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H2H HBCD

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GB 2379099 A **US 5543702 A**

(58) Field of Search:
UK CL (Edition X) **H2H**
INT CL[7] **H01M, H02J**
Other: **EPODOC, WPI, INSPEC**

(54) Abstract Title: **Regenerating batteries using regulated, constant, low current**

(57) A constant regulated current is applied to batteries, particularly non-rechargeable, dry cell batteries (e.g. alkaline cells), to regenerate them. The current may be below 35mA and may be regulated to within +/- 10%. The rate of change of the voltage of the battery is monitored and the current is terminated when an increase in the rate of change the voltage is detected. Rechargeable batteries may also be regenerated using this method. The apparatus comprises a start switch 1, a voltage source with current stabiliser 2, battery 3, a control device 4 and an indicator 5.

The battery may also be exposed to ultrasound vibrations or infra-red radiation during the application of the current.

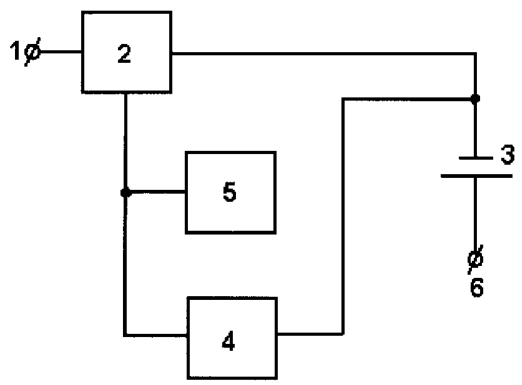

Fig 1

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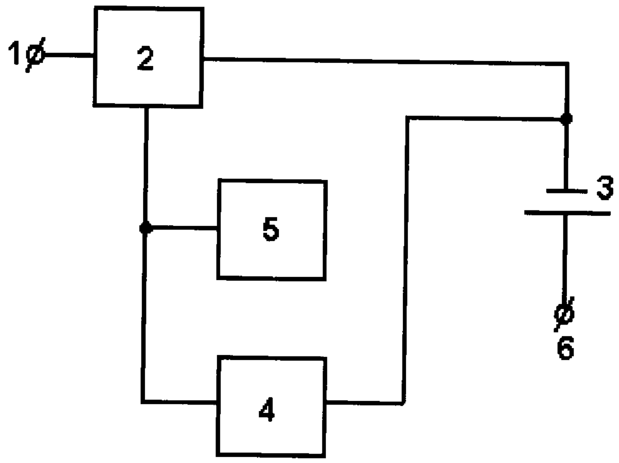

