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OHM'S LAW AS A TOOL FOR QUALITY CONTROL

Godspower O. Ashaka[1*] , Minaibim Ellerton Abbey[1], Ngiangia T. Alalebo[2]

Abstract— Ohm's Law was employed as a quality control method in determining the highest quality of a battery life span in this study. The voltage, current, and time at which five selected dry cell batteries discharge their stored voltage were determined using a Voltmeter, Ammeter, and a timer in an experiment. A model was proposed to calculate the performance rate of Tudor, PowerSuper, Motoma, Tunar Max, and Loncell dry cell batteries using Ohm's Law, Least Square Estimation, and the Reliability Function. The failure rates for the batteries are λt=0.2258, λl=0.3251, λp= 0.2221, λtm =0.3258 and λm= 0.2041, respectively, according to the research findings, while a model for the reliability functions determined that Motoma battery has about 20% lower failure rates, making it more reliable, followed by Tudor and PowerSuper with 22% failure rate, and while Loncell and Tunar Max have about 33% failure rate. The results collected can assist us in making an informed selection about which battery quality to purchase among the ones investigated in this study.

Index Terms— Reliability, quality control, model, performance rate, Mean time to failure.

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1 Introduction

The use of remote control, wall clocks, and other portable devices are often limited by the capacity of the employed dry cell batteries [1] The battery performance rate can be used to predict their life span by defining how long the battery can last when it is being discharged. In this research, the discussion of Ohm's Law as a quality control tool is in terms of the performance rate and reliability of the battery [2]. Many researchers have been working both experimentally and theoretically on the dry cell battery performance and discharge rate. Some research was done on the problem associated with measuring the reliability of a system, components, and even subsystems and it was observed that most problems in reliability could be solved by adequate knowledge of mathematics and probability [3]. Product quality and reliability are crucial competence factors and hence the major concerns of manufacturing industries. To achieve world-class quality, the manufacturer of a product must satisfy customer needs using quality materials, models, tools, and techniques to help manage reliability and quality for their products, hence the need for all manufacturers to model a reliable system that rolls out their products to the market [4]. Dry cells are single-use batteries because they are not rechargeable. Therefore, modeling the performance rate of dry cell batteries can provide adequate information to manufacturers to help calculate, and probably extend their duration in the case of these batteries here understudy. There are many, unlike battery models that have been established over the years. Nevertheless, with these models, one can only calculate lifetimes for exact discharge outlines and not for capabilities, in general, using Ohm's law. In this research work, the focus is to measure the performance rate in terms of reliability functions for some five selected dry cell batteries in a bid to use their reliability exponential distribution to predict their performance rate and to know the efficacy of each battery under study [5]. The model focuses on the quality and reliability function of the batteries based on user-defined performance requirements. Most of the batteries in the market are not reliable considering the nominal voltage assigned to them [6]. This study will help to provide information to the manufacturer of some dry cell batteries on how to use the findings in this research work to improve their manufacturing processes [7]. The result of this research has been considered to allow the user to make an informed decision as regards the performance rate in terms of their quality and reliability function distribution. This research work can also be a source of useful information for the Standard Organization of Nigeria in checking the importation of substandard dry cell batteries into the Nigerian economy.

- *Godspower O. Ashaka[1]. Department of Physics/Instrumentation and Control Technology, School of Applied of Sciences, Federal Polytechnic of Oil and Gas Bonny, Rivers State, Nigeria. E-mail: Ashakagp@gmail.com*
- *Minaibim Ellerton Abbey, Department of Physics/Instrumentation and Control Technology, School of Applied of Sciences, Federal Polytechnic of Oil and Gas Bonny, Rivers State, Nigeria. E-mail: abbeyminaibim@gmail.com*
- *Ngiangia T. Alalebo, Department of Physics, University of Port Harcourt, Rivers State, Nigeria*

2 Theoretical Analysis

Reliability of a product is the probability that an item performs specific functions under given conditions for a specified period without failure. The theoretical concept for this study looks at the statistical calculation using the reliability function of certain AA batteries ('DOUBLE A'). AA batteries measure at 1.5 volts and are used in portable devices such as wall clocks. We considered the Reliability analysis study on the batteries which is the time frame within the period this study was carried out, measured at every one-hour interval, using the Reliability function.

$$R(t) = \exp(-\lambda t) \quad (1)$$

Where λ is the slope of the line which represents the failure rate, t is the time in hours and R(t) is the reliability function.

