Journal of Scientific Research & Reports
5(3): 228-233, 2015; Article no.JSRR.2015.090
ISSN: 2320-0227

SCIENCEDOMAIN *international*
www.sciencedomain.org

Nine-Volt Battery Life: A Failure of Quality Control

Ted R. Miller[1*], Soma Bhattacharya[1] and Jeffrey Levy[1]

[1]Pacific Institute for Research and Evaluation, 11720 Beltsville Drive, Suite 900, Calverton, MD 20705, USA.

Authors' contributions

This work was carried out in collaboration between all authors. Author TRM conceptualized this study and supervised its execution. Author JL analyzed the data under Author SB supervision. All authors drafted or substantially rewrote portions of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2015/13776
Editor(s):
(1) Grigorios L. Kyriakopoulos, School of Electrical and Computer Engineering, National Technical University of Athens (NTUA), Greece.
(2) Luigi Rodino, Professor of Mathematical Analysis, Dipartimento di Matematica, Università di Torino, Italy.
Reviewers:
(1) Anonymous, Rajamangala University of Technology Thanyaburi (RMUTT), Thailand.
(2) Guanjun Ding, Beijing Information Technology Institute, