

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
15 March 2001 (15.03.2001)

PCT

(10) International Publication Number  
**WO 01/18893 A2**

(51) International Patent Classification<sup>7</sup>: H01M 6/06

Franklin, MA 02038 (US). VU, Viet, H. [US/US]; 8 Wildebrook Road, Medway, MA 02053 (US). **WOODNORTH, Douglas** [US/US]; 90 Manning Street, Needham, MA 02494 (US).

(21) International Application Number: PCT/US00/40838

(74) Agents: **HANDELMAN, Joseph, H.**; Ladas & Parry, 26 West 61 Street, New York, NY 10023-7604 et al. (US).

(22) International Filing Date:  
7 September 2000 (07.09.2000)

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(25) Filing Language: English

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

(26) Publication Language: English

**Published:**

(30) Priority Data:  
09/393,043 9 September 1999 (09.09.1999) US

- With international search report.
- Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:  
US 09/393,043 (CON)  
Filed on 9 September 1999 (09.09.1999)

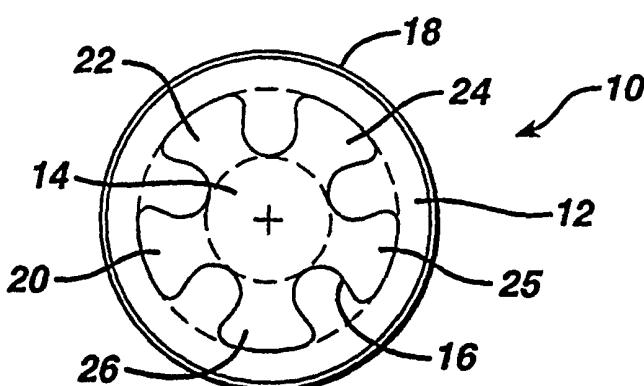
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(71) Applicant (for all designated States except US): **THE GILLETTE COMPANY** [US/US]; Prudential Tower Building, Boston, MA 02199 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **LUO, Weifang** [CN/US]; 234 Rock Street, Norwood, MA 02062 (US). **PATEL, Bhupendra, K.** [US/US]; 393 Franklin Street, Mansfield, MA 02048 (US). **SHELEKHIN, Alexander, B.** [RU/US]; 5 Paul Revere Road, Acton, MA 01720 (US). **SILLESKY, John, D.** [US/US]; 25A Hawthorne Village,

(54) Title: BATTERY



(57) Abstract: A primary alkaline battery (10) includes a housing (18), a cathode (12) within the housing, an anode (14) within the housing, and a separator (16) electrically separating the anode and the cathode. The battery has a substantial (S/V)<sup>2</sup> value.

WO 01/18893 A2

- 1 -

## BATTERY

This invention relates to batteries.

Batteries, such as alkaline batteries, are commonly used as energy sources. Generally, alkaline batteries include a cathode, an anode, a separator, and 5 an electrolytic solution. The cathode is typically formed of an active material (e.g., manganese dioxide), carbon particles, and a binder. The anode can be a gel including an active material (e.g., zinc particles). The separator is usually disposed between the cathode and the anode. The electrolytic solution, which is dispersed throughout the battery, can be a hydroxide solution.

10 Alkaline batteries include the conventional AA, AAA, AAAA, C, and D batteries commonly sold in stores. These conventional alkaline batteries include a cylindrical container containing a central, cylindrical zinc gel anode surrounded by a ring-shaped manganese dioxide cathode.

15 It generally is desirable for a battery to have a long service life. One measure of the service life of a battery is the length of time the battery can discharge under a given load before the voltage drops to an unacceptable level.

The invention relates to a battery having a good service life when discharged continuously, for example, at 1 amp. The good service life is provided by including a high interface area between the cathode and the anode in the battery.

20 One way to provide a relative measure of interface area between the anode and the cathode is to approximate the "effective thickness" of the cathode. For a particular battery (e.g., a AA battery), the smaller the cathode thickness, the greater the interface area per cathode volume. The relative effective thickness of a cathode can be estimated by using the equation  $(S/V)^2$  where S is the separator 25 surface area and V is the cathode volume.

In another aspect, the invention features a AA battery in which  $(S/V)^2$  is greater than 0.38, preferably greater than 0.40, and more preferably greater than 0.42 or 0.45.

30 In another aspect, the invention features a AAA battery in which  $(S/V)^2$  is greater than 0.70, preferably greater than 0.75, and more preferably greater than 0.80 or 0.82.

In another aspect, the invention features a AAAA battery in which

- 2 -

(S/V)<sup>2</sup> is greater than 1.2, preferably greater than 1.3, and more preferably greater than 1.4 or 1.5.

In another aspect, the invention features a C battery in which (S/V)<sup>2</sup> is greater than 0.110, preferably greater than 0.120, and more preferably greater than 0.125 or 0.130.

In another aspect, the invention features a D battery in which (S/V)<sup>2</sup> is greater than 0.65, preferably greater than 0.70, and more preferably greater than 0.75, 0.80, 0.9, or 1.0.

In another aspect, the invention features a AA battery including a single cavity anode within the cathode. The (S/V)<sup>2</sup> of the battery is greater than 0.15, preferably greater than 0.20, and more preferably greater than 0.30, 0.35, or 0.40.

In another aspect, the invention features a AAA battery including a single cavity anode within the cathode. The (S/V)<sup>2</sup> of the battery is greater than 0.3, preferably greater than 0.4, and more preferably greater than 0.5 or 0.6.

In another aspect, the invention features a AAAA battery including a single cavity anode within the cathode. The (S/V)<sup>2</sup> of the battery is greater than 0.6, preferably greater than 0.8, and more preferably greater than 1.0, 1.2 or 1.5.

In another aspect, the invention features a C battery including a single cavity anode within the cathode. The (S/V)<sup>2</sup> of the battery is greater than 0.06, preferably greater than 0.08, and more preferably greater than 0.09, 0.10, or 0.11.

In another aspect, the invention features a D battery including a single cavity anode within the cathode. The (S/V)<sup>2</sup> of the battery is greater than 0.03, preferably greater than 0.04, and more preferably greater than 0.05, 0.06, 0.07, or 0.08.

In another aspect, the invention features a battery including a cylindrical housing, a first electrode, and a one-cavity second electrode within the first electrode. The battery has a (S/V)<sup>2</sup>/cathode OD vs. cell diameter value of at least 0.01, more preferably at least 0.02, and most preferably at least 0.03 or 0.04, above Plot A, which is subsequently defined.

In another aspect, the invention features a battery including a cylindrical housing, a first electrode, and a second electrode within the first

- 3 -

electrode. The battery has a  $(S/V)^2$ /cathode OD vs. cell diameter value of at least 0.01, more preferably at least 0.02, and most preferably at least 0.03 or 0.04, above Plot B, which is subsequently defined.

Preferably, the batteries described above have a cathode including  
5 manganese dioxide and an anode including zinc.

In some preferred embodiments, one electrode (e.g., the anode) includes a lobed cavity within the other electrode. The lobed cavity may include, for example, two, three, four, five, or nine lobes. In fact, in another aspect, the invention features a battery including a nine-lobed electrode.