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3 Materials and Method

Five different types of brand new batteries were used for the experiment (Tudor – type R6-P 1.5V size, Loncell AA R6 UM-3 1.5V size, Tunar Max Tech –AA R6 UM-3 1.5V, Motoma –AA-R6P-SUM-3 1.5V, and PowerSuper Extra – AA R6P UM-3 1.5V), A stopwatch for measuring time, E-M408 Voltmeter 0-2 volts for measuring the potential difference (V), J0407 Ammeter 0-1 amper to measure the current (I), Zigma torch bulb, 2.5volts, 0.5mm stranded wire, Micrometer screw gauge, Ordinary thermometer for measuring temperature. The model described here-in is a calculated method that was developed from the data collected from the experiment performed at the Physics Department Laboratory (Federal Polytechnic of Oil and Gas Bonny) at a temperature of about 30°C.

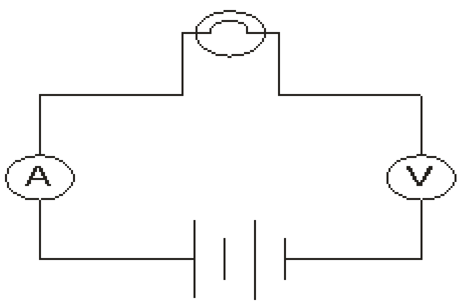

Figure 1: Circuit diagram used for the experiment

Using Electrical power = Current X voltage, the current and voltage measured was converted to electrical power in Watts.

To test their performance rate, the batteries were connected to an external circuit. The voltage, current, and power rating readings were taken and recorded at the end of every hour (see Figure 1). The average power of Tudor, Loncell, PowerSuper Extra, Tunar Max Tech and Motoma batteries are 0.23watts, 0.21watts, 0.24watts, 0.21watts and 0.22watts respectively in table (1). After an hour, the power dropped of Tudor, Loncell, PowerSuper Extra, Tunar Max Tech and Motoma batteries are 0.13watts, 0.10watt, 0.20watts, 0.17watts and 0.20watts respectively. Finally, the Loncell battery's power dropped to zero after six hours, and all five batteries' power dropped to zero after seven hours.

The experiment was repeated other days at a temperature of 27°C to check and ascertain the consistency of the performance rate of the batteries and the results obtained were consistent with the previous results. Sixteen (16) pieces of brand new batteries each of Tudor, Loncell, PowerSuper Extra, Tunar, and Motoma batteries, and type R6-P 1.5, AA R6 UM-3 size.

4 Results and Discussion

The results are presented both in tables and figures. The Table 3-7 were estimated from equation 1.

Table 1: Average Power (Watts) of batteries.

Time (hrs)	Tudor (watts)	Loncell (Watts)	PowerSuper (Watts)	Tunar Max (watts)	Motoma (watts)
0	0.23	0.21	0.24	0.21	0.22
1	0.13	0.10	0.20	0.17	0.20
2	0.09	0.06	0.18	0.14	0.19
3	0.01	0.02	0.13	0.14	0.13
4	0.004	0.004	0.08	0.02	0.11
5	0.006	0.001	0.02	0.006	0.08
6	0.00	0.00	0.01	0.00	0.01
7	0.00	0.00	0.00	0.00	0.00

Table 2: Time to Failure of batteries

Battery brands	**Time (hour)**						
	1	2	3	4	5	6	7
Loncell	4	2	3	2	3	1	1
Motoma	3	2	1	4	1	3	2
PowerSuper	4	2	2	1	3	3	2
Tudor	1	2	4	2	3	1	3
Tunar Max	2	2	4	3	3	1	1