Fig 1

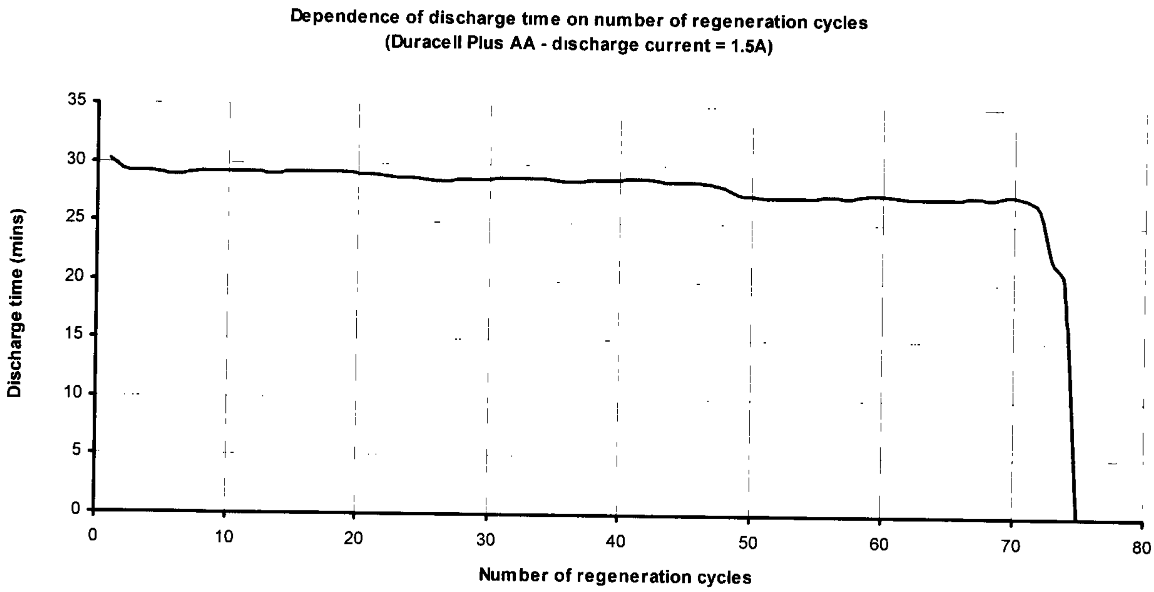

Fig 2

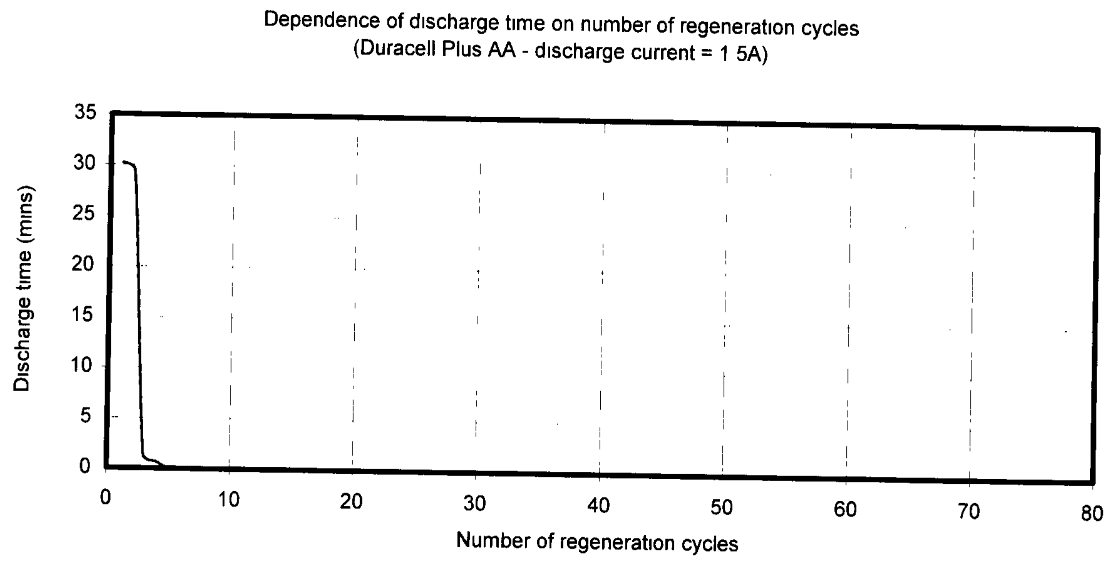
Dependence of discharge time on number of regeneration cycles
(Duracell Plus AA - discharge current = 1 5A)
Discharge time (mins)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
Number of regeneration cycles

Fig 3

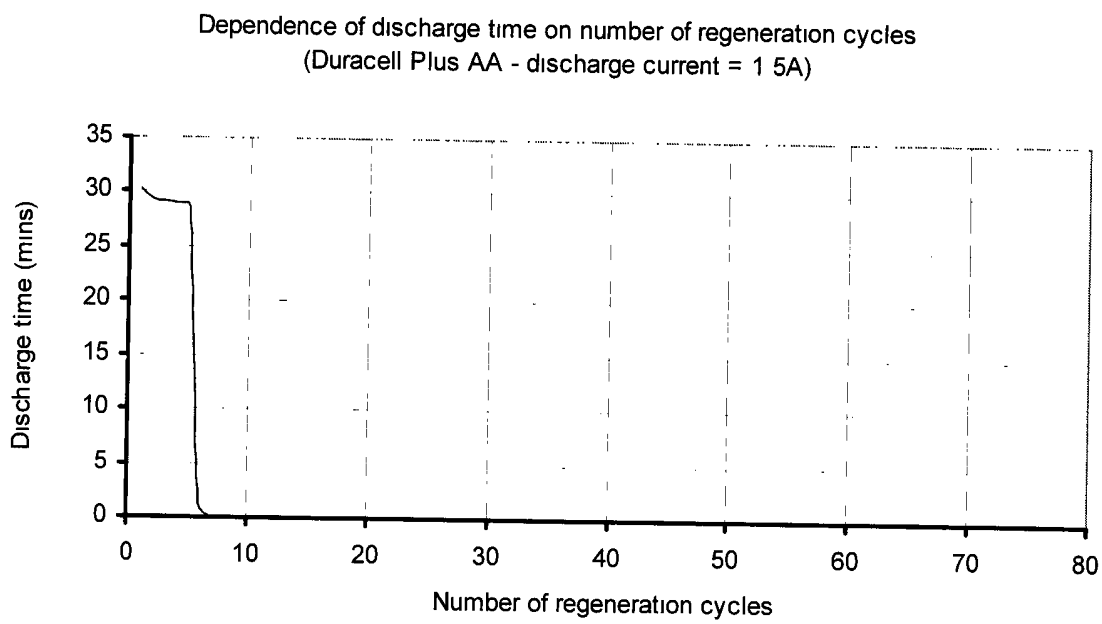
Dependence of discharge time on number of regeneration cycles
(Duracell Plus AA - discharge current = 1 5A)
Discharge time (mins)
0
5
10
15
20
25
30
35
0
10
20
30
40
50
60
70
80
Number of regeneration cycles

Fig 4

Dependence of discharge time on number of regeneration cycles
(Cegasa Evolution AA - discharge current = 1A)

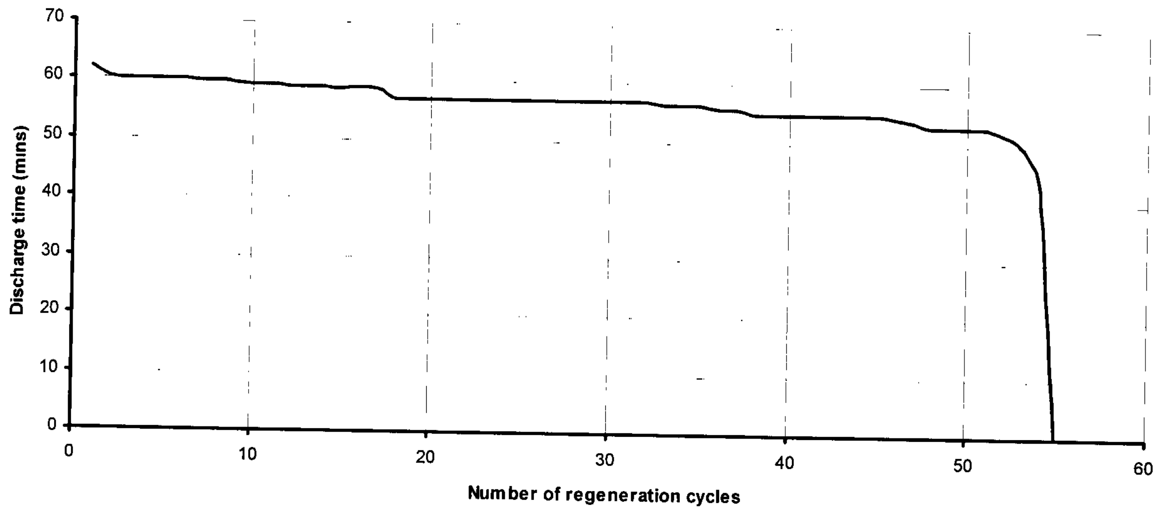

Fig 5

Dependence of discharge time on number of regeneration cycles
(Cegasa Evolution AA - discharge current = 1A)

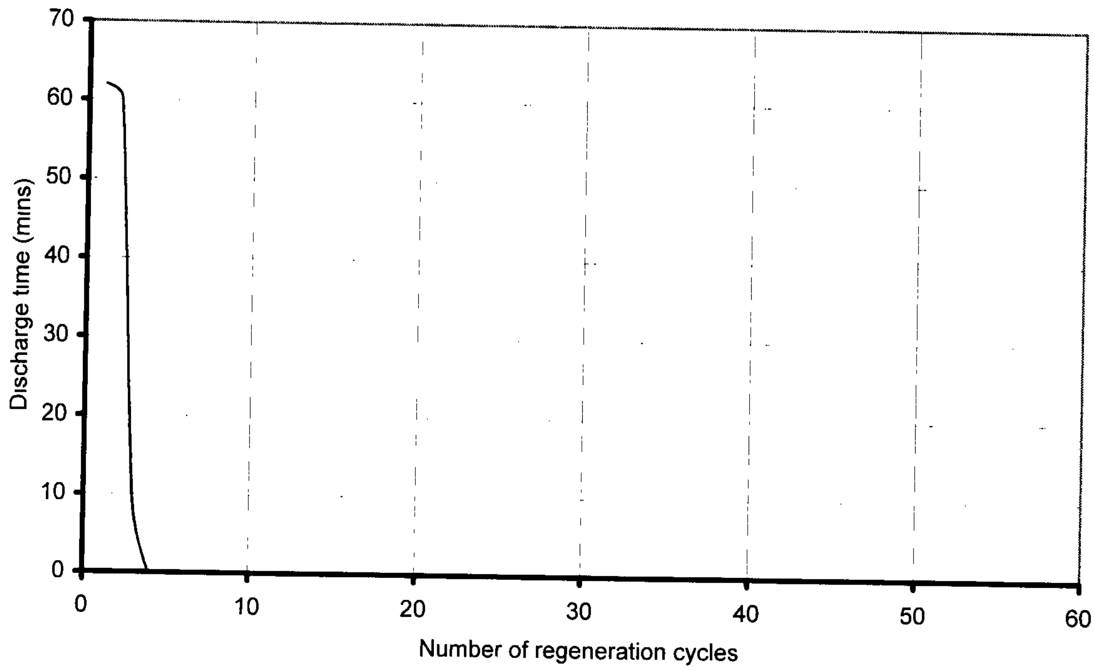

Fig 6

Dependence of discharge time on number of regeneration cycles
(Cegasa Evolution AA - discharge current = 1A)