10 In other preferred embodiments, one electrode (e.g., the anode) includes multiple cavities within the other electrode. For example, the multiple cavities may include cylindrical cavities, D-shaped cavities, or pie-shaped cavities. The cavities may be connected by a narrow connecting portion.

15 Other features and advantages of the invention will be apparent from the description of the preferred embodiments thereof, and from the claims.

Fig. 1 is a side-sectional view of a battery including a central anode having five lobes taken through the center of the battery;

Fig. 2 is a cross-sectional view of the battery in Fig. 1, taken at II-II in Fig. 1;

20 Fig. 3 is a plot of Voltage v. Capacity (Ah) for two AA batteries discharged continuously at 1 amp.;

Fig. 4 is a plot of capacity (Ah) at 1.0V cutoff versus current (mA) for two AA batteries;

25 Fig. 5 is a cross-sectional view of a battery including an anode including two D-shaped cavities;

Fig. 6 is a perspective view of a battery including an anode including four pie-shaped cavities;

Fig. 7 is a cross-sectional view of a battery including a central anode having nine lobes; and

30 Fig. 8 is a plot of  $(SV)^2$ /cathode diameter v. cell diameter for five batteries.

Referring to Figs. 1 and 2, battery 10 includes a cathode 12, an anode

- 4 -

14, separator 16 and a cylindrical housing 18. Anode 14 includes five lobes (20, 22, 24, 25, and 26). Battery 10 also includes current collector 28, seal 30, and a negative metal top cap 32, which serves as the negative terminal for the battery. The cathode is in contact with the housing, and the positive terminal of the battery 5 is at the opposite end of the battery from the negative terminal. An electrolytic solution is dispersed throughout battery 10. For purposes of the dimensions for the example described below, battery 10 is a AA battery.

Cathode 12 includes manganese dioxide, carbon particles, and a binder.

10 Any of the conventional forms of manganese dioxide used for cathodes can be used. The preferred manganese dioxide is EMD, although CMD can also be used. Distributors of such manganese dioxides include Kerr McGee, Co. (Trona D), Chem Metals, Co., Tosoh, Delta Manganese, Mitsui Chemicals and JMC. Generally, the cathode will include between 80% and 88% of manganese 15 dioxide by weight.

The carbon particles also can be any of the conventional carbon particles used in cathodes. They can be synthetic or nonsynthetic, and they can be expanded or nonexpanded. In certain embodiments, the carbon particles are nonsynthetic, nonexpanded graphite particles. In these embodiments, the graphite 20 particles preferably have an average particle size of less than about 20 microns, more preferably from about 2 microns to about 12 microns, and most preferably from about 5 microns to about 9 microns as measured using a Sympatec HELIOS analyzer. Nonsynthetic, nonexpanded graphite particles can be obtained from, for example, Brazilian Nacional de Grafite (Itapecirica, MG Brazil (MP-0702X)). 25 Generally, the cathode will include between 5% and 8% of carbon particles by weight.

Examples of binders include polyethylene powders, polyacrylamides, Portland cement and fluorocarbon resins, such as PVDF and PTFE. An example of a polyethylene binder is sold under the tradename Coathylene HA-1681 (Hoescht). 30 Generally, the cathode includes between 0.1 percent to about 1 percent of binder by weight.

Cathode 12 can include other additives. Examples of these additives

- 5 -

are disclosed in U.S. Patent No. 5,342,712, which is hereby incorporated by reference. Cathode 12 may include, for example, from about 0.2 weight percent to about 2 percent  $TiO_2$  weight.

5 The electrolyte solution also is dispersed through cathode 12, and the weight percentages provided above are determined after the electrolyte solution has been dispersed.

Anode 14 can be formed of any of the standard zinc materials used in battery anodes. For example, anode 14 can be a zinc gel that includes zinc metal particles, a gelling agent and minor amounts of additives, such as gassing inhibitor.

10 In addition, a portion of the electrolyte solution is dispersed throughout the anode.

The zinc particles can be any of the zinc particles conventionally used in gel anodes. Other examples of zinc particles used in the anode include those described in U.S.S.N. 08/905,254. U.S.S.N. 09/115,867 and U.S.S.N. 09/156,915, which are assigned to the assignee in the present application and are hereby incorporated by reference. Generally, the anode includes between 67% and 71% of zinc particles by weight.

15 Gelling agents that can be used in anode 14 include polyacrylic acids, grafted starch materials, salts of polyacrylic acids, polyacrylates, carboxymethyl-cellulose or combinations thereof. Examples of such polyacrylic acids are Carbopol 940 and 934 (B.F. Goodrich) and Polygel 4P (3V), and an example of a grafted starch material is Waterlock A221 (Grain Processing Corporation, Muscatine, IA). An example of a salt of a polyacrylic acid is Alcosorb G1, (Ciba Specialties). The anode generally includes from 0.1 percent to about 1 percent gelling agent by weight. These weight percentages correspond to when the electrolytic solution is dispersed throughout the anode.

20 Gassing inhibitors can be inorganic materials, such as bismuth, tin, lead and indium. Alternatively, gassing inhibitors can be organic compounds, such as phosphate esters, ionic surfactants or nonionic surfactants. Examples of ionic surfactants are disclosed in, for example, U.S. Patent No. 4,777,100, which is hereby incorporated by reference.

25 Separator 16 can have any of the conventional designs for battery separators. In some embodiments, separator 16 can be formed of two layers of

- 6 -

nonwoven, non-membrane material with one layer being disposed along a surface of the other. To minimize the volume of separator 16 while providing an efficient battery, each layer of nonwoven, non-membrane material can have a basis weight of about 54 grams per square meter, a thickness of about 5.4 mils when dry and a 5 thickness of about 10 mils when wet. In these embodiments, the separator preferably does not include a layer of membrane material or a layer of adhesive between the nonwoven, non-membrane layers. Generally, the layers can be substantially devoid of fillers, such as inorganic particles.

In other embodiments, separator 16 includes an outer layer of cellophane with a layer of nonwoven material. The separator also includes an additional layer of nonwoven material. The cellophane layer can be adjacent cathode 12 or the anode. Preferably, the nonwoven material contains from about 78 weight percent to about 82 weight percent PVA and from about 18 weight percent to about 22 weight percent rayon with a trace of surfactant. Such nonwoven materials are available 15 from PDM under the tradename PA36.

The electrolytic solution dispersed throughout battery 10 can be any of the conventional electrolytic solutions used in batteries. Typically, the electrolytic solution is an aqueous hydroxide solution. Such aqueous hydroxide solutions include potassium hydroxide solutions including, for example, between 20 33% and 38% by weight percent potassium hydroxide, and sodium hydroxide solutions.

Housing 18 can be any conventional housing commonly used in primary alkaline batteries. The housing typically includes an inner metal wall and an outer electrically nonconductive material such as heat shrinkable plastic. 25 Optionally, a layer of conductive material can be disposed between the inner wall and the cathode 12. This layer may be disposed along the inner surface of wall, along the outer circumference of cathode 12 or both. This conductive layer can be formed, for example, of a carbonaceous material. Such materials include LB1000 (Timcal), Eccocoat 257 (W.R. Grace & Co.), Electrodag 109 (Acheson Industries, Inc.), Electrodag 112 (Acheson) and EB0005 (Acheson). Methods of applying the 30 conductive layer are disclosed in, for example, Canadian Patent No. 1,263,697, which is hereby incorporated by reference.

