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A Study of Dry Cell Battery Performance Indices

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Abstract: The dry cell batteries were designed and constructed by varying the dimensions of three different zinc containers sizes from the size of normal battery (torch light battery). The variations of three zinc containers were designed and constructed. They include:
Length and diameter as of standard 1.5 volts dry cell battery (A - size);
Double of the length of standard 1.5 volts dry cell battery but of the same diameter (B - size);
Double of the diameter of standard 1.5 volts dry cell battery but the same length (C - size).
The components used $ZnCl_2$, MnO_2, NH_4Cl, H_2O, Granulated carbon, and were mixed and introduced in the zinc container. The carbon rod was inserted to serve as an anode. The determined voltages from the varied sizes of the batteries are:
A - Size - 1.46 V,
B – Size – 1.45 V,
C – Size -1.48 V and all the sizes gave the same quantity of current of 0.01A
Keywords: Dry cell, Double of the length of standard 1.5 Volts, Double of the diameter of standard 1.5 Volts, standard length and diameter as of standard 1.5 Volts and performance indices

I. INTRODUCTION

We think of a simple dry cell battery as a source of portable electrical power, but it is no exaggeration to say that battery is one of the most important inventions in the history of mankind. Volta's pile was at first a technical curiosity but this new electrochemical phenomenon quickly opened the door to new branches of both Physics and Chemistry and a myriad of discoveries, inventions and applications, power engineering and much of the chemical industries of today were founded on discoveries made possible by the battery [5].

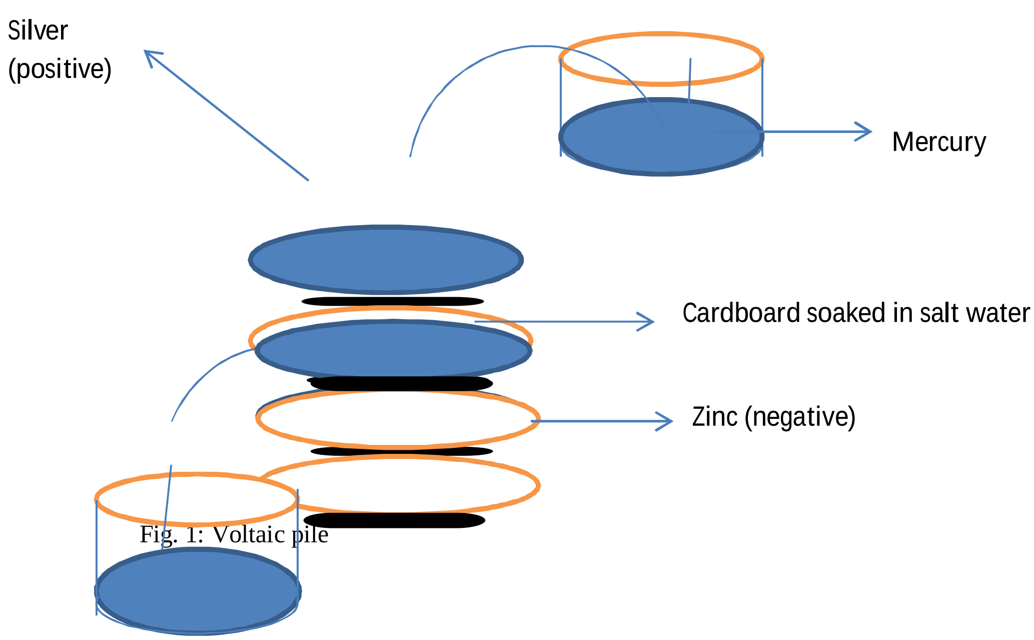

Fig. 1: Voltaic pile

It is often overlooked that through the nineteenth century, most of the electrical experimenters, mentors and engineers who made these advances possible had to make their own batteries before they could start their investigations. For many years the telegraph, and later the telephone industries were the only consumers of batteries in modest volumes and it was not until the twentieth century that more applications created the demand that made the battery a commodity [8]. Galvani's experiment with frogs had led him to believe that the source of the electricity was frog; however Volta sought to prove that the electricity came from the dissimilar metals used to probe the specimen. His "Voltaic pile" was initially presented in 1800 as an "artificial electric organ" to demonstrate that the electricity was independent of the frog. It was constructed from pairs of dissimilar metals zinc and silver separated by a fibrous diaphragm (cardboard) moistened with brine and provide the world's first continuous electric current. The pile produced a voltage of between one and two volts. To produce a higher voltage he connected several piles together with metal strips to form a "battery" [4]. The ground zero for battery technology is the carbon – zinc cells, the heirs of George's Leclanche 1886 invention. Carbon – zinc cells are probably the most common batteries in the world, known under a variety of names including dry cell and flash light battery. Carbon – zinc cells are the lowest storage density of any common battery [8]. Batteries actually have two voltage ratings, one at no load and the other at normal load. The cell's rated voltage at normal load is the one used. The no load voltage of a cell will be greater because of the internal resistance of the cell. All cells have some internal resistance. As the cell ages and power is used, the electrodes and the electrolyte begin to detoriate. This causes them to become less conductive, which results in an increase of internal resistance. As the internal resistance increases, the terminal voltage decreases [2].