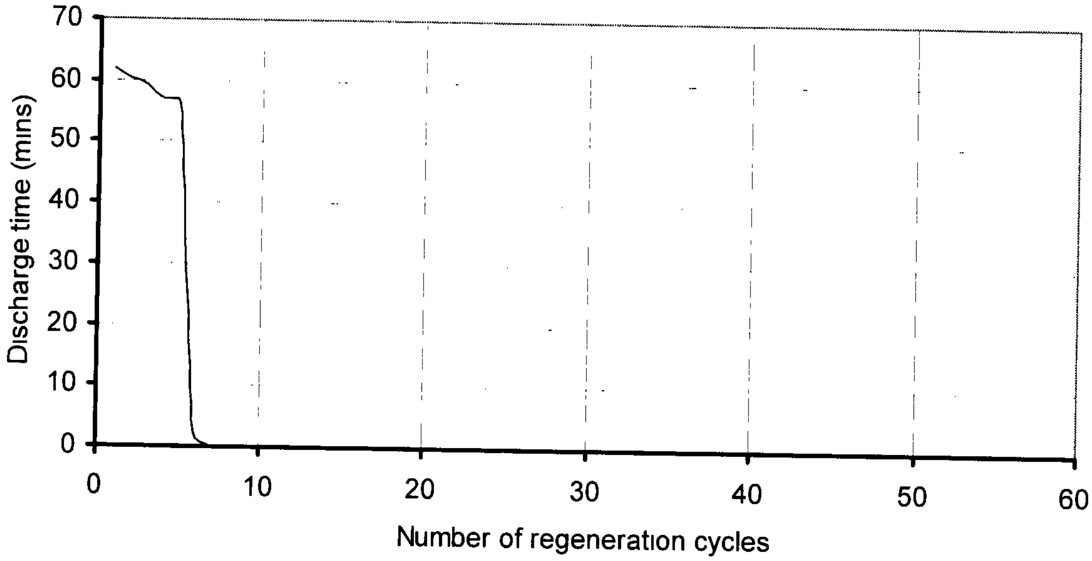

Fig 7

Dependence of discharge time on number of regeneration cycles
(Duracell Ultra AAA - discharge current = 1 5A)

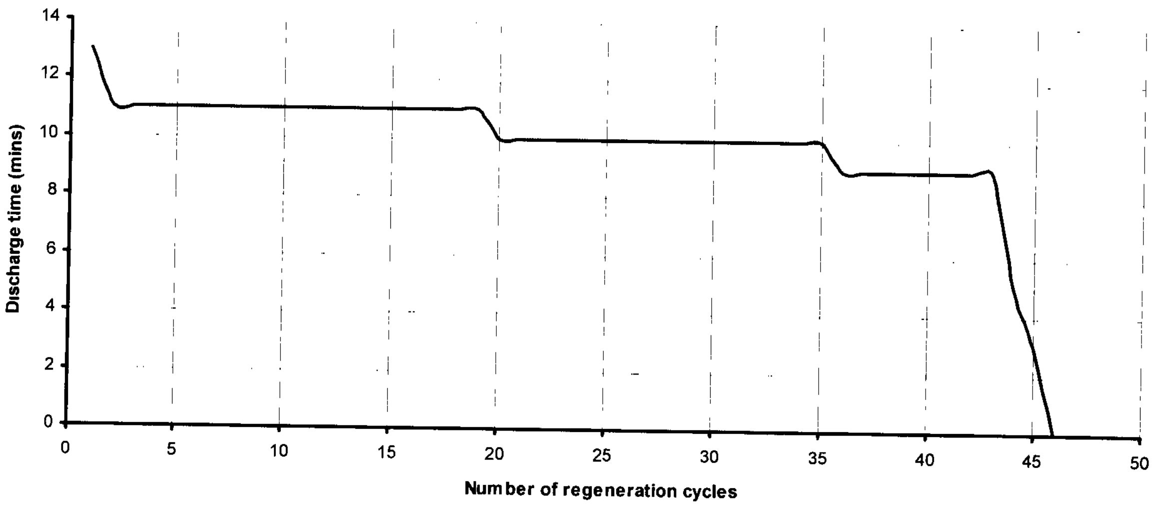

Fig 8

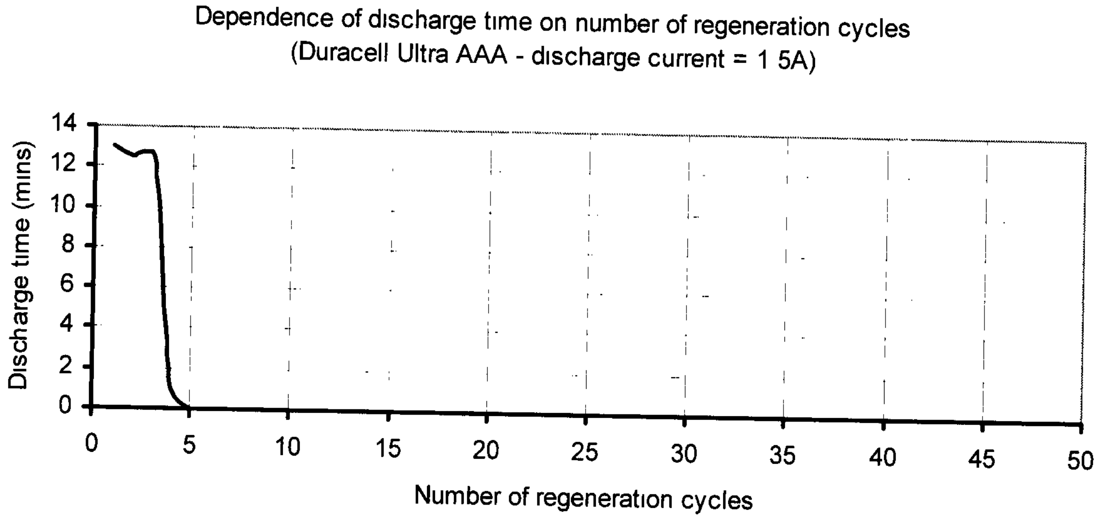
Dependence of discharge time on number of regeneration cycles
(Duracell Ultra AAA - discharge current = 1 5A)
Discharge time (mins)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
40
45
50
Number of regeneration cycles

