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PERFORMANCE TESTING OF MOBILE PHONE BATTERIES

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ABSTRACT

This paper reports the performance of mobile phone batteries. The performance tests carried out include determination of the battery capacity (Ampere-hour rating), measurement of the battery's talk time, self-discharge test and ohm test. These tests were carried out using Cadex C8000, an advanced programmable battery testing system. Results show that the battery type (whether it's a battery that came along with newly purchased mobile phone or a replacement battery) had significant effect on the battery's actual Ampere-hour capacity and talk time. Therefore, it is concluded that batteries which came along with newly purchased mobile phones perform better than replacement batteries obtained from mobile phone accessory shops. This confirms the claim of consumers on the underperformance of replacement batteries; consequently, there is need for standards for mobile phone batteries imported into the Nigerian market.

Keywords: Mobile phone, Battery capacity, Talk time, Battery performance.

1.0 INTRODUCTION

Cell phone is also known as mobile phone. The name indicates that the phone does not have to be stationed in one location. These phones operate without a cord of the necessity of a home base. It is easy to be carried by the user and isused to make and receive calls among many other applications [1]. Mobile phones are equipped with a wide range of applications for work, play and for communicating with smart networks. The use of mobile phones has now been integrated into human lives; it has become a general populace item that cannot be done without. The continuous use of a mobile phone has been made possible by the components integrated into the device such as resistors, capacitors, diodes, inductors, transistors, integrated circuit (IC) and battery, to mention but a few. The battery in a mobile phone serves as an energy storage device.

The tremendous increase in the applications running on mobile phones means more energy is required from the energy storage device (battery).The increase of mobile phone users and usage has sprung replacement parts manufacturers and retail shops, most especially for the battery, which is a frequently failed part. As different companies manufacture batteries, there are bound to be differences in the batteries'quality and reliability in terms of meeting the need for powering the device, as may be claimed by those manufacturers. A challenge of meeting the need of users has been observed to lead to an individual having more than one battery for a mobile phone [2]. As a new mobile phone comes with at least one battery, replacement batteries are also available in the market for phones whose batteries are no longer good. The replacement batteries are not necessarily manufactured by the mobile phones' manufacturers and their economic values are not the same, as the replacement batteries are also of different prices. The choice of purchase is a function of users' financial buoyancy and usage experience.

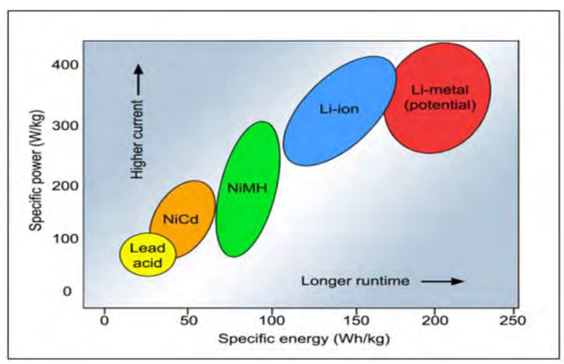
Improper disposal of batteries cause harm to the environment and the health of the consumers. Although Li-Ion batteries which are used in modern mobile phones are free of heavy metals (lithium has a low atomic number), lithium's high degree of chemical activity can create environmental problems. When exposed to water, which is present in most landfills, the metal can burn, causing underground fires that are difficult to extinguish. Landfill is not sustainable; dumping mobile phone batteries creates long term pollution risk to the environment. Since hundreds of millions of mobile phones batteries and their replacements are in use in Nigeria, there is a high risk of hazard caused to the health of the consumers and the environment if the batteries are improperly disposed.Therefore, this study focuses on testing the performance of mobile phone batteries; comparing the manufacturers' specifications with results obtained. This will help to identify batteries that do not meet up with specifications, thus controlling the influx of substandard batteries in the country. This results in better performance of the batteries and consequently, customers' satisfaction. It guarantees that Nigerians purchase durable batteries which have the performance stated in their labels. Also, it minimizes the adverse environmental effects of disposing the batteries.

2.0 THEORY

A battery stores electrical energy and delivers it through an electro-chemical reaction. A battery is made up of electro-chemical cells. An electrochemical cell consists of a cathode and an anode which areseparated by an electrolyte. Electric current is created as a result of the flow of electrons from the anode to the cathode. Primary cells (or batteries) are used once and discarded while secondary cells (or batteries) are rechargeable and can be used several times.