Two important characteristics of a battery are its electromotive force, Emf, which characterizes the energy that the battery provides the charge carriers, and the internal resistance which is the battery's own resistance. A voltmeter placed across the battery measures the battery terminal potential difference, V, and an ammeter placed measures the current I. A graph of V versus I given by the equation $V = E - Ir$ is shown as:

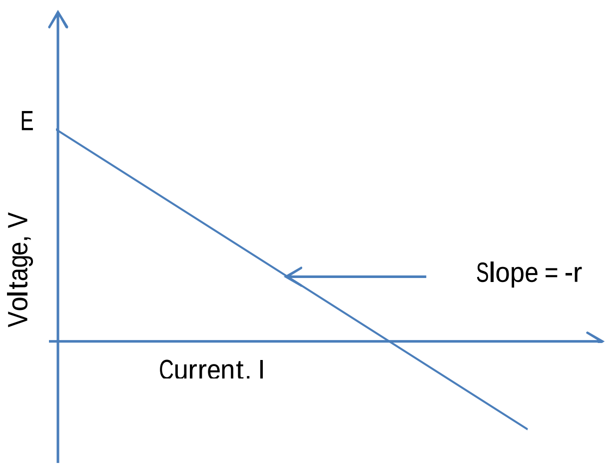

Fig. 2: A graph of potential difference versus current

The graph's intercept equals the value of Emf, E, and its slope gives the internal resistance, r. thus the battery's Emf is its terminal potential difference when the current in the battery is zero. That is $E = V$ (when I = 0).

Each component has different functions. The zinc container constructed from the metal sheet and being a transition metal plays a very role in construction of dry cell battery. It serves as anode and forms the shell of the battery.

Due to the fact that it is a metal, there is a tendency that it gives out its valence electron for current flow in the cell. In electrochemical reaction, conversion of chemical energy into electric energy occurs by an oxidation reaction contributing electrons to an external circuit through the electrode (anode) [7]. Electrons are supplied to the external circuit by the anode reaction: $Zn\,(s) \rightarrow Zn^{2+}\,(aq) + 2e^-$.

Carbon being a group four element in the periodic table equally has six (six) as the atomic number. It has valence of -4. This element has the tendency of accepting electron from the zinc metal as the anode. Due to the fact that it has valence of -4, it accepts valence electrons from zinc. From this fact, reduction reaction occurs and electrons from the external circuit are removed through an electrode (cathode) during electrochemical conversion [3].

$MnO_2\,(s) + H_2O\,(l) \rightarrow MnO(OH)(s) + OH^-\,(aq)$ [1].

Chemical reactions occur in every part of the battery to allow for energy storage; the reactions can be described using balanced chemical equations that delineate the electron flow. The paste of ammonium chloride reacts according to the following half reaction:

$2NH_4\,(aq) + 2e^- \rightarrow 2NH_3(g) + H$

Manganese dioxide is blackish – powdered compound called depolarizer. Depolarization takes place more slowly than the rate

at which hydrogen is liberated by the action of zinc and ammonium chloride paste. Therefore when the cell is in continuous use, some depolarization takes place and the electromotive force of the cell drops. The manganese (IV) oxide in the cell removes the hydrogen produced by the ammonium, according to the following reaction: $2MnO_2\ (s) + H_2(g) \rightarrow Mn_2O_3\ (s) + H_2O\ (l)$.
The electrochemical series is built up by arranging various redox equilibra in order of their standard electrode potential (redox potential). The most negative E^o values are placed at the top of the electrochemical series, and the most positive at the bottom. The difference in the position of equilibrium causes the number of electrons which build up on the metal electrode and the platinum of the hydrogen to be different. That produces a potential difference which is measured as a voltage.
Metals at the top of the series are good at giving away electrons. They are good reducing agents. Metal ions at the bottom of the series are good at picking up electrons. They are good oxidizing agent. The oxidizing ability of the metal ions increases as you go down the series. At standard condition, the cell potential, $E_{cell} = E^o_{cathode} - E^o_{anode}$ but in real Voltaic cell, it differs from the standard conditions using Nernst equation, $E_{cell} = E^o_{cell} - \frac{RT}{nF}\ln Q$, where E^o_{cell} is the standard potential for a cell, R is gas constant, T is the temperature in Kelvin, Q is the thermodynamic reaction quotient, F is the Faraday's constant, n is the number of electron transferred. Since the concentrations of the metal solids are assigned the value 1M, then $E_{cell} = E^o_{cell}$ since both electrodes are in solid form [6]. The standard potential of both electrodes are -0.76 V and +0.74 V for zinc and graphite (carbon rod). Therefore it is expected that the standard electrode potential should be 1.5 V [5].

II. EXPERIMENTAL DETAILS

The zinc container is constructed from zinc metal sheet. The sample of standard 1.5 volts dry cell battery size was measured in all its dimensions like the diameter and length with aid of Venier caliper. The diameter used on the plane metal is determined from the circumference obtained with the measured diameter. The dimensions were also varied as regards the double of the diameter and double of the length of the standard 1.5 volts dry cell battery size respectively. The parts cut – off were fixed on the bench vice and scraped the unwanted parts by filing. The required size was sent to an adjustable machine for bending. The machine was adjusted to the required size of zinc container and the cylindrical shaped-part bended. The machine equally did also joining the ends of the cylindrical shape material. Then, the closed bottom cover was depressed manually to the required position. After this, the cylindrical shape material was sent for soldering the bottom cover and the cylindrical shape part together. The same construction technique was used for the double diameter and double and length sizes. The masses of different components were measured. For all that requires high capacity at low current drains (for example, transistor radio), the ratio of manganese dioxide to carbon is 10: 1. This black mixture (manganese dioxide + carbon) also contains electrolyte amounting about 25% of the total weight. The volume = $\pi R^2 H$ of cylindrical shaped zinc container need to be calculated so that the energy density of the cell in (J/m^3). Energy density = Energy/Volume[1]. The radius of A-size cell =0.0125m, the height of A-size cell = 0.055m. The mass of $ZnCl_2$ was measured from the weighing balance and also that of NH_4Cl. These two compounds were mixed with water to be in paste form. This electrolytic paste was introduced into the pores between the separator and zinc container. The mass of carbon was measured and equally that of manganese dioxide. These were mixed with the help of small quantity of water and added between the separators, surrounding the carbon rod. In the production processes, the zinc container was brought and the separator as a blotting paper inserted both horizontal and vertical positions to separate the two electrodes against contact. The carbon rod is inserted in the center of the cell where mixture of granulated carbon and manganese dioxide were packed round the rod. This mixture enclosed with blotting paper and the mixture of ammonium chloride and zinc chloride surrounding the blotting paper and zinc container. The bitumen seal is applied to prevent leakages. Then the protective casing is attached to the zinc container.

Table 1: Data for normal size cell battery (D - size)

Material used	Mass of material used (g)
mnO_2	16.9
NH_4Cl	7.0
Zn	22.5
$ZnCl_2$	14
Carbon rod	6.5
Granulated carbon	3.1
Blotting paper	1.2
Plastic seal	5.1
Total mass	76.3

III. RESULTS AND DISCUSSION

When the weight of the compounds or elements is added into the zinc cup, the carbon rod is inserted at the center of the cell. Then the cells' voltages and currents are measured with aid of AVO meter.

Table 2: Battery sizes and their respective Voltage, Current and power produced

Battery size	Voltage (V)	Current (A)	Power (mW)	
A – size	1.46	0.01	14.6	
B – size	1.48	0.01	14.8	
C – size	1.45	0.01	14.5	

These show that different sizes of the batteries have corresponding voltage, current and power value not regarding the size of the cell.

Table 3: Battery sizes and their respective volume, mass, density and energy density

Quantity	A – size battery	B – size battery	C – size battery
Volume (m^3)	2.7×10^{-5}	5.4×10^{-5}	10.8×10^{-5}
Mass (kg)	0.0763	0.1546	0.305
Density (kg/m^3)	2.83×10^{3}	2.86×10^{3}	2.76×10^{3}
Energy density (J/m^3), E	8.6×10^{-8}	4.3×10^{-8}	2.1×10^{-8}

The densities of all the sizes are the same, the energy density produced by B – size is half of A – size. Also that of B – size is twice of the C – size. Mathematically, $\frac{EA}{EB} = \frac{EB}{EC} = 2$.