Fig 9

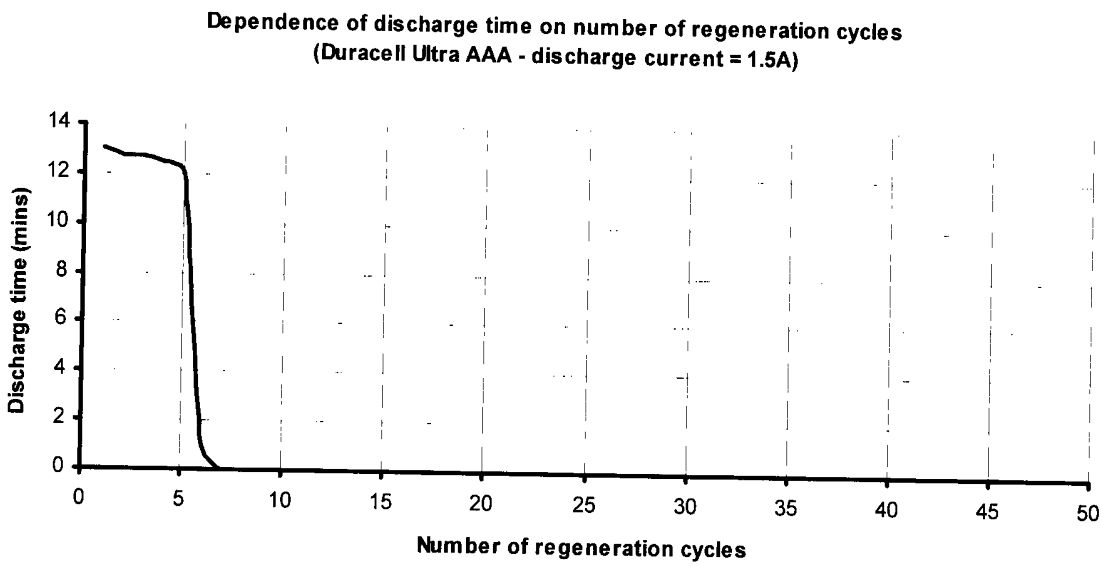
Dependence of discharge time on number of regeneration cycles
(Duracell Ultra AAA - discharge current = 1.5A)
Discharge time (mins)
0
2
4
6
8
10
12
14
0
5
10
15
20
25
30
35
40
45
50
Number of regeneration cycles

Fig 10

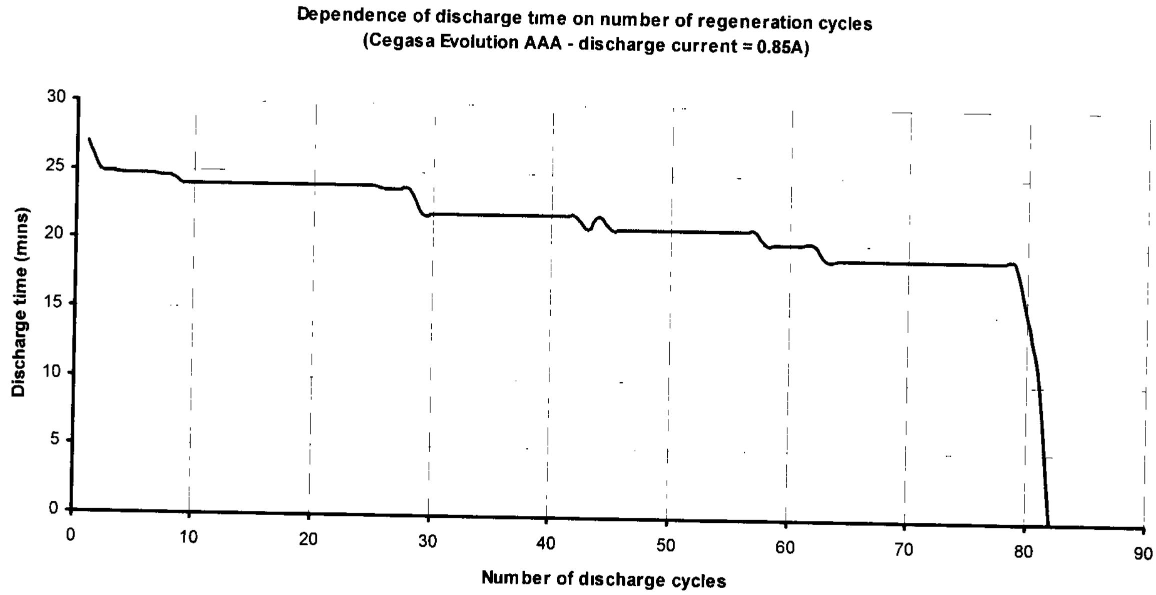
Dependence of discharge time on number of regeneration cycles
(Cegasa Evolution AAA - discharge current = 0.85A)
Discharge time (mins)
Number of discharge cycles
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90

