrode of said metal
5 hydrogen cell via which said regulator cell is chargeable
6 and dischargeable independent of the charging and
7 discharging of said rechargeable working cells.

1 5. A battery according to claim 1, including
2 means for sensing the gas pressure within said gas space
3 wherein said sensed gas pressure can be used to control the
4 charging and discharging of said regulator cell.

1 6. A battery according to claim 1, including
2 means for sensing a temperature of said battery wherein
3 said sensed temperature can be used to control the charging
4 and discharging of said regulator cell.

1 7. A sealed rechargeable storage battery
2 comprising:
3 a sealed housing;
4 a plurality of rechargeable working cells within
5 the sealed housing;
6 means for connecting said working cells in
7 electrical series relationship with each other;
8 positive and negative terminals connected through
9 a wall of the sealed housing to respective positive and
10 negative ends of the series connected working cells;
11 at least one regulator cell within said sealed
12 housing and having a common gas space with said working
13 cells;
14 a metallic electrode and a hydrogen electrode in
15 said regulator cell;
16 a hydrogen terminal connected through a wall of
17 the sealed housing to the hydrogen electrode in said
18 regulator cell; and
19 means to make external connection to said
20 metallic electrode of said regulator cell.

1 8. A battery as set forth in claim 7, including
2 an electrolyte in each of said cells; and means to prevent
3 intermingling of the electrolytes of said working cells and
4 said regulator cell.

1 9. A battery as set forth in claim 7, including
2 a pressure sensor connected to be responsive to the
3 pressure in said common gas space of said sealed housing.

1 10. A battery as set forth in claim 7, wherein
2 said regulator cell is capable of generating or consuming
3 hydrogen within said common gas space.

1 11. A battery as set forth in claim 7, wherein
2 the regulator cell is capable of being charged or
3 discharged independently of the charging or discharging of
4 the working cells in the battery.

1 12. A sealed rechargeable storage battery
2 comprising in combination:
3 a sealed housing;
4 at least one rechargeable cell inside said
5 sealed housing;
6 a pressure regulator cell inside said
7 housing;
8 a pressure sensor mounted to sense pressure
9 inside said sealed housing;
10 a common gas space inside said housing for
11 said at least one rechargeable cell and said pressure
12 regulator cell; and
13 at least three terminals extending in a
14 sealed manner through the housing and connected to said at
15 least one rechargeable cell and to said pressure regulator
16 cell.

1 13. The battery as set forth in claim 12,
2 wherein said sealed housing common gas space contains
3 hydrogen.

1 14. The battery as set forth in claim 12,
2 wherein the gas pressure in said common gas space is
3 regulated by means of charging or discharging said
4 regulator cell in response to said pressure sensor.

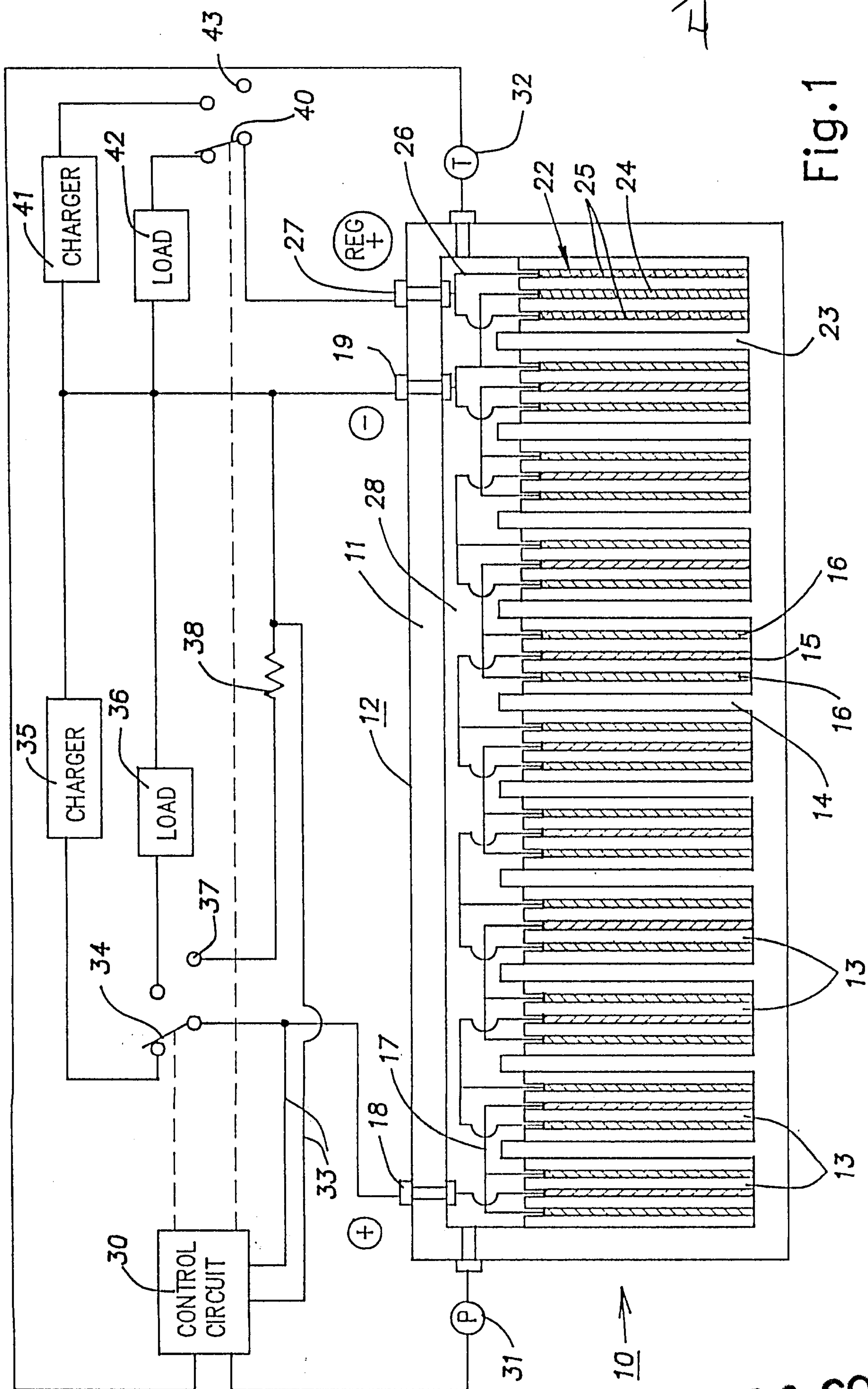
1 15. The battery as set forth in claim 12,
2 wherein one of said three terminals is connected solely to
3 said pressure regulator cell.

1 16. The battery as set forth in claim 14,
2 wherein the charging of the battery is terminated upon any
3 one of the pressure in the common gas space rising above or
4 dropping below a given pressure range, with temperature
5 rising above a given value, and with the voltage of the
6 battery rising above a given value.

1 17. The battery of claim 12, wherein the
2 rechargeable cell is any one of nickel-cadmium, nickel-
3 zinc, silver-zinc, nickel-metal hydride, nickel-iron,
4 manganese-zinc, and lead-acid (Pb-PbO₂).

1 18. The battery as set forth in claim 12,
2 wherein the regulator cell is comprised of a metal-hydrogen
3 reversible cell.

1 19. The battery of claim 18, wherein the
2 regulator cell is a rechargeable cell of any one of
3 cadmium-hydrogen, iron-hydrogen, zinc-hydrogen, metal
4 hydride-hydrogen and a lead-hydrogen cell.



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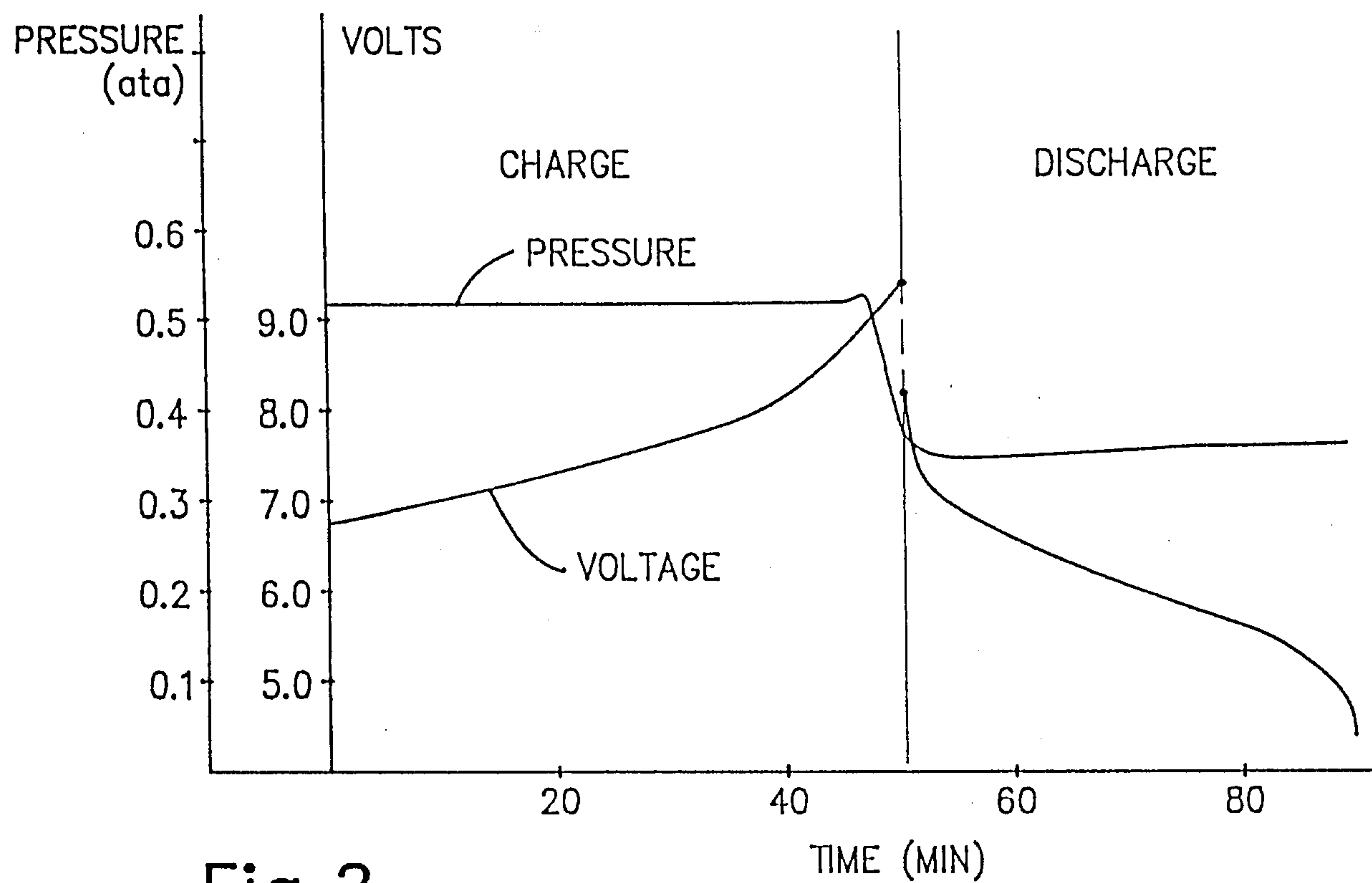


