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MAGNESIUM PRIMARY CELL

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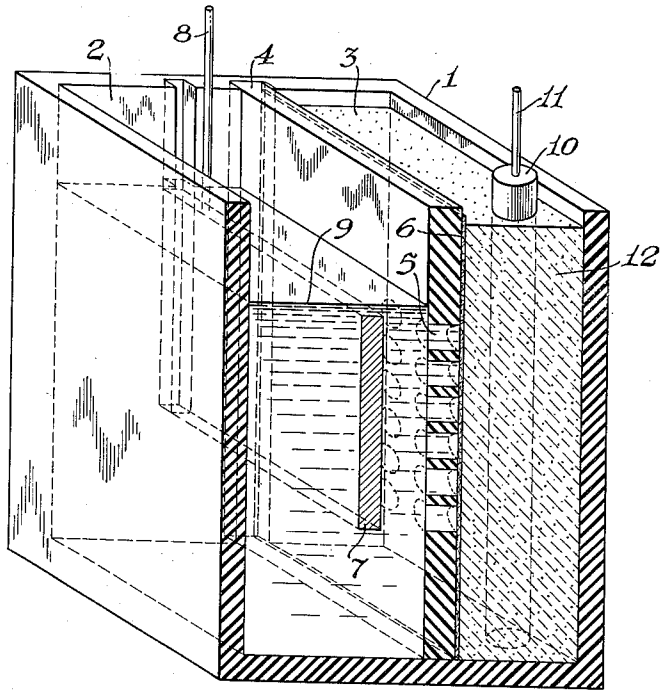


Fig. 1

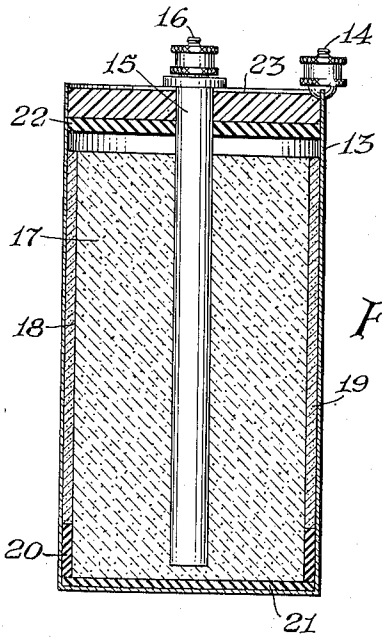


Fig. 2

INVENTORS.
Ashford B. Fry
Roy C. Kirk
Percy F. George
BY Griswold & Burdick
ATTORNEYS

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MAGNESIUM PRIMARY CELL

Ashford B. Fry, Roy C. Kirk, and Percy F. George, Midland, Mich., assignors to The Dow Chemical Company, Midland, Mich., a corporation of Delaware

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The invention relates to an improved primary cell.

One of the objects of the invention is to provide a primary cell utilizing as the anode material, more effectively than heretofore, magnesium and its alloys. Another object is to provide a primary cell having a high capacity and voltage, coupled with a long shelf life. Still other objects and advantages will become apparent from the following description of the invention.

The essential elements of the new primary cell are briefly: a metallic anode of magnesium or magnesium-base alloy in which the magnesium content exceeds about 50 per cent and preferably exceeds about 80 per cent of the alloy by weight; an aqueous electrolyte comprising a bromide of an alkali or alkaline earth metal, the electrolyte advantageously containing corrosion-inhibiting amounts of a chromic acid salt of a base consisting of an alkali metal base, an alkaline earth metal base including magnesium, and ammonium; and a cathode of a chemically inert, electrically conducting material such as carbon or graphite in combination with a depolarizer of manganese dioxide.

The three essential elements of the cell are arranged in a suitable manner to provide a voltaic system in which the anode is separated from the cathode and the electrolyte provides a path for the passage of electrical current between them as in conventional cell construction.

THE ANODE

Referring more particularly to the elements of the cell, the anode, we have found, may be made of magnesium itself, although better cells are obtained with our combination of elements when magnesium-base alloys are used, particularly those in which the alloying constituents are aluminum, zinc and manganese, as in the usual structural magnesium-base alloys. For lowest corrosion rates of the anode, magnesium or alloy of the highest purity grade is to be used, having no more than traces of the impurities Fe, Cu and Ni, which promote corrosion of the metal. While impurities in the magnesium affect the shelf life of the cells they do not seriously limit the capacity of the cells or their useful life on continuous, or many kinds of intermittent, service. The usual commercial grades of magnesium are generally satisfactory for anode material, especially when the iron content does not exceed about 0.002 per

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cent and that of nickel 0.001 per cent. The term "magnesium" as hereinafter employed includes not only magnesium, either in the pure or in the impure form, but also the magnesium alloys in which magnesium is the predominant constituent.

The following tabulation sets forth examples of magnesium-base alloys which are suitable for anode material and their corresponding A. S. T. M. designations.

TABLE I

Anode compositions

Alloy No.	A. S. T. M. Designation	Nominal Composition [1]				
		Al	Mn	Zn	Zr	Ce
1	A3	3	0.2			
2	A4	4	0.2			
3	A8	8	0.1			
4	A10	10	0.1			
5	A12	12	0.1			
6	AZ31	2.8	0.3	1.0		
7	AZ33	3	0.2	3		
8	AZ61	6.5	0.2	0.7		
9	AZ63	6	0.2	3		
10	AZ81	8.5	0.2	0.5		
11	AZ91	9	0.2	0.6		
12	AZ92	9	0.1	2.0		
13	E6					6
14	EM42		2			4
15	EM62		2			6
16	M1		1.5			
17	M2		2			
18	ZK30			3	0.7	
19	ZK60			6	0.7	
20	Z1			1		

[1] Balance commercial magnesium.

The anode material may be in any of the usual forms such as rolled plate or sheet, extrusions, forgings, stampings, and castings.

THE ELECTROLYTE

The electrolyte may be prepared by dissolving the bromide salt in water in a concentration between about 30 grams per liter and that producing a nearly saturated solution at ordinary temperatures. The actual concentration used does not appear to be critical, although for best results certain concentrations are to be preferred depending upon the particular bromide or combination of bromides used. For example, preferred concentrations of the alkali metal bromides are from about 150 to 500 grams of the salt per liter of solution. Of the alkali metal bromides, lithium bromide produces the most desirable results, particularly in concentrations of about 300 grams per liter. Similar concentrations may be

used with the alkaline earth metal bromides. As used herein, the term "alkaline earth metal bromide" includes the bromides of Mg, Ca, Ba, and Sr. Of these, magnesium bromide is to be preferred. Its most effective concentration is about 300 grams per liter of solution.

While a single bromide may be used as the electrolyte, we have found that still better results are had with combinations of the aforesaid bromides, particularly combinations of an alkali metal bromide with an alkaline earth metal bromide, these results being manifest in greater shelf life and higher capacity than that exhibited by single bromide electrolytes. For example, we have found that an electrolyte containing magnesium bromide in combination with any one of the other aforementioned bromides or ammonium bromide produces an improved cell. Particularly advantageous as a mixed bromide electrolyte is the combination of magnesium bromide and lithium bromide. A somewhat more economical cell results when sodium bromide is substituted for the lithium bromide.

It is desirable to include in the electrolyte an alkali metal, alkaline earth metal (including magnesium), or ammonium salt of chromic acid in corrosion-inhibiting amounts, such as from 0.01 gram per liter of solution to concentrations producing saturation in the presence of the bromide therein. A preferred concentration of the chromic acid salt is 0.05 to 2 grams per liter of solution.

THE CATHODE

The cathode comprises an inert conductor such as a piece of carbon or graphite to which a terminal may be affixed, if desired, and a depolarizer of manganese dioxide having in admixture therewith from about 5 to 25 per cent by weight of finely divided carbon such as carbon black. Acetylene black is preferred and may be used in a proportion of about 5 per cent to 15 per cent and preferably about 10 per cent by weight.