- 7 -

Current collector 28 is made from a suitable metal, such as brass.

Seal 30 can be made, for example, of nylon.

An example of battery 10 (AA) was prepared according to the following procedure. An MnO<sub>2</sub> cathode mix is prepared by combining 85.5% EMD 5 (from Kerr McGee), 7.3% graphite (Coathylene HA1681 from Hoescht), 0.3% polyethylene binder (MP-0702X from Nacional de Graphite), and 6.9% electrolyte solution. The MnO<sub>2</sub> mix then is compressed under pressure in a die slotted with a five lobe cavity using the following equipment and procedure:

10 Equipment: Carver Automatic Press, 3888, 1DI0A00, Pellet Die Assembly (Pellet Die Sleeve, Bottom Punch and Core Pin, 29.88 mm, height gage, Top Punch and Core Extractor, Bottom Plate), Balance (3 decimal place), Digital Calipers (0.01 mm).

Procedure:

1. Assemble the pellet die tooling by placing the core pin inside the bottom punch. Slide the pellet die sleeve over the core pin and bottom punch and place the assembly on the bottom plate.
2. Weigh out the granulated MnO<sub>2</sub> mix and pour evenly into the assembly.
3. Place the top punch over the core road and press down until the punch is seated. Slide the height gage around the punch rod.
4. Place the core remover on top of the assembly and load the assembly inside the Carver Automatic Press.
5. Set the press to 5000 psi compression strength and 75% compression speed. Dwell time is set at 4 seconds.
- 25 6. Depress both the activator buttons to raise the assembly until 700 psi registers on the read-out. Allow the press to finish its cycle.
7. Remove the assembly and place the core remover on the bottom of the pellet die assembly. Insert the core pin remover into the assembly and place back into the press.
- 30 8. Depress both of the activator buttons until the top punch closes to approximately 1 cm of the pellet die sleeve. If a read-out in excess of 400 psi occurs, reject the pellet.

- 8 -

9. Remove the core rod and reinsert the assembly. Place the core remover over the assembly and place in the press.
10. Depress the activator buttons until the pellet die sleeve has been separated from the formed pellet.
- 5 11. Measure the height of each pellet. Reject any pellets that are not in spec (10.85 +/- 0.15 mm). Place all in-spec material in a moisture resistant heat sealable bag and label for the Recompaction Procedure.

Four pellets were inserted into a housing (a DBD can with flattened 10 rim area) and recompacted inside the housing using the following equipment and procedure:

Equipment: Carver Automatic Press, 38881DI0A00, Pellet Recompaction Assembly (can sleeve, PIP Backing Plate, Recompaction die and 3 prong can remover, core pin, punch retainer, 15 and bottom plate), Balance (3 decimal place), Digital Calipers (0.01 mm).

Procedure:

1. Slide the recompaction die onto the punch retainer.
2. Select 4 pellets and measure and record the height and weight of 20 each in-spec pellet.
3. Slide each pellet onto the core pin. Reject any pellets that are too tight or become cracked or chipped.
4. Place a bottom insulator into the DBD can and slide over the stacked pellets. Make sure the can is firmly pressed down all the way.
- 25 5. Place the can sleeve over the can and place the PIP support on top of the assembly. Insert the 3 prong can remover into the hole in the punch retainer. Place the assembly inside the Carver Automatic Press.
6. Switch the press to manual mode and set to 1500 psi compression strength and 30% compression speed.
- 30 7. Depress both of the activator buttons to raise the assembly until

- 9 -

- 1500 registers on the read-out. When the dwell time reads 4 seconds, depress the stop button.
8. Remove the can sleeve and PIP support from the assembly.
  9. Place the two columns of the support blocks (3 inch height/double stack) inside the press. Place the recompacted can, with the punch retainer and recompaction die, between the two columns and over the edges of the support blocks.
  - 5 10. Depress both of the activator buttons to raise the assembly until the can freely slides away from the core pin assembly.
  - 10 11. Keep the recompaction die in place to facilitate the insertion of the separator.

The separator (P.G.I. Nonwoven 7638) is placed within the five lobe cavity. An anode mixture was prepared by combining (in weight percentages) 70% zinc powder (Zinc Corp. of America 1216), a gelling agent (Carbopol 940 from BF Goodrich), and 30% electrolyte (composed of 98.6% liquid electrolyte and 1.4% of the dissolved gelling agent). The anode mixture then was dispersed into the cavities. The top assembly including top cap 32, current collector 28, and seal 30, was placed over the housing and mechanically crimped over to seal the battery. A sealant (Spec Seal) was applied to the side of the housing prior to the assembly.

20 The surface area of separator 16 in battery 10 (AA battery) is 2149 mm<sup>2</sup>. The surface area of the separator was calculated by determining the inner perimeter of cathode, and multiplying the perimeter by the cathode height. The cathode volume in battery 10 is 3200 mm<sup>3</sup>. The cathode volume was calculated by determining the cross-sectional area of the cathode itself, and then multiplying the area with cathode height to give the volume. Thus, battery 10 has an (S/V)<sup>2</sup> value of 0.451.

25 Referring to Fig. 3, battery 10 has a higher service life when discharged continuously at 1 amp, in comparison with a commercially available AA battery (ULTRA<sup>®</sup>) having the same components except including a cylindrical anode and having an (S/V)<sup>2</sup> value of 0.121.

30 Referring to Fig. 4, the battery 10 has a higher capacity in comparison to the commercially available AA battery.

- 10 -

Referring to Fig. 5, battery 36 includes cathode 38, an anode consisting of two generally D-shaped cavities 40, separator 42, and cylindrical housing 44.

5 Referring to Fig. 6, battery 48 includes a cathode 50, an anode consisting of four pie shaped cavities 52, separators 54, and cylindrical housing 56.

Referring to Fig. 7, battery 58 includes a cathode 60, and anode 62 including nine lobes (see, e.g., lobe 64), a separator 66, and a cylindrical housing 68.

10 Table 1 provides  $(S/V)^2$  information for the embodiments shown in Figs. 1, 2, and 5-7, for various battery sizes, along with estimates for  $(S/V)^2$  for the four cavity design in Mick et al., U.S. Pat. 5,869,205 (the "Mick Patent").