The major types of rechargeable batteries include: Lead Acid, Nickel Cadmium (NiCd), Nickel Metal Hydride (NiMH) and Lithium Ion (Li-Ion). Lithium-Ion batteries are the most advanced and most expensive batteries used in mobile phones today. They are commonly used in mobile phones because they have excellent power/weight ratio, longer talk time and do not experience "memory effect". Memory effect is a condition whereby rechargeable batteries lose their maximum energy capacity if they are not allowed to deeply discharge before being recharged.

Fig. 1 illustrates the energy and power densities of lead acid, nickel-cadmium (NiCd), nickel-metal-hydride (NiMH) and the Li-ion family (Li-ion).Specific energy is the capacity a battery can hold in watt-hours per kilogram (Wh/kg); specific power is the battery's ability to deliver power in watts per kilogram (W/kg) [3].



(Source:http://batteryuniversity.com/learn/article/global_battery_markets)
Figure 1: Specific energy and specific power of rechargeable batteries

2.1 LI-ION BATTERY TECHNOLOGY

Pioneer work with the lithium battery began in 1912 under G.N. Lewis but it was not until the early 1970s when the first non-rechargeable lithium batteries became commercially available. Lithium is the lightest of all metals, has the greatest electrochemical potential and provides the largest energy density for weight. Attempts to develop rechargeable lithium batteries failed due to safety problems. Because of the inherent instability of lithium metal, especially during charging, research shifted to a non-metallic lithium battery using lithium ions. Although slightly lower in energy density than lithi um metal, lithium-ion is safe, provided certain precautions are met when charging and discharging. In 1991, the Sony Corporation commercialized the first lithium-ion battery. Other manufacturers followed suit [4].

Rechargeable lithium batteries involve a reversible insertion/extraction of lithium ions (guest species) into/from a host matrix (electrode material), called lithium insertion compound, during the discharge/charge process. The lithium insertion/extraction process occurring with a flow of ions through the electrolyte is accompanied by the reduction/oxidation reaction of the host matrix combined with a flow of electrons through the external circuit. The name of lithium-ion battery is usually determined by cathode material, for example, lithium iron phosphate, and lithium cobalt battery [5]. The principle behind the chemical reaction in the lithium ion battery is one where the lithium in the positive electrode lithium cobalt oxide material is ionized during charge, and moves from layer to layer in the negative electrode. During discharge, the ions move to the positive electrode and return to the original compound. The chemical reactions for charge and discharge are as shown in equations 1, 2 and 3[6]:

Positive electrode

$$LiCoO_2 \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftarrows}} Li_{1-x}CoO_2 + xLi^+ + xe^- \quad (1)$$

Negative electrode

$$C + xLi^+ + xe^- \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftarrows}} CLi_x \quad (2)$$

Battery as a whole

$$LiCoO_2 + C \underset{\text{Discharge}}{\overset{\text{Charge}}{\rightleftarrows}} Li_{1-x}CoO_2 + CLi_x \quad (3)$$

3.0 METHODOLOGY

3.1 EQUIPMENT USED

Cadex C8000, which is an advanced programmable battery testing system was used to measure the performances of the mobile phone batteries. The Cadex C8000 battery testing system is equipped with digital drivers to handle batteries from 50mAh to 100Ah [7].

3.2 BATTERY TESTING

Seven mobile phone batteries were subjected to performance tests. Batteries A1, A2 and A3 were batteries used in Nokia mobile phones; batteries B1 and B2 were used in Samsung mobile phones while batteries C1 and C2 were used in Techno mobile phones. A1, B1 and C1werebatteries that came along with newly purchased mobiles while A2, A3, B2 and C2 were replacement batteries for the phones. Battery A3 was purchased at twice the price of Battery A2. All the batteries were new batteries. Listed in table 1 are the batteries' specifications:

Table1: Specifications of the batteries tested

BATTERY	A			B		C	
	A1	A2	A3	B1	B2	C1	C2
Model	BL-5CB	BL-5C	BL-5C	AK	AK	BL-6GT	BL-6 GT
Battery Chemistry	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion	Li-Ion
Ah Rating	800 mAh	1020 mAh	1020m	800m/	800 mAh	1800m	1800m Ah
Voltage Rati	3.7V	3.7V	3.7 V	3.7V	3.7V	3.7V	3.7V
Energy Ratir	3.0 Wh	3.8 Wh	3.8 Wh	2.96W	2.96 Wh	6.66' Wh	6.66 Wh
Country Manufacture	Country	Count	Count	Count	Count	Count	-

The batteries were subjected to performance tests to ascertain their practical performances as compared to their specifications. Cadex C8000, an advanced programmable battery testing system was used to measure the performances of the mobile phone batteries. The tests conducted include [7]:

i. **Determination of the battery capacity (Ah rating).** The batteries were discharged to obtain the first capacity; then they were charged and discharged to determine the second capacity (the first capacity is the capacity after the first discharge while the second capacity is the capacity after the second discharge). The charge and discharge cycle was repeated until the difference between capacities from one cycle and the next was less than 5%.

ii. **Measurement of the battery's talk time:** Simulated GSM or CDMA discharge pulse was used to determine the battery's talk time. The batteries were charged,and then discharged using the GSM or CDMA discharge pulse.

iii. **Self-Discharge Test**: Self-discharge test identifies the self-discharge or the amount of charge a battery loses if it is left alone for a period of time. The standard time was 24 hours. The batteries were charged and discharged to obtain their capacities (first capacity). The batteries were then charged and left for a 24-hour rest period; during this time, the batteries lost energy through self-discharge. Then, the batteries were discharged to determine their capacities (second capacity). The difference between the second and first capacity is the self-discharge rate.

iv. **Ohm Test**: The ohm test measures the resistance of the battery which is an estimate of the battery capability to handle load.

3.3 STATISTICAL ANALYSIS

The tests results were analysed using one-way ANOVA to determine if the battery type (either battery that came along with newly purchased mobile phone or replacement battery) had significant effect on the test results. SPSS software was used for the analysis.

4.0 RESULTS AND DISCUSSION

4.1 Determination of the battery capacity (Ah rating)

Table 2 shows the measured capacities of the batteries while tables 3 and 4 show the statistical analysis of the results.

There was a statistically significant difference between groups as determined by one-way ANOVA ($F(2,4) = 153.176$, $p = .000$). This shows that the battery type(whether it's a battery that came along with newly purchased mobile phone or a replacement battery) had significant effect on the actual Ah capacity of the battery. The actual Ah capacities of the batteries that came along with newly purchased mobile phones were between 95-100% of their specifications while the replacement batteries showed poor results. However, battery A3 which was purchased at twice the price of battery A2 showed better result (89% of the manufacturer's specified value) when compared to battery A2.

Moreover, table 2 also shows that the capacities of the batteries after their first discharge were low. This is because lithium-based battery chemistries should not be stored at full charge state so as to minimize age-related capacity loss. Hence, new batteries should be charged to full capacity before use. Also, lithium-based battery chemistries should not be stored at too low state-of-charge so as to keep the battery in operating condition and allow self-discharge.

Table 2: Capacities of the batteries

BATTERY	A			B		C	
	A1	A2	A3	B1	B2	C1	C2
Ah Rating Specification (mAh)	800	1020	1020	800	800	1800	1800
1st *Capacity* (%)	40	3	53	55	3	53	1
2nd Capacity (%)	100	17	93	97	17	96	3
Final Capacity (%)	100	18	89	97	17	95	3
Actual Ah Capacity Available (mAh)	800	183.6	907.8	776	136	1710	54

Table 3: Descriptives Table (Battery Capacity)

	Sum Squares	df	Mean Square	F	Sig.
Between Groups	.381	2	.190	.571	.605
Within Groups	1.33	4	.333		
Total	1.71	6			

Table 4: ANOVA Table (Battery Capacity)

95% Confidence Interval for Mean								
Battery	N	Mean	Std. I	Std. Error	Lowe Boun	Uppe Boun	Min	Max
A1-C1	3	97.333	2.516	1.452	91.08	103.5	95.0	100.00
A2-C2	3	12.666	8.386	4.841	-8.16	33.49	3.00	18.00
A3	1	89.000	.	.	.	.	89.0	89.00
Total	7	59.857	44.52	16.83	18.67	101.0	3.00	100.00

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11743.524	2	5871.762	153.176	.000
Within Groups	153.333	4	38.333		
Total	11896.857	6			

4.2 Measurement of the battery's talk time

Table 5 shows the battery talk time results while table 6 is the output of the ANOVA analysis. Statistically significant difference between groups was found for the GSM and CDMA tests (GSM: $F(2,4) = 203.949$, $p = .000$; CDMA: $F(2,4) = 171.914$, $p = .000$). This shows that the battery type had significant effect on the battery talk time.

From Table 5, battery A1's talk time seemed lower than that of battery A3 because battery A1 had a lower Ah rating (800mAh) compared to battery A3 (1020mAh). Also, battery A3 which was purchased at twice the price of battery A2 showed better results when compared to battery A2.

Talk time can differ because they are dependent on the mobile phone battery, mobile phone, mobile phone features, service provider, network conditions, strength of network signals, etc.

Table 5: Battery Talk Time

BATTERY		A			B		C	
		A1	A2	A3	B1	B2	C1	C2
GSM	Capacity (%)	98	25	98	97	24	94	13
	Talk time (mins)	11	34	136	11	29.5	227	32.5
CDMA	Capacity (%)	10	27	100	98	22	94	13
	Talk time (mins)	12	43	159	12	28.5	269	39.5

Table 6: ANOVA Table (Battery talk time)

		Sum of Squares	df	Mean Square	F	Sig.
GSM	Between Groups	9925.524	2	4962.762	203.949	.000
	Within Groups	97.333	4	24.333		
	Total	10022.857	6			
CDMA	Between Groups	10257.524	2	5128.762	171.914	.000

Within Groups	119.333	4	29.833
Total	10376.857	6	

4.3 Self-Discharge Test

Table 7 shows the self-discharge test results. From table 8, the battery type didn't have any significant effect on the self-discharge of the battery ($p > 0.05$).According to Cadex[8], self-discharge increases with age, cycling and elevated temperature. A battery should be discarded if the self-discharge reaches 30 percent in 24 hours.

Table 7: Self-discharge test results

BATTERY	A			B		C	
	A1	A2	A3	B1	B2	C1	C2
Ah Rating Specification (mAh)	*800*	*1020*	*1020*	*800*	*800*	*180*	*1800*
1st Capacity (%)	*99*	*23*	*94*	*97*	*19*	*95*	*3*
2nd Capacity (%)	99	22	93	96	18	95	3
Capacity loss	0	1	1	1	1	0	0
Ah Capacity Loss (mAh)	0	10.2	10.2	8	8	0	0

Table 8: ANOVA Table (Self-Discharge Test)

4.4 Ohm Test

Table 9 shows the self-discharge test results while table 10 shows the ANOVA analysis results. From table 10, the battery type didn't have any significant effect on the resistance of the battery ($p > 0.05$).

Table 9: Resistances of the batteries

BATTERY	A			B		C	
	A1	A2	A3	B1	B2	C1	C2
Resistance (mOhm)	144.40	222.40	155.70	218.00	218.30	141.30	220.00

Table 10: ANOVA Table (Ohm Test)

	Sum of Squares	df	Mean Squa	F	Sig.
Between Groups	5369.882	2	2684.941	2.842	.171
Within Groups	3778.307	4	944.577		
Total	9148.189	6			

5.0 CONCLUSION

Batteries A1, B1& C1 which came along with newly purchased mobile phones had better performance results than replacement batteries A2, A3, B2 & C2, and they conformed to their stated manufacturer's specifications to a large extent. This verifies some users' complaints about their dissatisfaction with the performances of replacement batteries when compared to the batteries that come along with newly purchased mobile phones.Moreover, cost is a major factor, as Battery A3 which was a replacement battery bought at twice the price of Battery A2 performed better than Battery A2.

Hence, there is need to set up standards for mobile phone battery and create policy framework to regulate imported mobile phone batteries. This ensures better performance of mobile phone batteries, value for the money spent to purchase the batteries and reduction of the adverse environmental effects associated with the disposal of these batteries.

REFERENCES

[1] O. Krejcar,"Testing the Battery Life of Mobile Phones and PDAs" 2011 International Conference on Software and Computer Applications, IPCSIT Vol.9 (2011) © (2011) IACSIT Press, Singapore

[2] O. A. Babatunde, C. A. Eguma, B. T. Oyeledun, O. C. Igwilo, O. G. Awosanyaand O. Adegbenro, "Mobile Phone Usage and Battery Disposal in Lagos, Nigeria" International Journal of Applied Psychology 2014, 4(4): 147-154,

[3] Battery University, "Global Battery Markets"See http://batteryuniversity.com/learn/article/global_battery_markets (Accessed 25 August, 2012)

[4] [Battery University, "Is Lithium-ion the IdealBattery?" See http://batteryuniversity.com/learn/article/is_lithium_ion_the_ideal_battery (Accessed 20 July, 2012)

[5] P. Tao, "Potential economic and environmental advantages of lithium-ion battery manufacturing using geothermal energy in Iceland"Thesis submitted to the School of Science and Engineering at Reykjavík University, MSc of Sustainable Energy, 2011

[6] Panasonic, "Lithium Ion Batteries", 2007. See http://industrial.panasonic.com/www-data/pdf/ACA4000/ACA4000PE3.pdf (Accessed 20 July, 2012)

[7] C8000 Battery Testing System User Manual *(V2.x)*Cadex® Electronics Inc. Part Number: 89-207-3033, Document Number: PSMAN0056 Rev 2, 2010

[8] Battery University, "BU-802b: Elevating Self-discharge" See http://batteryuniversity.com/learn/article/elevating_self_discharge (Accessed 8 January, 2015)