In preparing the cathode depolarizing mixture, it is desirable first to mix the manganese dioxide depolarizer with the finely divided carbon so as to obtain uniform distribution of the carbon black throughout the manganese dioxide, which is also pulverulent. Thereafter the mixture may be moistened with electrolyte so as to obtain a moldable mixture, as when the mixture is to be molded into a dry cell bobbin. Suitable proportions of electrolyte and dry cathode mixture are about 36 c. c. of electrolyte per 100 grams of mixture, although other proportions may be used.

CELL ASSEMBLY

Cells of either the "wet" or "dry" type may be assembled in various ways employing the three elements above described. Probably the most commercially valuable application of the invention lies in the "dry" cell field where the instant cell has the advantage of high capacity and voltage coupled with lightness in weight. In compounding a cell of the dry cell type according to the invention the anode may take the form of the vessel in which the other two elements of the combination are contained and the electrolyte may be thickened or jellied as in conventional dry cell practice by the inclusion therein of a thickening agent such as cereal flour or starch or a mixture of them in the proportions of about 1 gram of thickening agent per 6 c. c. of electrolyte solution. In cells of this type the cathode is formed into a bobbin as by molding the manganese dioxide-carbon black mixture around a central electrode of carbon, the whole being moistened with electrolyte before introducing the bobbin into the cup which constitutes the anode. In assembling the combination of the dry cell elements it is convenient to place in the cup or can a quantity of the electrolyte solution mixed with the thickening agent and suitable insulation to keep the bobbin from coming into direct contact with the anode before inserting the bobbin.

The invention may be further explained and illustrated with reference to the accompanying drawing in which

Fig. 1 shows a cutaway isometric view of a "wet" cell;

Fig. 2 shows a vertical section of a "dry" cell.

The cell illustrated in Fig. 1 is contained in a container or jar 1 of suitable insulating material such as glass, hard rubber or plastic, which is divided into an anode compartment 2 and a cathode compartment 3 by means of a partition 4. Partition 4 consists of a board or plate of suitable insulating material which is conveniently made of molded phenol-formaldehyde resin. It is provided with a plurality of perforations 5 arranged in a regular pattern, to permit passage of current through the electrolyte between the electrodes. On the cathode side of the partition 4 is a porous filter medium 6, such as a sheet of filter paper, which serves as a liquid-permeable retainer for the contents of the cathode. In compartment 2 is disposed an anode 7 consisting of a plate of magnesium or alloy thereof in which magnesium is the predominant constituent. To the anode is secured a terminal rod 8, the anode being immersed in a body of the liquid electrolyte 9 already described. Cathode 10 is disposed in compartment 3 and is provided with a terminal wire 11. The cathode 10 is embedded in a mass 12 of a depolarizer mix composed of powdered manganese dioxide and finely divided carbon, e. g. carbon black or acetylene black moistened with the electrolyte.

The cell of Fig. 2, which is of the dry cell type, is contained in the vessel or cup 13. The vessel 13 serves as the anode and is formed of magnesium or alloy thereof in which the magnesium is the predominant constituent. The upper edge of the vessel may be provided with a terminal or binding post 14. Arranged inside the container and projecting above it is the carbon or graphite electrode 15 which may be provided with a terminal or binding post 16. Associated with the electrode 15 is the depolarizing mixture 17 of manganese dioxide and carbon black which may be molded or pressed into a cake around the electrode and, together with the electrode, forms a bobbin 18. The bobbin 18 preferably is more or less saturated with the aqueous electrolyte, already described, before inserting the same into the vessel 13. The bobbin 18 fits inside the vessel, leaving a space 19 between the outside of the bobbin and the inside of the vessel which is filled with gelled electrolyte. The bobbin 18 is prevented from touching the vessel by the insulating bushing 20 and washer 21 at the lower end of the vessel and by the washer 22 and sealing compound 23 at the upper end of the vessel. In some instances, if desired, the space 19 may be filled with a porous insulating material such as blotting paper soaked with electrolyte.

The following examples, tabulated in Table II, are illustrative of wet cells made up in accordance with the invention.