Fig. 2

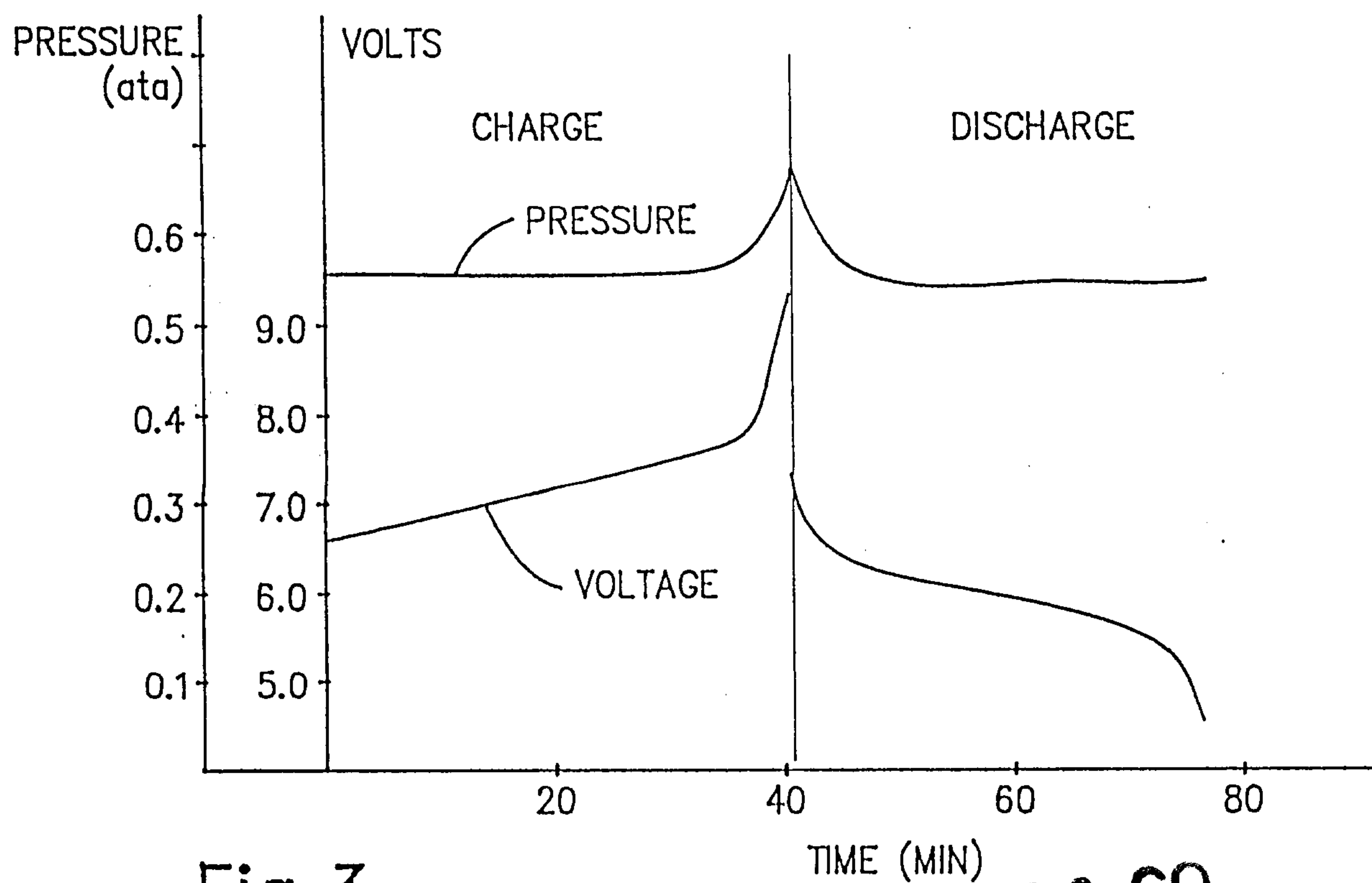


Fig. 3

Fig. 4 COMMON VESSEL SEALED RECHARGEABLE