IV. CONCLUSION

The carbon – zinc cells (Leclanche cells) are the cheapest battery everyone can buy in the sense that they are less expensive. Also, the carbon zinc cells are widely available. In trying to double the diameter or length of normal of normal size dry cell battery, the voltage will not be increased rather it will remain the same as that of the normal size since the mass – volume ratio remains the same. To produce more voltage from a battery, six individual cells rated at 1.5 V have to be connected in series. Battery in this form usually takes a rectangular shape form.

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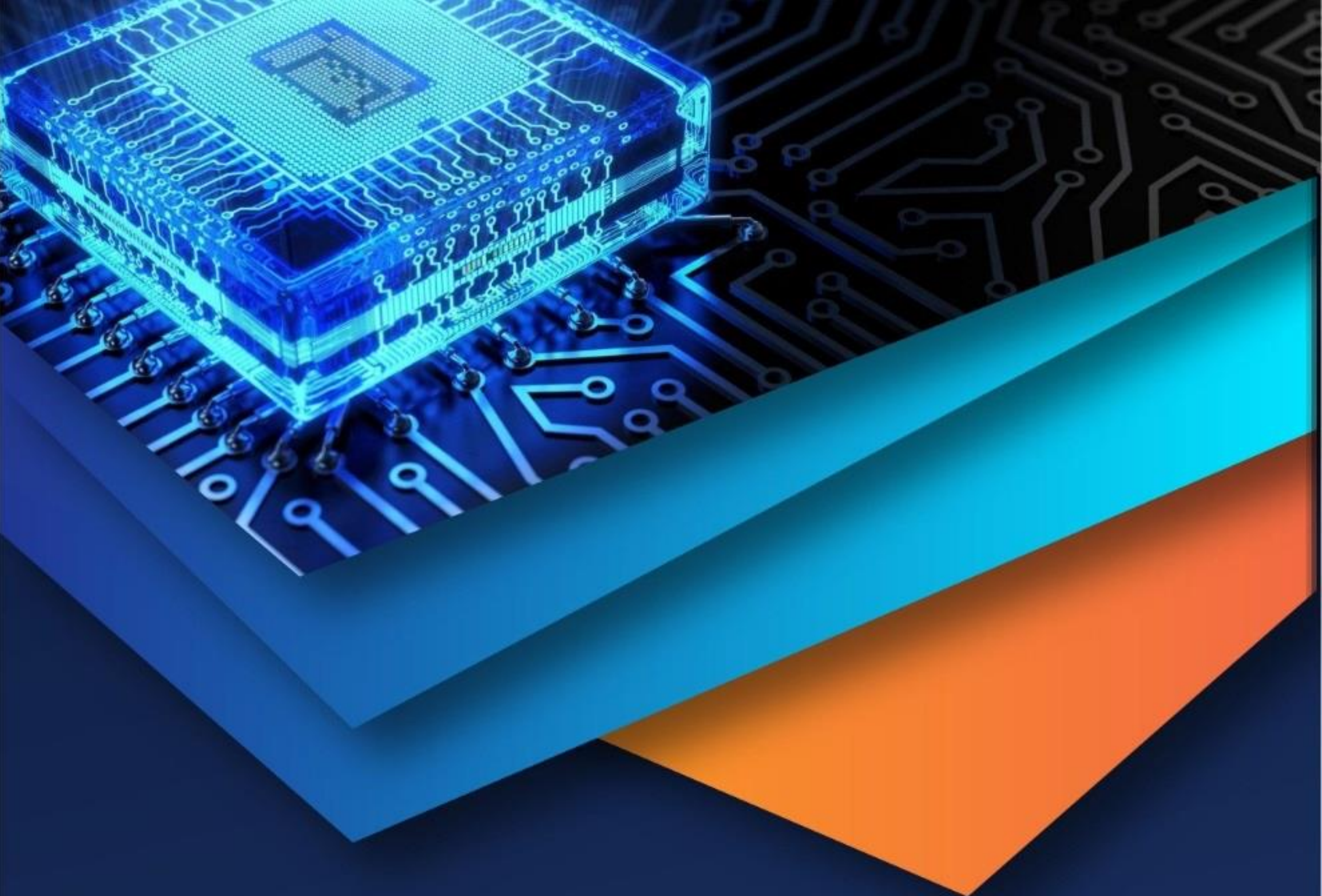

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