TABLE II

Wet cells

Cell No.	Electrolyte [1]		Cathode Depolarizer Mixture, Per Cent		Anode Material [2]	Amp. Hrs. to 1 Volt
	Grams per Liter	Salt	MnO_2	A. B.		
1	1,000	LiBr	90	10	AZ31	20
2	1,000	$SrBr_2.6H_2O$	90	10	do	10
3	1,160	do	90	10	do	8.5
4	1,150	do	90	10	AZ61	8.0
5	200	do	50	50	do	3.0
6	200	do	75	25	do	2.5
7	200	do	90	10	do	4.0
8	1,150	do	90	10	M1	8.0
9	200+100	$SrBr_2.6H_2O$ + $MgBr_2.6H_2O$.	90	10	Z1	8.0

[1] Volume of electrolyte per cell 300 c. c.
[2] Rolled plate 3.5" x 2" x 0.25". Iron content <0.002%; nickel content <0.001%.

In the tabulation above, the electrolytes of the cells are aqueous solutions containing the bromides already set forth, and the anodes are formed of the magnesium-base alloy whose composition corresponds to the A. S. T. M. designation given in Table I, and the cathodes are depolarized with manganese dioxide in admixture with acetylene black (designated: A. B.) in the proportions shown. The elements of the cells are arranged as in Fig. 1, the cell container having inside dimensions of 3.25 inches long, 2.63 inches wide, and 3.5 inches deep.

In testing the performance of these cells each of them was discharged through an adjustable resistance set at a value which produced a current density on one face of the anode of 6 amperes per square foot at the commencement of the discharge. Thus each cell was started to discharge at the same current density per unit of anode area, and the discharge was continued until the voltage at the terminals of the cells while discharging was 1 volt. The resulting energy output during the discharge was computed in ampere hours and set forth in the last column of the table.

Examples of dry cells embodying the invention are tabulated in Table III. These cells are of the same construction as that illustrated in Fig. 2, and conform in size to conventional D size dry cells. The cathode material is a mixture of 90 parts of manganese dioxide and 10 parts by weight of acetylene black moistened with electrolyte of the composition set forth in the table. Cells numbered 1 to 21 inclusive contain single bromide electrolytes, while cells numbered 22 to 27 inclusive contain mixtures of the aforesaid bromides.

The capacity data set forth in the last three columns of Table III are based upon tests described in the bulletin No. JAN–B–18A entitled "Joint Army and Navy Specification Batteries Dry," published by the United States Government October 7, 1947. In the BA–8 tests the cells were discharged through a resistance of 83⅓ ohms continuously until the cell voltage dropped to 1.13 volts. The number of hours of such discharging is set forth in the column headed BA–8. In the BA–30 tests the cells were discharged through a resistance of 6⅔ ohms for four minutes every ½ hour for 10 hours each day 5 days per week until the cell voltage dropped to 0.935 volt. In the column headed "Initial" there are set forth the number of days of discharging according to the BA–30 schedule, the discharging commencing as soon as the manufacture of the cells was completed. In the last column the BA–30 discharge test was commenced after the cells had been held in storage for 3 months on open circuit at about 70° F. Data was not obtained where blanks exist in the capacity columns.

From Table III it is evident that cells in which the electrolyte contains magnesium bromide either alone or in combination with an alkali metal bromide exhibit exceptional capacity both for continuous as well as for intermittent service. Particularly advantageous are cells in which the anode material is a magnesium-base alloy of the AZ type, or more particularly magnesium alloys containing about 2 to 9 per cent of aluminum, 0.5 to 3 per cent of zinc, 0.1 to 0.5 per cent of