ALKALINE BATTERY
DISCHARGE CAPACITY, C/2 RATE

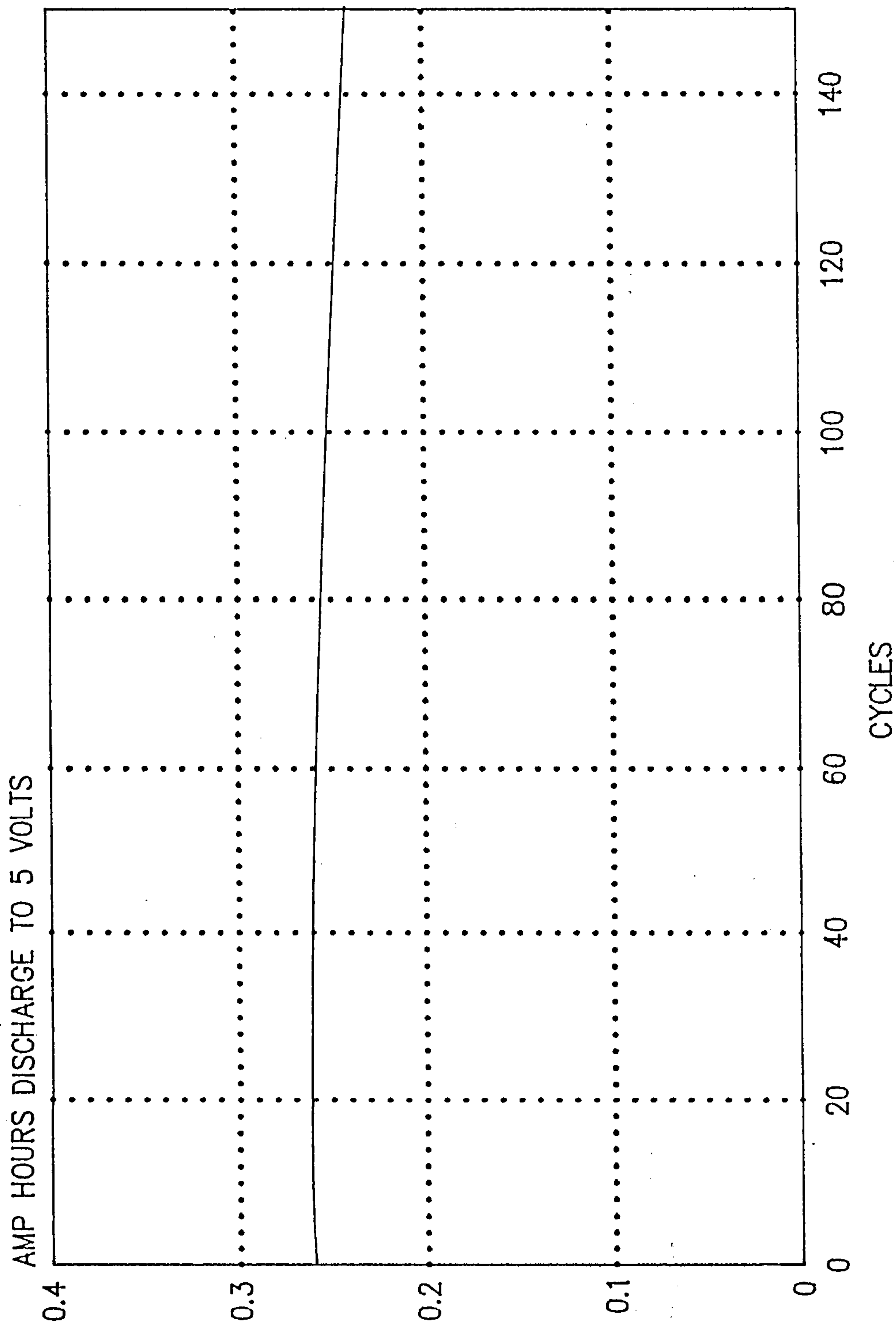


Fig. 5