TABLE 1

15	V=cathode volume				
	S=cathode surface area between anode - cathode (~ separator surface area)				
	D=cathode (OD) outside diameter				
<b>PRESENT ART</b>					
20	Cell size ID	$(S/V)^2$	$(S/V)^2/D$	Cell_OD	Cathode OD
	AAAA	0.454	0.06135	7.8	7.4
	AAA	0.248	0.02532	10.175	9.775
	AA	0.121	0.00906	13.81	13.31
	C	0.041	0.00168	25.21	24.71
25	D	0.024	0.00074	32.89	32.39
	<b>5 Lobes</b>				
	AAAA	1.741	0.23527	7.8	7.4
	AAA	0.846	0.08655	10.175	9.775
	AA	0.451	0.03388	13.81	13.31
30	C	0.134	0.00542	25.21	24.71
	D	0.078	0.00241	32.89	32.39
	<b>9 Lobes</b>				
	AAAA	2.92	0.93459	7.8	7.4
	AAA	1.396	0.14281	10.175	9.775
	AA	0.81	0.06086	13.81	13.31
	C	0.249	0.01008	25.21	24.71
	D	0.144	0.00445	32.89	32.39

- 11 -

$V$ =cathode volume $S$ =cathode surface area between anode - cathode (~ separator surface area) $D$ -cathode (OD) outside diameter					
PRESENT ART					
Cell size ID	$(S/V)^2$	$(S/V)^2/D$	Cell_OD	Cathode OD	
<b>2 Cavities</b>					
5	AAAA	1.15	0.15541	7.8	7.4
	AAA	0.613	0.06273	10.175	9.775
	AA	0.334	0.02510	13.81	13.31
	C	0.118	0.00478	25.21	24.71
	D	0.07	0.00216	32.89	32.39
<b>4 Cavities</b>					
10	AAAA	2.2	0.29730	7.8	7.4
	AAA	1.106	0.11315	10.175	9.775
	AA	0.65	0.04884	13.81	13.31
	C	0.203	0.00822	25.21	24.71
	D	0.121	0.00374	32.89	32.39
<b>MICK (estimated from their 4 cavity anode)</b>					
15	AAAA	1.072	0.14492	7.8	7.4
	AAA	0.611	0.06240	10.175	9.775
	AA	0.332	0.02496	13.81	13.31
	C	0.096	0.00390	25.21	24.71
	D	0.056	0.00173	32.89	32.39

20 Referring to Fig. 8,  $(S/V)^2$ /cathode OD is plotted against cell diameter for commercial AAAA, AAA, AA, C, and D batteries, the four anode cavity battery in the Mick patent, and the embodiments shown in Figs. 1, 2, and 5-7. The plot for the commercial batteries will be referred to herein as "Plot A"; the plot for the four anode cavity battery in the Mick patent will be referred to herein as "Plot B"; the plot for the embodiment in Fig. 5 will be referred to herein as "Plot C"; the plot for the embodiment in Fig. 6 will be referred to herein as "Plot D"; the plot for the embodiment in Figs. 1 and 2 will be referred to herein as "Plot E"; and the plot for the embodiment in Fig. 7 will be referred to herein as "Plot F". Plots C-F are above Plot A, and Plots D-F are above Plot B.

25

30 Other embodiments are within the claims. For example, the positions of the anode and cathode may be reversed. In addition, the anode may include two

- 12 -

lobes, three lobes, four lobes, or six to eight lobes.

- 13 -

C L A I M

1. A primary alkaline AA battery, comprising:
  - a housing;
  - a cathode within the housing;
  - 5 an anode within the housing; and
  - a separator electrically separating the anode and the cathode;
  - wherein the battery has an  $(S/V)^2$  value of greater than 0.38.
2. The battery of claim 1, wherein the battery has an  $(S/V)^2$  value of greater than 0.42.
- 10 3. The battery of claim 1, wherein the battery has an  $(S/V)^2$  value of greater than 0.45.
4. A primary alkaline AAA battery, comprising:
  - a housing;
  - a cathode within the housing;
  - 15 an anode within the housing; and
  - a separator electrically separating the anode and the cathode;
  - wherein the battery has an  $(S/V)^2$  value of greater than 0.70.
5. The battery of claim 4, wherein the battery has an  $(S/V)^2$  value of greater than 0.75.
- 20 6. The battery of claim 4, wherein the battery has an  $(S/V)^2$  value of greater than 0.8.
7. A primary alkaline AAAA battery, comprising:
  - a housing;
  - a cathode within the housing;
  - 25 an anode within the housing; and
  - a separator electrically separating the anode and the cathode;
  - wherein the battery has an  $(S/V)^2$  value of greater than 1.2.
8. The battery of claim 7, wherein the battery has an  $(S/V)^2$  value of greater than 1.4.
- 30 9. The battery of claim 7, wherein the battery has an  $(S/V)^2$  value of greater than 1.5.
10. A primary alkaline C battery, comprising:

- 14 -

- a housing;
- a cathode within the housing;
- an anode within the housing; and
- a separator electrically separating the anode and the cathode;
- 5 wherein the battery has an  $(S/V)^2$  value of greater than 0.110.
- 11. The battery of claim 10, wherein the battery has an  $(S/V)^2$  value of greater than 0.120.
- 12. The battery of claim 10, wherein the battery has an  $(S/V)^2$  value of greater than 0.125.
- 10 13. A primary alkaline D battery, comprising:
  - a housing;
  - a cathode within the housing;
  - an anode within the housing; and
  - a separator electrically separating the anode and the cathode;
  - 15 wherein the battery has an  $(S/V)^2$  value of greater than 0.065.
- 14. The battery of claim 13, wherein the battery has an  $(S/V)^2$  value of greater than 0.07.
- 15. The battery of claim 13, wherein the battery has an  $(S/V)^2$  value of greater than 0.075.
- 20 16. A primary alkaline AA battery, comprising:
  - a housing;
  - a cathode within the housing;
  - a single cavity anode within the cathode; and
  - a separator electrically separating the anode and the cathode;
  - 25 wherein the battery has an  $(S/V)^2$  value of greater than 0.15.
- 17. The battery of claim 16, wherein the battery has an  $(S/V)^2$  value of greater than 0.20.
- 18. The battery of claim 16, wherein the battery has an  $(S/V)^2$  value of greater than 0.30.
- 30 19. A primary alkaline AAA battery, comprising:
  - a housing;
  - a cathode within the housing;

- 15 -

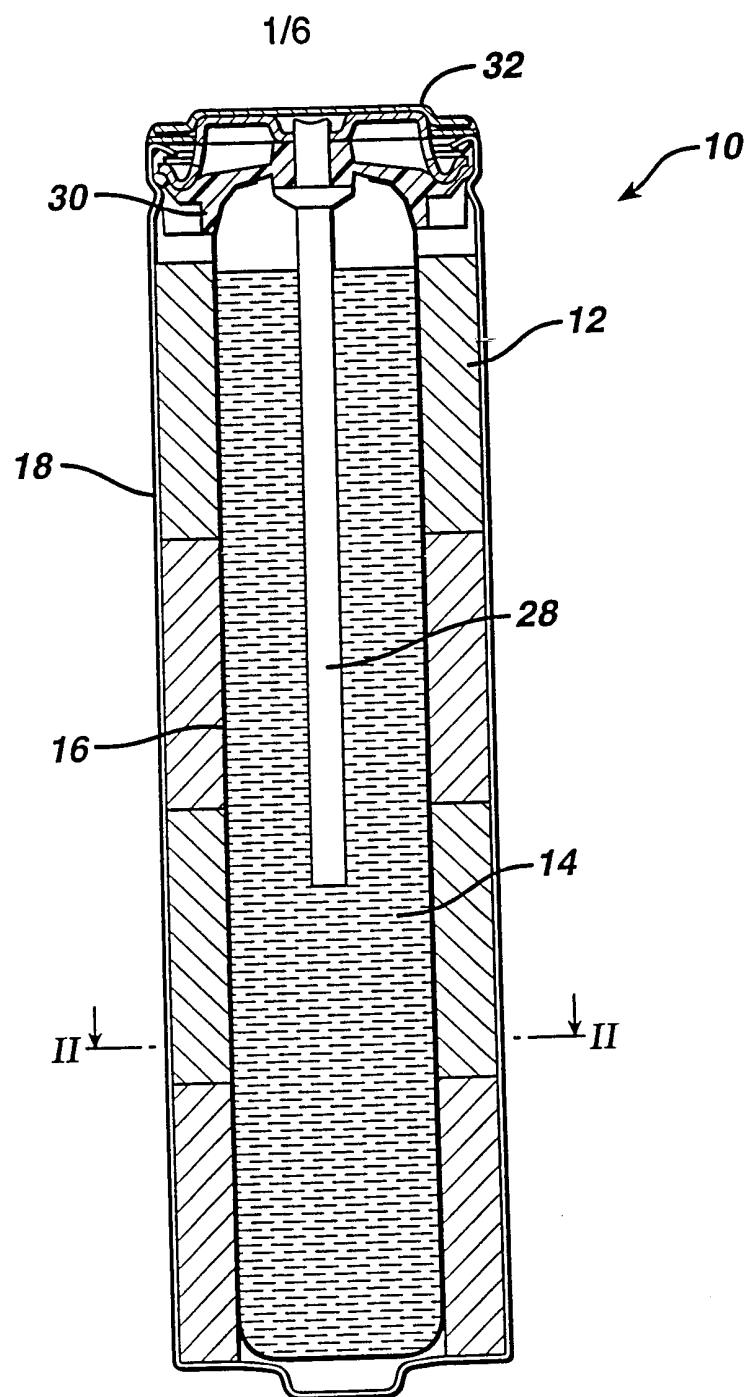
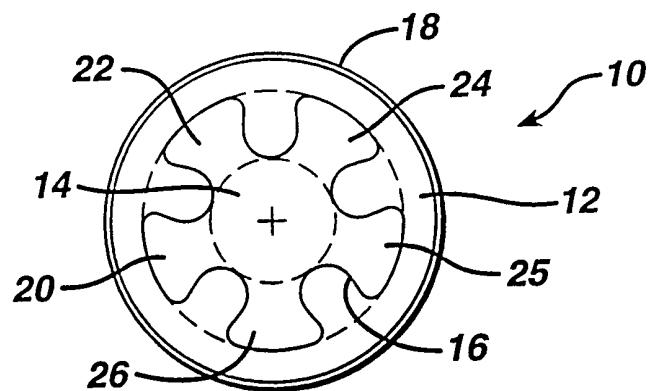
- a single cavity anode within the cathode; and
  - a separator electrically separating the anode and the cathode;
  - wherein the battery has an  $(S/V)^2$  value of greater than 0.3.
20. The battery of claim 19, wherein the battery has an  $(S/V)^2$  value of  
5 greater than 0.4.
21. The battery of claim 19, wherein the battery has an  $(S/V)^2$  value of  
greater than 0.5.
22. A primary alkaline AAAA battery, comprising:  
a housing;
- 10 a cathode within the housing;
- a single cavity anode within the cathode; and
- a separator electrically separating the anode and the cathode;
- wherein the battery has an  $(S/V)^2$  value of greater than 0.6.
23. The battery of claim 22, wherein the battery has an  $(S/V)^2$  value of  
15 greater than 0.8.
24. The battery of claim 22, wherein the battery has an  $(S/V)^2$  value of  
greater than 1.0.
25. A primary alkaline C battery, comprising:  
a housing;
- 20 a cathode within the housing;
- a single cavity anode within the cathode; and
- a separator electrically separating the anode and the cathode;
- wherein the battery has an  $(S/V)^2$  value of greater than 0.06.
26. The battery of claim 25, wherein the battery has an  $(S/V)^2$  value of  
25 greater than 0.08.
27. The battery of claim 25, wherein the battery has an  $(S/V)^2$  value of  
greater than 0.10.
28. A primary alkaline D battery, comprising:  
a housing;
- 30 a cathode within the housing;
- a single cavity anode within the cathode; and
- a separator electrically separating the anode and the cathode;

- 16 -

- wherein the battery has an  $(S/V)^2$  value of greater than 0.03.
29. The battery of claim 28, wherein the battery has an  $(S/V)^2$  value of greater than 0.04.
30. The battery of claim 28, wherein the battery has an  $(S/V)^2$  value of 5 greater than 0.05.
31. The battery of claim 1, 4, 7, 10, 13, 16, 19, 22, 25, or 28 wherein the cathode comprises manganese dioxide.
32. The battery of claim 1, 4, 7, 10, 13, 16, 19, 22, 25, or 28 wherein the anode comprises zinc.
- 10 33. The battery of claim 1, 4, 7, 10, 13, 16, 19, 22, 25, or 28 wherein the cathode comprises manganese dioxide and the anode comprises zinc.
34. The battery of claim 1, 4, 7, 10, 13, 16, 19, 22, 25, or 28, wherein the anode comprises a lobed cavity within the cathode.
35. The battery of claim 34, wherein the anode includes only two lobes.
- 15 36. The battery of claim 34, wherein the anode includes three lobes.
37. The battery of 34, wherein the anode includes four lobes.
38. The battery of claim 34, wherein the anode includes five lobes.
39. The battery of claim 34, wherein the anode includes nine lobes.
40. The battery of claims 1, 4, 7, 10, 13, 16, 19, 22, 25, or 28, wherein 20 the anode includes multiple cavities within the cathode.
41. The battery of claim 40, wherein the multiple cavities comprise two D-shaped cavities.
42. The battery of claim 41, wherein the anode further includes a connection between the two D-shaped cavities.
- 25 43. The battery of claim 41, wherein the anode does not include a connection between the D-shaped cavities.
44. The battery of claim 40, wherein the cavities include two pie-shaped cavities.
45. The battery of claim 44, wherein the cavities include three pie-shaped 30 cavities.
46. The battery of claim 45, wherein the cavities include four pie-shaped cavities.