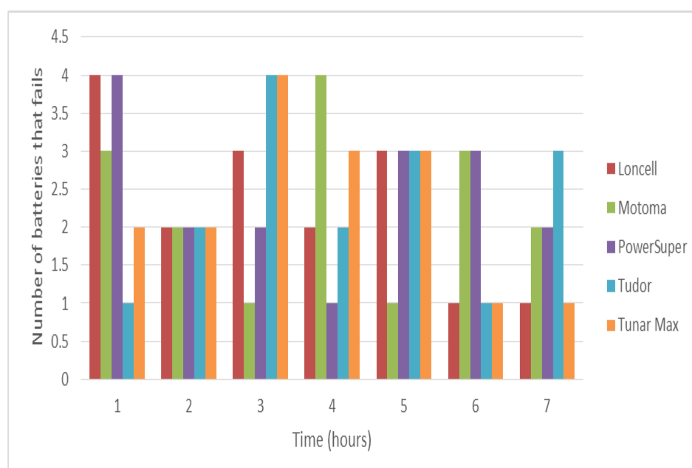

Figure 2: Time to Failure of batteries

From figure 2, it was observed that a brand of battery with the same nominal voltage rating of 1.5V failure rate differs at the same time interval when other physical parameters are kept constant.

Table 3: Time / Reliability Function Table for Tudor Batteries

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Time(hrs)	*1*	*2*	*3*	*4*	*5*	*6*
R(t)	1.000	0.9375	0.8125	0.5625	0.4375	0.250
-InR(t)	0.000	0.0645	0.2076	0.5754	0.8267	1.3863

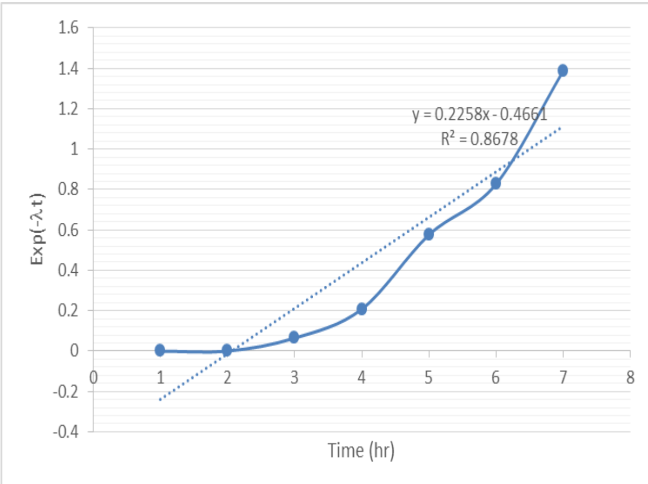

Figure 3: Reliability Function against Time for Tudor Batteries

Table 4: Time / Reliability Function Table for Loncell Batteries

Time(hrs)	*1*	*2*	*3*	*4*	*5*	*6*
R(t)	1.000	0.7500	0.6250	0.4375	0.3125	0.1250
-InR(t)	0.000	0.2877	0.4700	0.8267	1.1632	2.0794

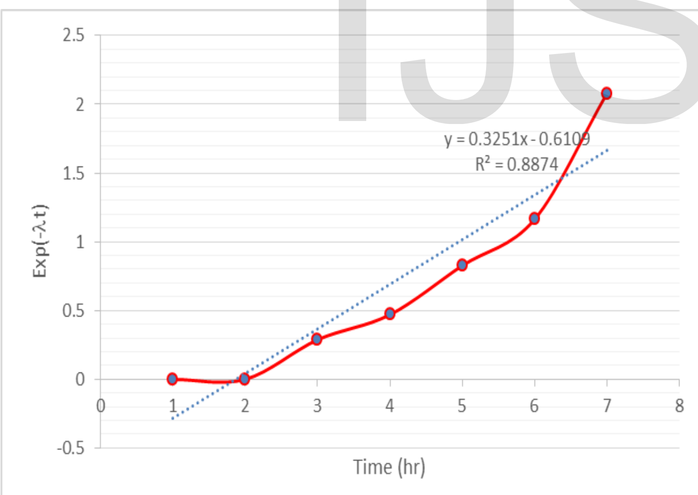

Figure 4: Reliability Function against Time for Loncell Batteries

Table 5: Time / Reliability Function Table for PowerSuper Extra Batteries

Time(hrs)	*1*	*2*	*3*	*4*	*5*	*6*
R(t)	1.000	0.7500	0.6250	0.5000	0.4375	0.2500
-InR(t)	0.000	0.2877	0.4700	0.6931	0.8267	1.3863