TABLE III

Dry cells

Cell No.	Anode Material [1]	Electrolyte, Grams per Liter		Hrs., BA–8	Capacity, BA–30; Days	
		Salt	Inhibitor		Initial	3 Months
1	AZ31	300 LiBr	5 $Na_2Cr_2O_7$	423	23.0	21.1
2	do	do	5 $(NH_4)_2CrO_4$	385	22.6	19.0
3	do	do	5 $Li_2Cr_2O_7$	449	21.0	21.9
4	do	do	5 $(NH_4)_2Cr_2O_7$	409	22.8	22.8
5	do	300 $MgBr_2.6H_2O$	1.0 $(NH_4)_2CrO_4$	473	23.8	
6	do	do	10 $(NH_4)_2CrO_4$	499	33.3	
7	do	do	None		24.6	
8	do	do	5 $(NH_4)_2CrO_4$		20.3	
9	do	do	10 Na_2CrO_4	347	23.6	24.8
10	do	do	10 $MgCrO_4$	361	24.0	25.0
11	do	300 $CaBr_2.2H_2O$	10 $(NH_4)_2CrO_4$	495	25.3	
12	do	300 KBr	5 $(NH_4)_2CrO_4$		10.1	
13	M1	1000 $SrBr_2.6H_2O$	0.2 $(NH_4)_2CrO_4$	142	10.2	
14	Z1	do	do	152	9.0	1.0
15	Magnesium	do	do	168	10.5	
16	AZ61	do	do	148	11.8	9.6
17	AZ31+0.2% Ca	do	None	147	11.0	9.3
18	do	100 LiBr	None		9.4	8.4
19	AZ31+0.15% Ca	200 NaBr	10 $(NH_4)_2CrO_4$		10.3	
20	do	300 $MgBr_2.6H_2O$	0.1 $CaCrO_4$		20.0	
21	AZ31+0.2% Ca	800 $BaBr_2.2H_2O$	None		9.1	9.6
22	AZ31	300 $MgBr_2.6H_2O$+25 LiBr	10 $(NH_4)_2CrO_4$	452	24.2	
23	do	100 $MgBr_2.6H_2O$+200 LiBr	5 $(NH_4)_2CrO_4$	357	22.2	16.7
24	do	100 $MgBr_2.6H_2O$+200 NaBr	do	373	18.2	14.3
25	do	100 $MgBr_2.6H_2O$+100 NH_4Br	10 $(NH_4)_2CrO_4$	284	19.3	
26	do	100 $MgBr_2.6H_2O$+200 KBr	5 $(NH_4)_2CrO_4$		17.5	
27	do	100 $MgBr_2.6H_2O$+200 $SrBr_2.6H_2O$	do	353	20.9	15.6

[1] Fe content less than 0.002%; Ni content less than 0.001%.

manganese, the balance being commercial magnesium in which the impurities iron and nickel preferably do not exceed about 0.002 and 0.001 per cent respectively, and the electrolyte is magnesium bromide in combination with lithium bromide. Long service cells are also obtained when ammonium bromide is used in the electrolyte along with either the alkali or alkaline earth metal bromide. In such instances the ammonium bromide may be used in a concentration of about 100–275 grams per liter of solution. A preferred concentration is about 150 grams of ammonium bromide per liter in combination with one of the other bromides aforementioned.

As aforementioned, we have found that it is desirable to include in the electrolyte a chromic acid salt of an alkali metal, an alkaline earth metal, or ammonium in corrosion-inhibiting concentrations such as 0.01 to 5 grams per liter of solution in order to reduce the open circuit corrosion and improve the uniformity of the closed circuit corrosion of the anode material, and a number of cells made up in this way are shown in Table III. Similar results are obtained with other chromic acid salts of the kind aforementioned such as Li_2CrO_4. However, the presence of one of the above mentioned chromic acid salts in the electrolyte sometimes has the disadvantage of causing a delay in the cell's attaining a working voltage following a rest period after a use of the cell. The delay is, we have found, a function of the concentration of the inhibitor, as shown by the data in Table IV.

TABLE IV

D size dry cells

Grams per Liter $(NH_4)_2CrO_4$	Seconds' Delay before Cell Attains 1 Volt
0.0	0.0
1.0	2.0
2.0	3.0
5.0	5.3
10.0	10.0

Electrolyte: 300 g. p. l. $MgBr_2.6H_2O$.
Anode: AZ31, iron less than 0.002%, nickel less than 0.001%.
Cathode: 90% MnO_2+10% acetylene black.

We have discovered that the voltage attainment delay which results from the presence of the chromic acid salt in the electrolyte is greatly reduced if not overcome by alloying with the anode material a small amount of calcium, such as from about 0.05% to 0.5% of the weight of the anode alloy.