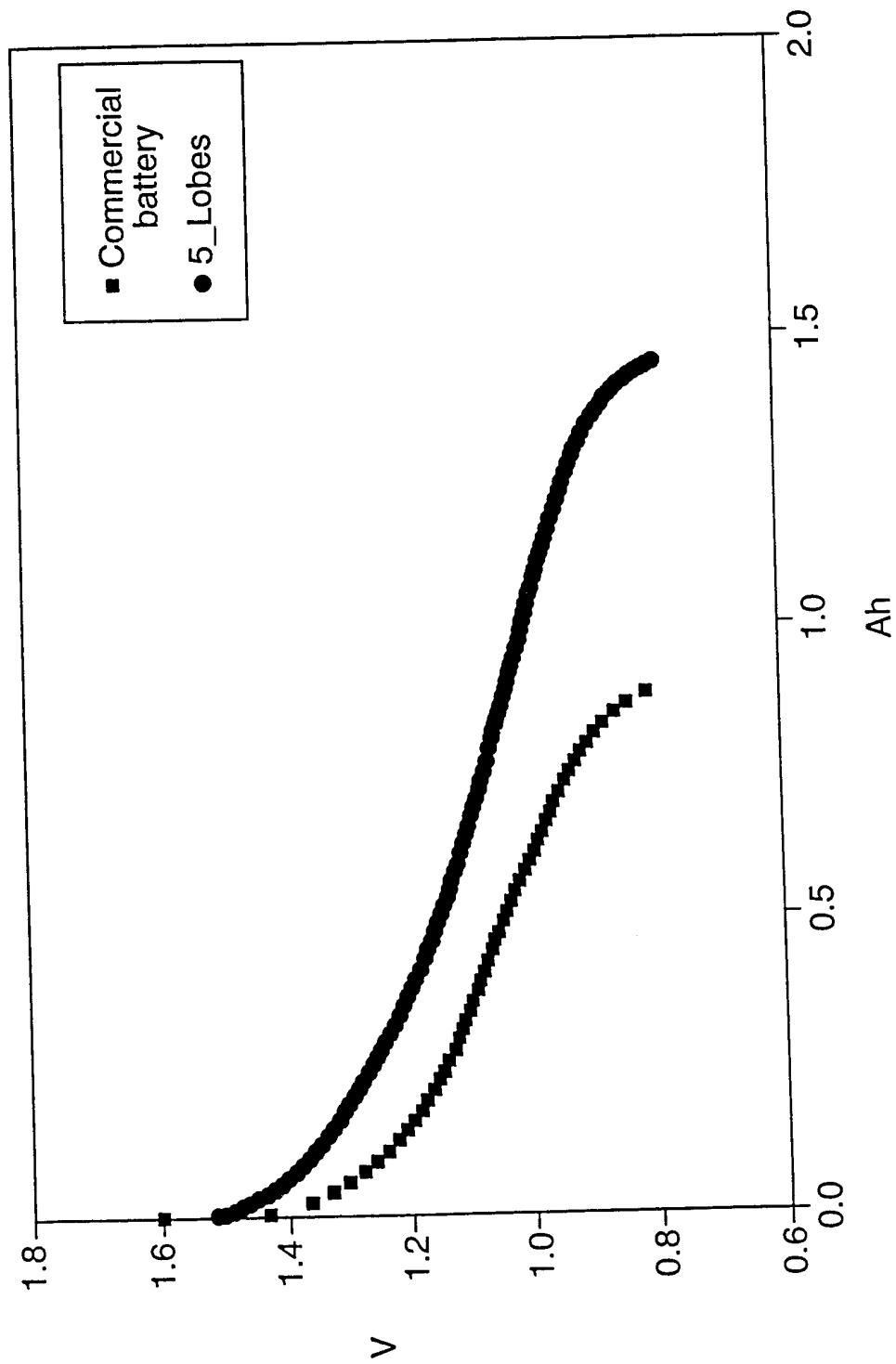
- 17 -

47. A battery comprising:
  - a housing;
  - a first electrode within the housing;
  - a second electrode within the first electrode, the second electrode
- 5 including nine lobes; and
  - a separator between the first electrode and the second electrode.
48. The battery of claim 47, wherein the housing is cylindrical.
49. The battery of claim 47, wherein the second electrode is an anode comprising zinc.
- 10 50. The battery of claim 47 or 49, wherein the first electrode is a cathode comprising manganese dioxide.
51. A battery comprising:
  - a housing;
  - a first electrode within the housing;
- 15 a second electrode within the first electrode, the second electrode consisting essentially of a single cavity; and
  - a separator between the first electrode and the second cavity;
  - wherein the battery has a  $(S/V)^2$  cathode OD v. cell diameter value at least 0.01 above Plot A.
- 20 52. The battery of claim 51, wherein the battery has a  $(S/V)^2$  cathode OD v. cell diameter value at least 0.02 above Plot A.
53. A battery comprising:
  - a housing;
  - a first electrode within the housing;
- 25 a second electrode within the first electrode; and
  - a separator between the first electrode and the second cavity;
  - wherein the battery has a  $(S/V)^2$  cathode OD v. cell diameter value at least 0.01 above Plot B.
54. The battery of claim 53, wherein the battery has a  $(S/V)^2$  cathode OD
- 30 v. cell diameter value at least 0.01 above Plot A.