Fig 11

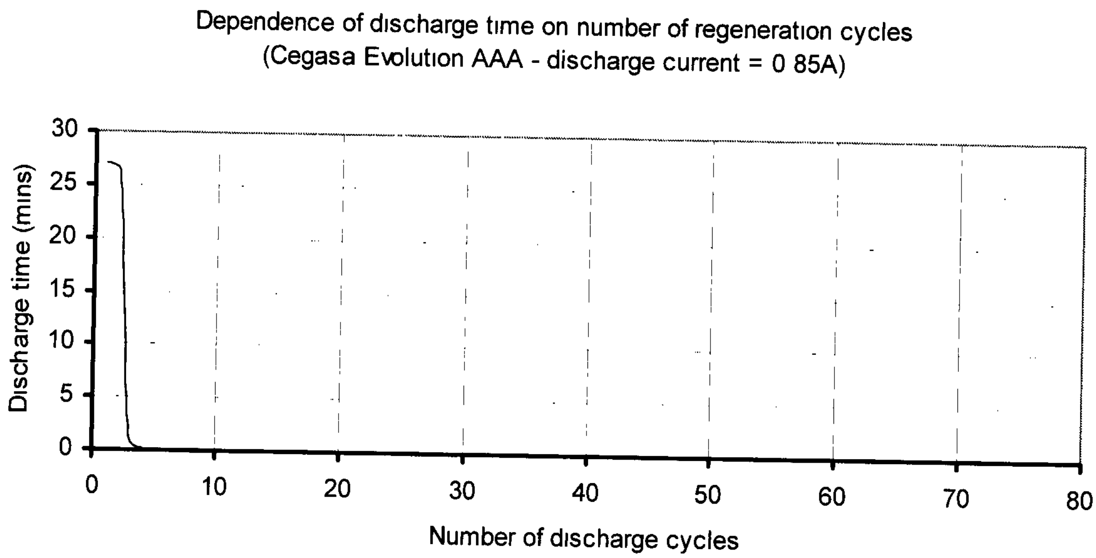
Dependence of discharge time on number of regeneration cycles
(Cegasa Evolution AAA - discharge current = 0 85A)
Discharge time (mins)
Number of discharge cycles
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80

Fig 12

Dependence of discharge time on number of regeneration cycles
(Cegasa Evolution AAA - discharge current = 0.85A)

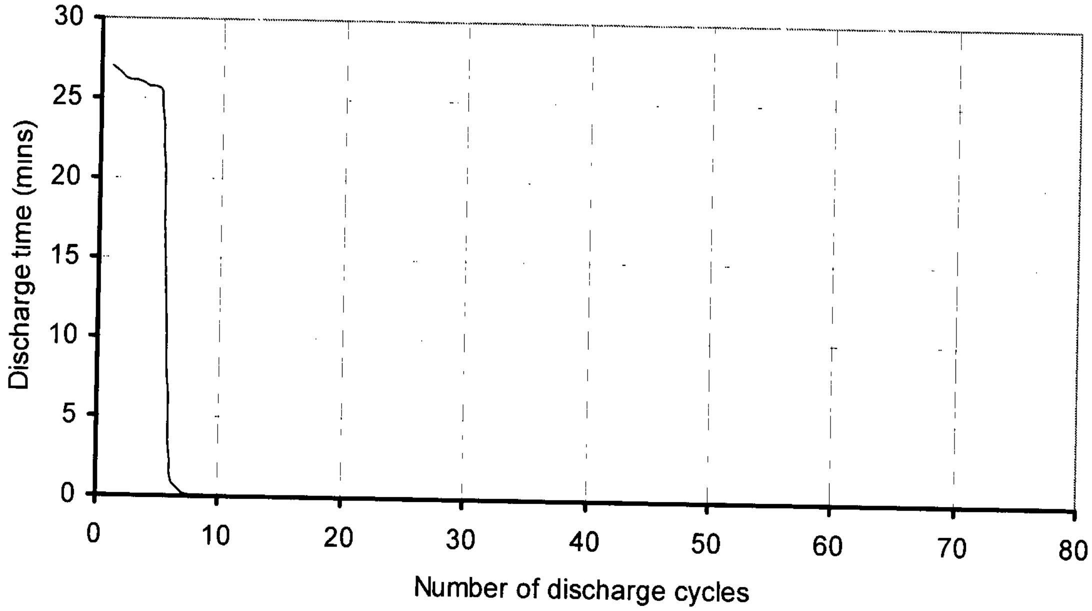

Fig 13

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METHOD OF AND APPARATUS FOR TREATING BATTERIES

Field of the Invention

This invention relates to a method of regenerating batteries, especially, but not exclusively, single-use non-rechargeable batteries such as alkaline cells, to a method of increasing the energy output of primary and secondary batteries, and to apparatus for treating dry cell batteries suitable for use in the methods of the invention.

Background to the Invention

Two general types of dry-cell battery are available for example for use in small domestic apparatus such as radios, personal stereo players, and cameras, namely rechargeable cells such as nickel cadmium (NiCd) cells and nickel metal hydride (NiMH) cells, and non-rechargeable or single-use cells such as alkaline cells in which the electrodes are zinc and manganese-oxide, with an alkaline electrolyte between them. Rechargeable cells tend to be more costly to buy initially, but can be cheaper overall, since the energy cost in recharging them is minimal. Single-use batteries, on the other hand, are cheaper to buy, but more expensive in use overall, and involve an additional environmental cost in their disposal.