The following data derived from measurements of voltage attainment characteristics of D size dry cells made up in accordance with the invention are illustrative of the advantage, as regards overcoming the delay in voltage attainment after a previous use of the cell, of including calcium in the anode metal.

TABLE V

Per Cent Calcium in Anode Metal	Seconds' Delay before Cell Attains 1 Volt
0 (Blank)	5.3
0.1	0.0
0.13	0.0
0.20	0.33
0.30	0.0
0.50	1.8

Electrolyte: 300 g. p. l. $MgBr_2.6H_2O$; 5 g. p. l. $(NH_4)_2CrO_4$.

In the foregoing table each delay reading is the average of two cells, and each cell was first discharged through a 5-ohm resistor for 1 hour, then rested for 17 hours before measuring the delay. After the rest period the average time in seconds required for the cells to attain 1 volt at the terminals on again being discharged through the 5-ohm resistor was recorded and set forth in the table above as the delay. Each cell employed a manganese dioxide-depolarized cathode formed of a mixture of 90 parts of manganese dioxide and 10 parts by weight of acetylene black.

In order to achieve a desirable control of anode corrosion in the cell, and at the same time avoid adverse effects on the time of attainment of operating voltage following a rest period after use, we have found that the concentration of the inhibitor should preferably not exceed about 2 grams per liter unless the anode metal contains calcium as aforesaid, in which case as much as 5 grams per liter may be used. Thus the presence of calcium in th eanode alloy is a distinct advantage, not only from the standpoint of reducing the delay in voltage attainment but also in permitting longer useful cell life before the anode wall becomes perforated due to corrosion by the electrolyte while at least partially overcoming the increased delay in voltage attainment occasioned by the presence of the inhibitor in the electrolyte.

Similar advantages are had as regards controlling delay in voltage attainment after a rest period following a use of the cell with cells compounded with mixed electrolytes. In Table VI delay data are set forth for examples of D size dry cells using mixed bromide electrolytes and anodes of AZ31 to which was added 0.15% of calcium. The electrolytes contained 1.0 gram per liter of ammonium chromate as inhiibtor.

TABLE VI

Cell No.	Electrolyte, Grams per Liter Salts	Seconds' Delay after Rest Period of	
		17 hrs.	1 Month
1	250 $MgBr_2.6H_2O$+50 $CaBr_2.2H_2O$	0	2.5
2	250 $MgBr_2.6H_2O$+50 NaBr	0	3.7
3	250 $MgBr_2.6H_2O$+50 NH_4Br	0	2.7
4	250 $MgBr_2.6H_2O$+50$SrBr_2$	0	0
5	250 $MgBr_2.6H_2O$+ 50 KBr	0	3.0
6	50 $MgBr_2.6H_2O$+250 $CaBr_2.2H_2O$	0	1.5
7	50 $MgBr_2.6H_2O$+250 NaBr	0	2.5
8	50 $MgBr_2.6H_2O$+250 NH_4Br	0	1.0
9	50$MgBr_2.6H_2O$+250 $SrBr_2$	0	0
10	50 $MgBr_2.6H_2O$+250 KBr	0	2.0

A characteristic of all the foregoing cells is their initial relatively high voltage of about 1.9 to 2.0 volts. Inasmuch as this high voltage does not persist for long on using the cell it is generally advantageous to short circuit each new cell for a short time, such as about 1.5 minutes, before use. This has the effect of lowering the cell voltage to a stable value of about 1.65 to 1.70 volts, which may be considered the nominal voltage of the cell. A similar effect as regards this reduction of the initial voltage of the cell to its nominal voltage may be had by rendering the electrolyte alkaline by adding to it a small amount of an alkali such as ammonia instead of short circuiting the cell.