**FIG. 1****FIG. 2**

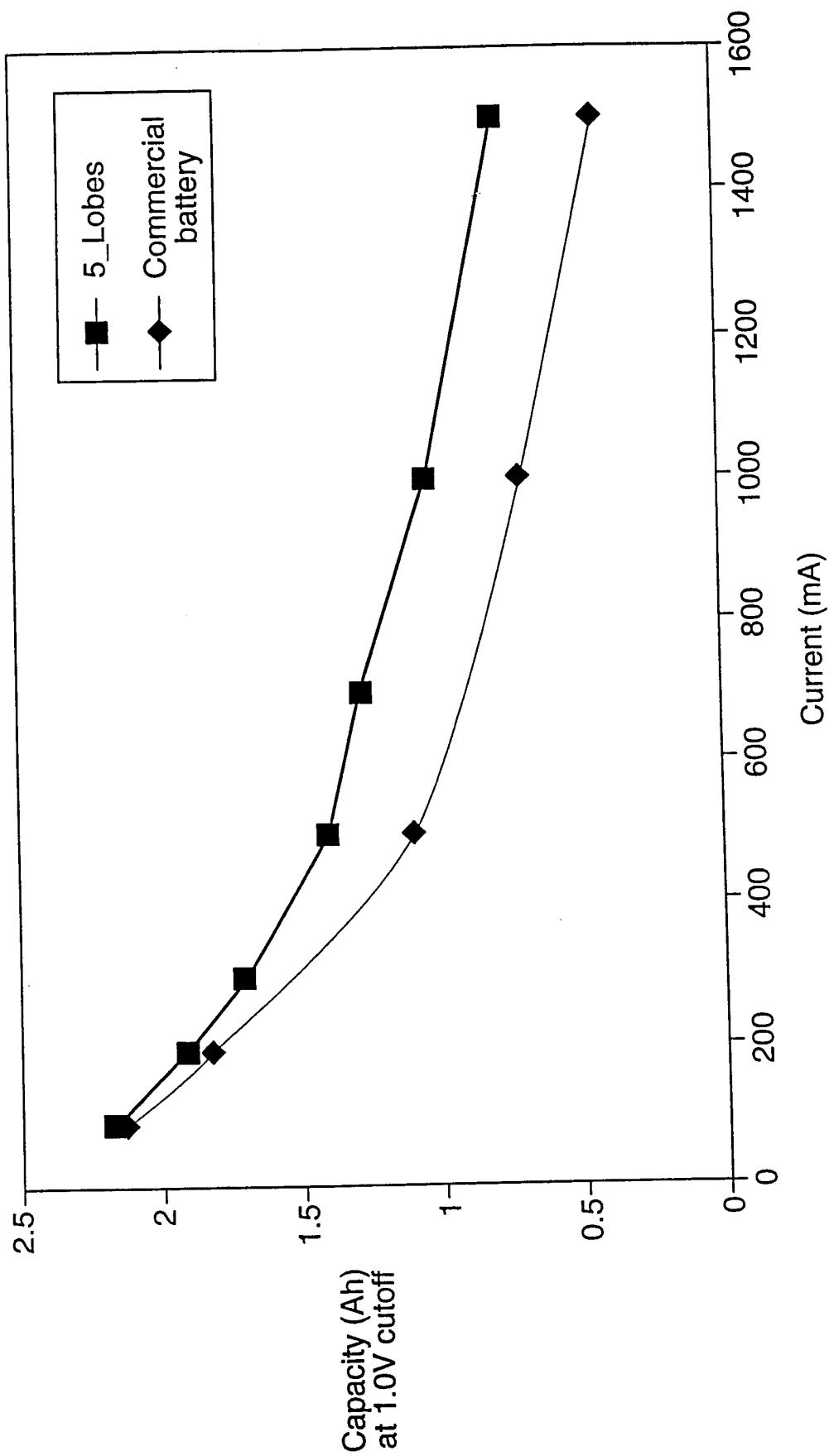
2/6

FIG. 3

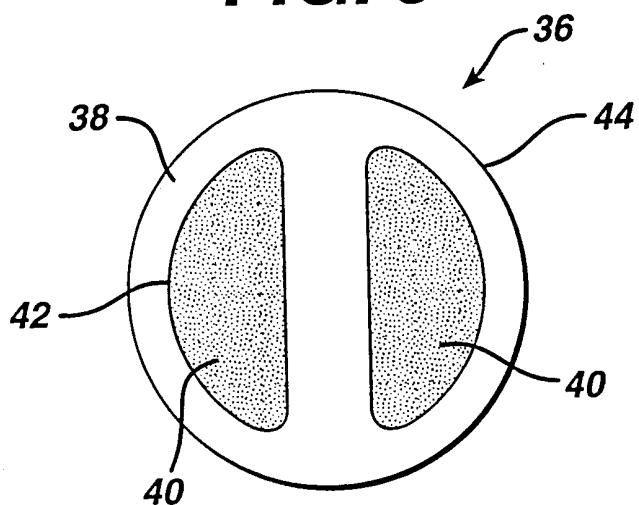
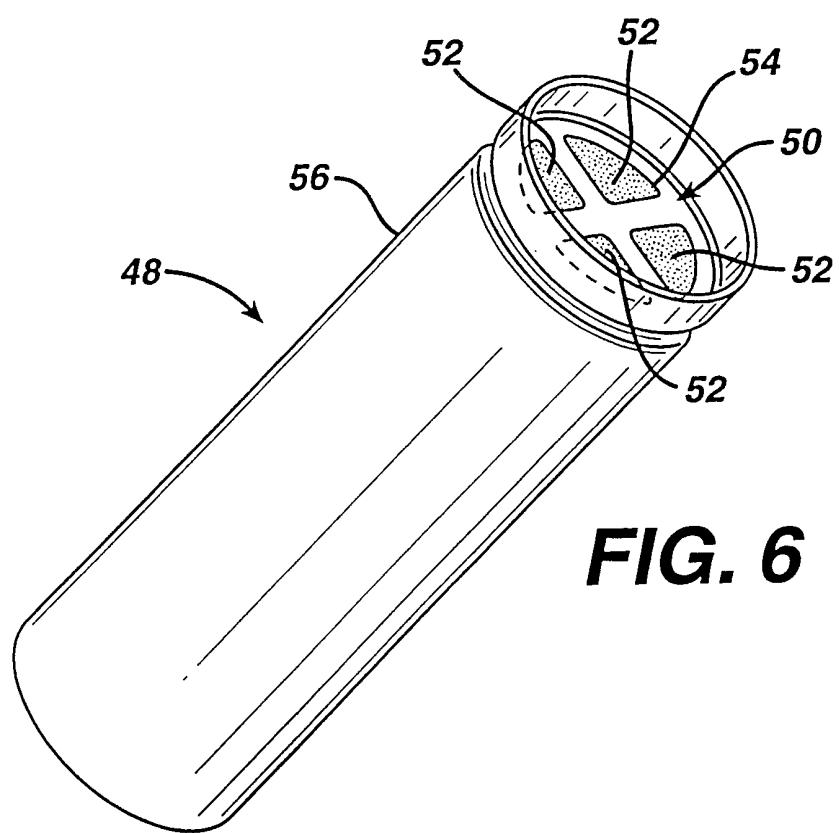