While single-use batteries are intended to be discarded when their voltage drops below a useful level, there have been attempts to recharge such batteries for re-use, both to reduce waste disposal problems with spent batteries and to save on the cost of replacing them. For example, in GB-A-2 292 024 there is disclosed a battery charging circuit for use in recharging single-use batteries. This applies a relatively high charging current to the batteries for predetermined periods of approximately 60 seconds with short discharge periods in between. The voltage is monitored and the charging is terminated when the charging voltage exceeds a preset value or when the rate of increase of the charging voltage is less than a preset value. The specification acknowledges that some batteries will not be capable of being recharged. Repeated recharging is generally not possible.

Summary of the Invention

It has now been found that by careful application of a regulated low current, single-use batteries can be repeatedly regenerated for re-use. It has also been found that rechargeable batteries and unused alkaline batteries can be treated to increase their discharge time (useful electrical energy output) significantly over untreated batteries.

According to the invention, there is provided a method of regenerating dry cell batteries, comprising applying to the battery a constant regulated current below 35mA, monitoring the rate of change of the voltage of the battery, and ceasing the current when an increase in the rate of change of the voltage is detected.

The 35mA threshold is conditioned by the physical and chemical parameters at the electrode-electrolyte interface. When raising this threshold in the very narrow, near-electrode potential barrier zone, deteriorating battery parameters are observed, regardless of the technology of their manufacture (the effects of current/microarc lacing).

The invention also provides a method of increasing the energy output of primary and secondary batteries, comprising applying to the battery a constant regulated current below 35mA, monitoring the rate of change of the voltage of the battery, and ceasing the current when an increase in the rate of change of the voltage is detected.

The rate of change of the voltage of the battery is conveniently monitored by measuring the voltage drop across the battery. It has been observed that during the conditioning process, the voltage rise is substantially linear; when the conditioning process is complete, there is a sudden change in the rate of increase.

Preferably, the current applied to the battery is 10mA or lower; although a significant number of regenerations can be achieved at higher currents, the best results have been obtained using a current in this lower range.

The current preferably needs to be regulated to ± 10%, and to ±1% for best results.

The regeneration cycle is especially applicable to alkaline batteries, and typically takes around 70 hours, depending on the manufacture of the battery. It has been found that the average useful number of regenerations achievable for various different manufactures and sizes of batteries is from 43 to 80 using a current of 10mA. Eventually, a stage is reached at which the battery can no longer store a useful amount of energy; the discharge time becomes very short.

The method of the invention is also applicable to rechargeable batteries such as NiCd and NiMH batteries, improving the capacity and rechargeable life of these batteries.

The invention also provides apparatus for regenerating dry cell batteries, comprising battery terminals for connection to a battery to be regenerated, a current source connected to the terminals to apply a regulated constant current to the terminals, a voltage circuit connected to said terminals to measure the voltage across the battery, in use, and control means for switching off the current source in response to detection of an increase in the rate of change of the measured voltage.

Preferably, the current source is adapted to maintain the applied current at less than 35mA, and more preferably at 10mA or lower. The regulation of the current is preferably to within ±10%, and ideally to within ±1%.

Brief Description of the Drawings

In the drawings:

Figure 1 is a block circuit diagram of an apparatus according to one embodiment of the invention; and

Figures 2 to 13 are graphs showing the results of tests as set out hereinafter in the Examples.

Detailed Description of the Illustrated Embodiment

Referring to Figure 1, the apparatus comprises a start switch 1 controlling a voltage source 2 with current stabiliser. The battery to be treated 3 is connected between the voltage source 2 and earth 6. A control device 4 measures the rate of voltage increase on the battery during the process, controlling the operation of the voltage source 2 and an indicator device 5.

In use, on receipt of a signal from the start switch 1 the voltage source with current stabiliser 2 applies a stabilised fixed current to the battery 3. Simultaneously the rate of voltage increase is monitored by the control device 4. Upon a significant rise in the rate of voltage increase on the battery being detected, the control device 4 switches off the voltage source with current stabiliser 2 and switches on the indicator device 5 to signal the end of the regeneration process.

Example 1

Primary alkaline batteries in AA and AAA sizes were studied to determine the capability of multiple regeneration using the method of the present invention, after full discharge.

The following batteries were studied:

- Duracell® Plus AA – 10pcs
- Cegasa® Evolution AA – 10pcs
- Duracell® Ultra AAA – 10pcs
- Cegasa® Evolution AAA – 10pcs

The batteries were discharged to a cutoff voltage of 0.8V for Duracell®® batteries and of 0.9V for Cegasa® batteries (accordant to the respective standard discharge regimes of these companies).

The batteries were then regenerated, stored in an idle state for 24 hours and then discharged under the same conditions at room temperature, using the maximum permissible discharge current for each type (again, accordant to respective standard discharge regimes of Duracell® and Cegasa®), as follows:

- Duracell® Plus AA – 1.5A
- Cegasa® Evolution AA – 1A
- Duracell® Ultra AAA – 1.5A
- Cegasa® Evolution AAA – 0.85A

The process was then repeated on multiple occasions.