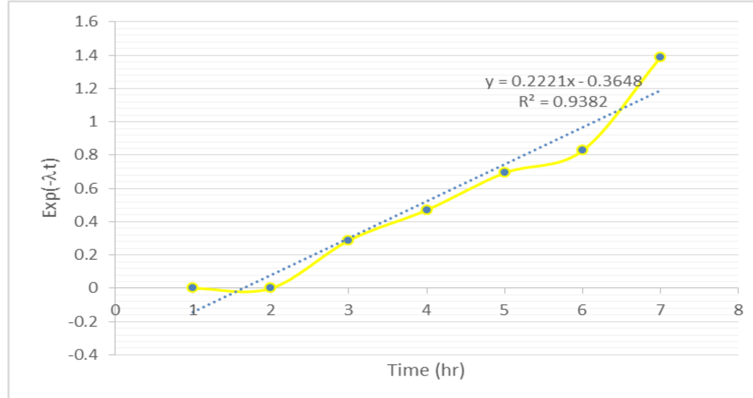

Figure 5: Reliability Function against Time for PowerSuper Extra Batteries

Table 6: Time / Reliability Function Table for Tunar Max Batteries

Time(hrs)	*1*	*2*	*3*	*4*	*5*	*6*
R(t)	1.000	0.8750	0.7500	0.5000	0.3125	0.1250
-InR(t)	0.000	0.1335	0.2877	0.6931	1.1630	2.0790

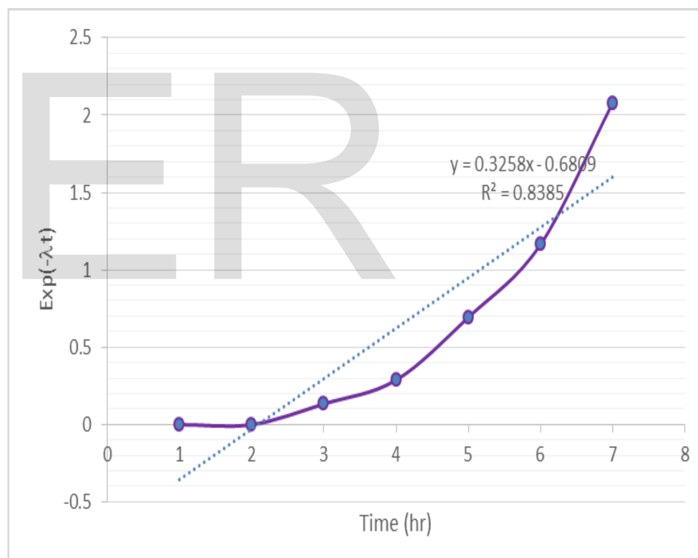

Figure 6: Reliability Function against Time for Tunar Max Batteries

Table 7: Time / Reliability Function Table for Motoma Batteries

Time(hrs)	*1*	*2*	*3*	*4*	*5*	*6*
R(t)	1.000	0.8125	0.6875	0.6250	0.3750	0.3125
-InR(t)	0.000	0.2076	0.3747	0.4700	0.9808	1.1632