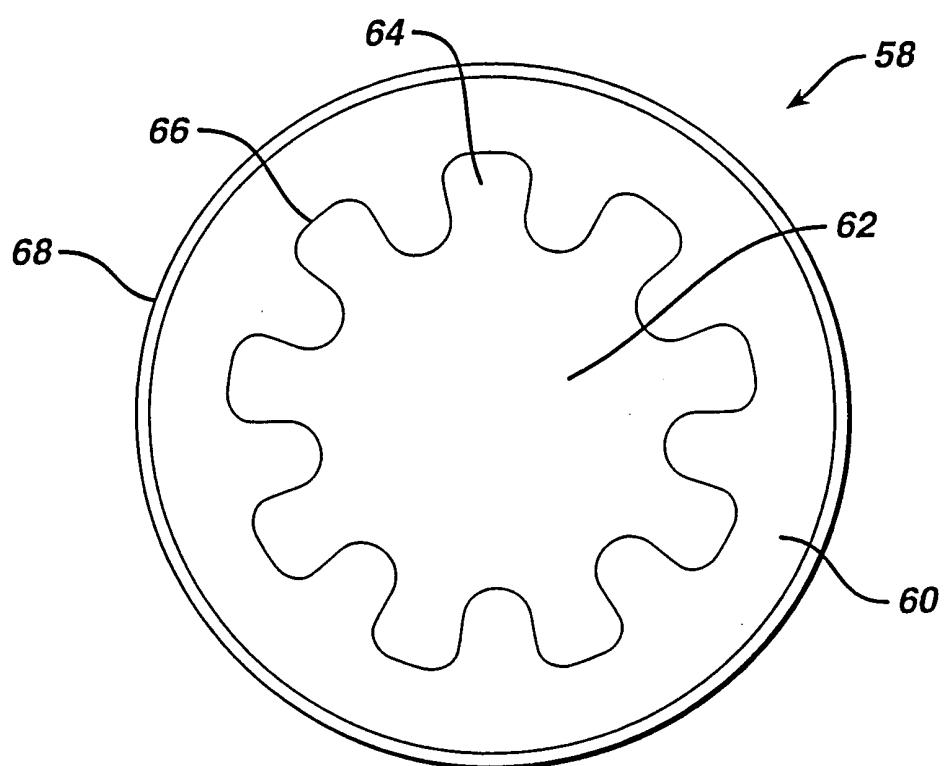
3/6

FIG. 4



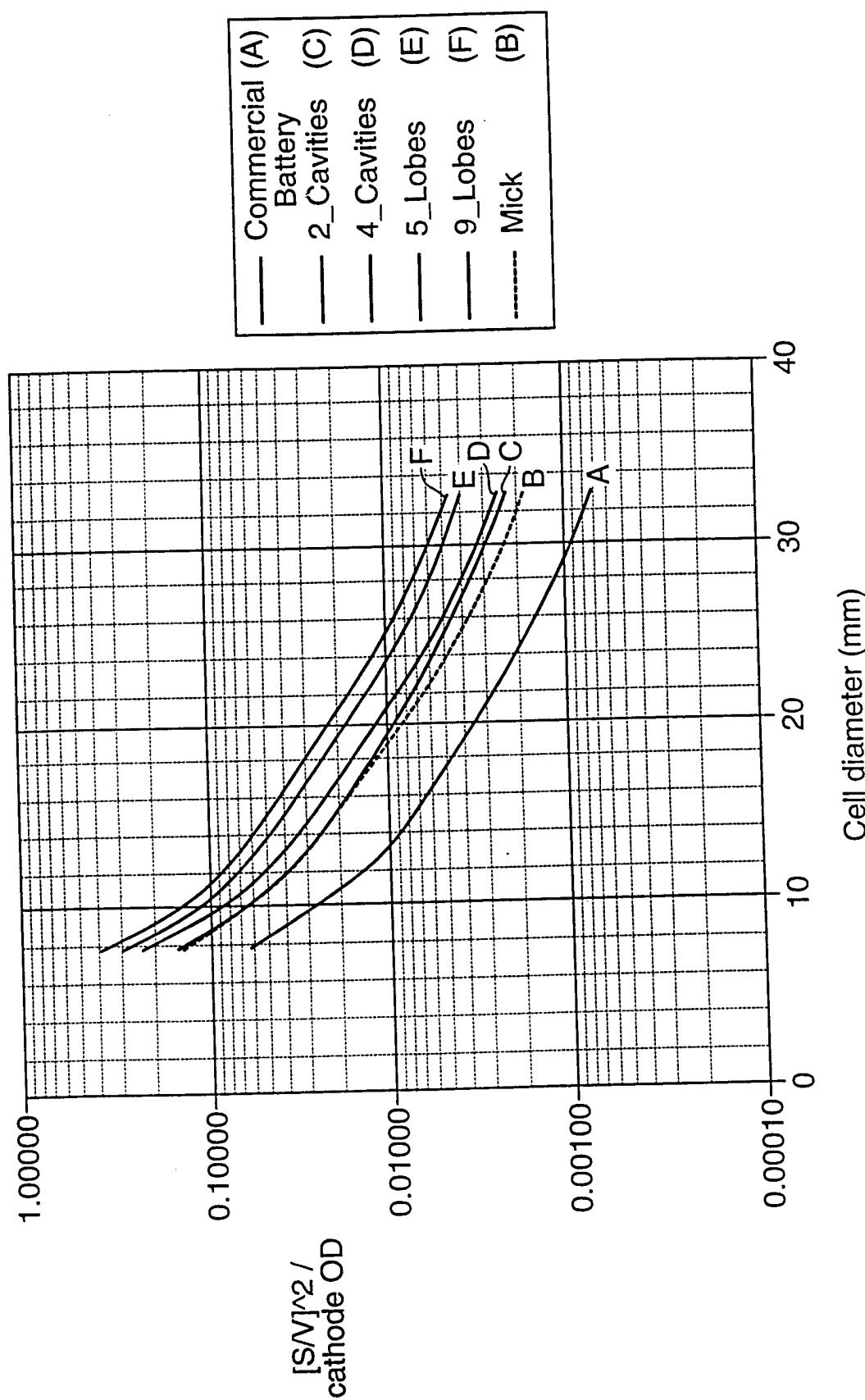
4/6

**FIG. 5****FIG. 6**

**FIG. 7**

6/6

FIG. 8



# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/40838

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC 7 H01M6/06

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 00 01022 A (EVEREADY BATTERY INC) 6 January 2000 (2000-01-06) page 10, line 4 -page 17, line 10; claims 1-12 ---	1,16
A	US 5 869 205 A (MICK ALVIN R ET AL) 9 February 1999 (1999-02-09) column 1, line 63 -column 5, line 53; claims 1-25 ---	1-15
A	FR 2 622 359 A (ACCUMULATEURS FIXES) 28 April 1989 (1989-04-28) page 3, line 21 -page 5, line 20; claims 1-7 --- -/-	1-54

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents :

- °A° document defining the general state of the art which is not considered to be of particular relevance
- °E° earlier document but published on or after the international filing date
- °L° document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- °O° document referring to an oral disclosure, use, exhibition or other means
- °P° document published prior to the international filing date but later than the priority date claimed

- °T° later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- °X° document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- °Y° document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- °&° document member of the same patent family

Date of the actual completion of the international search

14 February 2001

Date of mailing of the international search report

21/02/2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

De Vos, L

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/40838

**C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT**

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 16863 A (ESHRAGHI RAY R) 9 May 1997 (1997-05-09) page 3, paragraphs 1-3 page 8, paragraph 1 -page 10, paragraph 2; claims 1-20 ---	1-54
A	US 5 532 078 A (REDEY LASZLO I ET AL) 2 July 1996 (1996-07-02) column 12, line 28 -column 13, line 63 ---	1,16,34
A	GB 2 231 196 A (LANG TSAI ING;TUNG KWAN CHI) 7 November 1990 (1990-11-07) page 2, line 31 -page 3, line 31; claims 1-5 ---	1,16
A	US 5 677 080 A (CHEN JAMES CHIN-MING) 14 October 1997 (1997-10-14) column 5, line 22 -column 6, line 51 ---	1,16
A	US 1 995 294 A (JOHN R.CULLEN) 26 March 1935 (1935-03-26) page 2, column 1, line 39 -page 3, column 1, line 50; claims 1-10 -----	1,16,34

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

Continuation of Box I.2

Present claims 1-54 relate to a cylindrical primary alkaline battery defined by the value of  $(S/V)^2$  wherein S is the separator surface area and V the cathode volume .

The use of these parameters in the present context is considered to lead to a lack of clarity within the meaning of Article 6 PCT. It is impossible to compare the parameters the applicant has chosen to employ with what is set out in the prior art. In such prior art documents a high interface area between anode and cathode of the cell is only characterised by the form of the separator surface without specifying the dimensions. In view of the extended complicated surface structures of these separators, it is very difficult to calculate these dimensions, let alone to calculate an  $(S/V)^2$  value based on such dimensions. The lack of clarity is such as to render a meaningful complete search impossible.

Consequently, the search has been restricted to: cylindrical and preferably primary alkaline cells with high interface between cathode and anode obtained while using separators with great surface area in contact with cathodes of relatively small volume as represented on fig 2, 5, 6 and 7.

The applicant's attention is drawn to the fact that claims, or parts of claims, relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/40838

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
WO 0001022	A	06-01-2000	US 6074781 A		13-06-2000
			AU 4715699 A		17-01-2000
US 5869205	A	09-02-1999	NONE		
FR 2622359	A	28-04-1989	NONE		
WO 9716863	A	09-05-1997	US 6004691 A		21-12-1999
			AU 1116097 A		22-05-1997
			US 5916514 A		29-06-1999
			US 5928808 A		27-07-1999
US 5532078	A	02-07-1996	US 5283135 A		01-02-1994
			US 5340668 A		23-08-1994
			AU 666140 B		01-02-1996
			AU 2778192 A		03-05-1993
			CA 2120770 A		15-04-1993
			EP 0649569 A		26-04-1995
			JP 7500216 T		05-01-1995
			WO 9307650 A		15-04-1993
			US 5536593 A		16-07-1996
			MX 9205798 A		01-07-1993
			ZA 9207752 A		19-04-1993
GB 2231196	A	07-11-1990	NONE		
US 5677080	A	14-10-1997	NONE		
US 1995294	A	26-03-1935	NONE		