The average duration for a regeneration cycle was as follows:

- Duracell® Plus AA – 73 hours
- Cegasa® Evolution AA – 69 hours
- Duracell® Ultra AAA – 71 hours
- Cegasa® Evolution AAA – 68 hours

The average number of regeneration cycles performed per battery type:

- Duracell® Plus AA – 74 cycles
- Cegasa® Evolution AA – 54 cycles
- Duracell® Ultra AAA – 46 cycles

- Cegasa® Evolution AAA – 82 cycles

Each of Figures 2 to 13 is a graph of discharge time at the respective standard discharge current as set out hereinbefore against the number of regeneration cycles performed.

Figures 2 to 4 show the results of tests applied to Duracell® Plus AA batteries at regeneration currents of 10mA, 35mA and 34.5mA, respectively. In each case, the battery was first discharged from new over a period of 30.2 minutes. At a current of 35.2mA, no regeneration cycles were achieved.

Figures 5 to 7 show the results of tests applied to Cegasa® Evolution AA batteries at regeneration currents of 10mA, 35mA and 34.5mA, respectively. In each case, the battery was first discharged from new over a period of 62 minutes. At a current of 35.2mA, no regeneration cycles were achieved.

Figure 8 to 10 show the results of tests applied to Duracell® Ultra AAA batteries at regeneration currents of 10mA, 35mA and 34.5mA, respectively. In each case, the battery was first discharged from new over a period of 13 minutes. At a current of 35.2mA, no regeneration cycles were achieved.

Figures 11 to 13 show the results of tests applied to Cegasa® Evolution AAA batteries at regeneration currents of 10mA, 35mA and 34.5mA, respectively. In each case, the battery was first discharged from new over a period of 27 minutes. At a current of 35.2mA, no regeneration cycles were achieved.

It will be seen that it is possible reliably to regenerate single-use batteries multiple times with a substantial proportion of the original discharge time (i.e. charge capacity).

Example 2

The method of the invention can be applied also for enhancing the parameters of new, unused batteries, both primary non-rechargeable (single-use) and secondary, rechargeable (multiple-use) batteries. On average this improvement equals 15%.

For Duracell® Plus alkaline batteries, under a current of 10mA the capacity increased by 17%; at a current of 35mA the increase is equal to 1%. Over 35mA no improvement in capacity is observed.

For Ansmann® 2300 mAh NiMH batteries, under a current of 7mA the capacity increased by 11%; at a current of 35mA the increase is equal to 0.7%, while at currents over 35mA no improvement in capacity is observed.

CLAIMS

1. A method of regenerating dry cell batteries, comprising applying to the battery a constant regulated current below 35mA, monitoring the rate of change of the voltage of the battery, and ceasing the current when an increase in the rate of change of the voltage is detected.

2. A method of increasing the energy output of primary and secondary batteries, comprising applying to the battery a constant regulated current below 35mA, monitoring the rate of change of the voltage of the battery, and ceasing the current when an increase in the rate of change of the voltage is detected.

3. A method according to Claim 1 or 2, comprising applying a current of 10mA or lower.

4. A method according to Claim 1, 2 or 3, wherein the current is maintained at within ±10%.

5. A method according to Claim 4, wherein the current is maintained at within ±1%.

6. A method according to any preceding claim, comprising exposing the battery to ultrasound vibrations during application of the current.

7. A method according to Claim 6, wherein the ultrasound vibrations are applied at a frequency corresponding to the resonant frequency of the electrodes in the battery.

8. A method according to any preceding claim, comprising exposing the battery to infra-red radiation during application of the current.

9. A method according to Claim 8, wherein the infra-red radiation is at a frequency corresponding to the resonant frequency of the electrode-electrolyte interface in the battery.

10. Apparatus for treating dry cell batteries, comprising battery terminals for connection to a battery to be regenerated, a current source connected to the terminals to apply a regulated constant current to the terminals, a voltage circuit connected to said terminals to measure the voltage across the battery, in use, and control means for switching off the current source in response to detection of an increase in the rate of change of the measured voltage.

11. Apparatus according to Claim 10, wherein the current source is adapted to apply a regulated current of less than 35mA.

12. Apparatus according to Claim 11, wherein the current source is adapted to apply a regulated current of 10mA or lower.

13. Apparatus according to Claim 10, 11 or 12, wherein the current source is arranged to maintain the current within ±10%.

14. Apparatus according to Claim 13, wherein the current source is arranged to maintain the current within ±1%.

15. A method of regenerating dry cell batteries, substantially as described in the Examples and/or with reference to the drawings.

16. A method of increasing the energy output of primary and secondary batteries, substantially as described in the Examples and/or with reference to the drawings.

17. Apparatus for treating dry cell batteries, substantially as described with reference to Figure 1 of the drawings.

The Patent Office

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INVESTOR IN PEOPLE

Application No: GB0415639.4

Claims searched: All

Examiner: Mr Rowland Hunt

Date of search: 21 September 2005

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
Y	1-5, 10-14	US 5543702 A (PFEIFFER) see whole document
Y	1-5, 10-14	GB 2379099 A (SENDO) see whole document

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

H2H

Worldwide search of patent documents classified in the following areas of the IPC^{07}

H01M; H02J

The following online and other databases have been used in the preparation of this search report

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