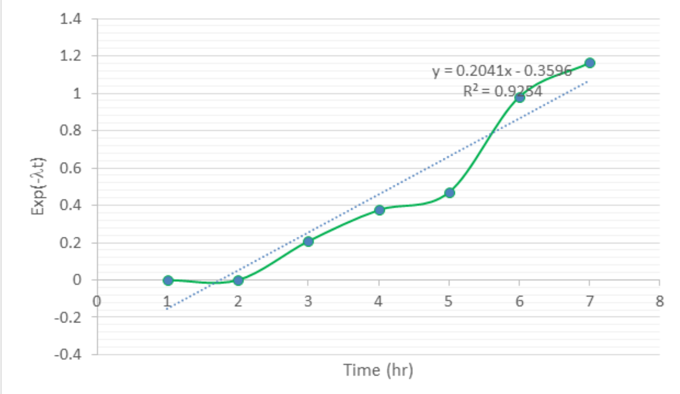

Figure 7: Reliability Function against Time for Motoma Batteries

Figure 3-7 depict the reliability function plot showing the instantaneous failure rate of all batteries and they all have positive correlation, implying a change in the reliability function will cause a corresponding change in the time.

Parameters of battery failure rate are: λ_t=0.2258, λ_l=0.3251, λ_p= 0.2221, λ_{tm}=0.3258 and λ_m= 0.2041

where λ_t, λ_l, λ_p, λ_{tm} and λ_m are the failure rate of Tudor(T), Loncell (L), PowerSuper (P), Tunar Max (Tm), and Motoma (M) batteries respectively.

The mean time to failure of the batteries are calculated below as follows:

MTTF = $\frac{1}{\lambda}$ (2)

α_T = 4.43, α_L = 3.08, α_P= 4.50, α_{Tm}= 3.07 and α_M= 4.90

$R_i(t) = e^{-\lambda_i t}$ (3)

MTTF = $\int_0^\infty R(t).dt$ (4)

Reliability R_T(t) =$e^{-\lambda t}$ = $e^{-0.2258t}$ (5)

Reliability R_L(t) =$e^{-\lambda t}$ = $e^{-0.3251t}$ (6)

Reliability R_P(t) =$e^{-\lambda t}$ = $e^{-0.2221t}$ (7)

Reliability R_{Tm}(t) =$e^{-\lambda t}$ = $e^{-0.3258t}$ (8)

Reliability R_M(t) =$e^{-\lambda t}$ = $e^{-0.2041t}$ (9)

Equation (5), (6), (7), (8), and (9) are the reliabilities of Tudor (T), Loncell (L), PowerSuper (P), Tunar Max (Tm), and Motoma (M) batteries respectively.

5 Conclusion

Any manufacturing process is subject to fluctuations, the specification to be satisfied by the product manufacturer is frequently made during the manufacturing process; effort is made during the production of the material to satisfy the required specification. In addition, the product quality control inspector inspects the product at the conclusion of production to ensure that it satisfies the needed quality standards before being released to the market for consumption. From our research, it was discovered that a Tudor battery whose failure rate is λT = 0.2258 and its reliability is $e^{-0.2258t}$ is out of hand. This finding applies to the remaining four batteries used for this research.

The Tudor(T), Loncell (L), PowerSuper (P), Tunar Max (Tm), and Motoma (M) batteries have an average failure rate λ_t=0.2258, λ_l=0.3251, λ_p= 0.2221, λ_{tm} =0.3258 and λ_m= 0.2041 respectively.

The failure –time distribution for the five batteries were obtained with the failure time distribution f(t)T = 0.2258$e^{-0.2258t}$; f(t)L = 0.3251$e^{-0.3251t}$;f(t)P = 0.2221$e^{-0.2221t}$; f (t)Tm = 0.3258$e^{-0.3258t}$, f(t)M = 0.2041$e^{-0.2041t}$. From the failure–time distribution, the reliability and failure rate of Tudor (T), Loncell (L), PowerSuper (P), Tunar Max (Tm), and Motoma (M) batteries are obtained, these variations are some of the problems usually experience from batteries manufacturers in the Nigerian market.

Furthermore, it was observed that a brand of battery with the same nominal voltage rating of 1.5V failure rate differs at the same time interval when other physical parameters are kept constant; while the reliability functions established that Motoma battery has about 20% lower failure rates, making it more reliable, followed by Tudor and PowerSuper with 22% failure rate, and Loncell and Tunar Max have about 33% failure rate.

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