In operation, cells made according to the invention constitute a unique voltaic system inasmuch as the cathode is depolarized by manganese dioxide operating in an alkaline medium. Attempts heretofore to use manganese dioxide as a depolarizer in an aqueous alkaline medium have been unsuccessful. For example, the zinc Le

Clanché cell becomes useless when the electrolyte becomes alkaline, due to the resulting large drop in voltage of the cell. In contra-distinction to this, in operation the electrolyte of our cells exhibits a pH of a least about 8.5, a pH at which conventional cells employing a manganese dioxide-depolarized cathode do not function. Thus the present cells make it possible to utilize effectively not only magnesium and its alloys as anodic material but also manganese dioxide in an alkaline voltaic system.

While the magnesium in the anode may be usual commercial quality which contains small amounts of some other elements as impurities, it is preferable to employ magnesium which does not contain more than about 0.005% of iron and 0.002% of nickel, if any. Thus the anode may be formed of either pure magnesium or of a magnesium-base alloy containing a major portion of the metal, all such materials being included with the term "magnesium" hereinafter employed.

It is to be understood that the foregoing description is illustrative rather than strictly limitative, and that other embodiments of the new cell are possible within the spirit of the invention and the scope of the following claims.

We claim:

1. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of an inorganic bromide selected from the group consisting of the bromides of the alkali and alkaline earth meta's.

2. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of an inorganic bromide selected from the group consisting of the bromides of the alkali and alkaline earth metals, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

3. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution containing the bromide of an alkali metal and the bromide of an alkaline earth metal.

4. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution containing the bromide of an alkali metal and the bromide of an alkaline earth metal, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

5. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of an alkaline earth metal bromide.

6. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of an alkaline earth metal bromide, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

7. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution containing magnesium bromide.

8. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution containing magnesium bromide, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

9. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution containing lithium bromide.

10. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution containing lithium bromide, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

11. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide and lithium bromide.

12. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide and lithium bromide, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

13. In a primary cell the combination comprising an anode of magnesium containing from 0.05 to 0.5 per cent of calcium, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of an inorganic bromide selected from the group consisting of the bromides of the alkali and alkaline earth metals.

14. In a primary cell the combination comprising an anode of magnesium containing from 0.05 to 0.5 per cent of calcium, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of an inorganic bromide selected from the group consisting of the bromides of the alkali and alkaline earth metals, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

15. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide and ammonium bromide.

16. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide and ammonium bromide, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hyroxide of an alkali metal, alkaline earth metal, and ammonium.

17. In a primary cell the combination comprising an anode of a magnesium-base alloy containing about 2 to 9 per cent of aluminum, 0.5 to 3 per cent of zinc, 0.1 to 0.5 per cent of manganese, the balance being magnesium, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide, said aqueous solution containing corrosion-inhibiting amounts of ammonium chromate.

18. In a primary cell the combination comprising an anode of a magnesium-base alloy containing about 2 to 9 per cent of aluminum, 0.5 to 3 per cent of zinc, 0.1 to 0.5 per cent of manganese, and 0.05 to 0.5 per cent of calcium, the balance being magnesium, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide.

19. In a primary cell the combination comprising an anode of a magnesium-base allow containing about 2 to 9 per cent of aluminum, 0.5 to 3 per cent of zinc, 0.1 to 0.5 per cent of manganese, and 0.05 to 0.5 per cent of calcium, the balance being magnesium, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting of the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

20. In a primary cell the combination comprising an anode of a magnesium-base alloy containing about 2 to 9 per cent of aluminum, 0.5 to 3 per cent of zinc, 0.1 to 0.5 per cent of manganese, 0.05 to 0.5 per cent calcium, the balance being magnesium, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution of magnesium bromide and strontium bromide, said aqueous solution containing corrosion-inhibiting amounts of ammonium chromate.

21. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, an an electrolyte comprising an aqueous solution containing calcium bromide.

22. In a primary cell the combination comprising a magnesium anode, a manganese dioxide-depolarized cathode, and an electrolyte comprising an aqueous solution containing calcium bromide, said aqueous solution containing corrosion-inhibiting amounts of a chromic acid salt of a base selected from the group consisting the hydroxide of an alkali metal, alkaline earth metal, and ammonium.

ASHFORD B. FRY.
ROY C. KIRK.
PERCY F. GEORGE.

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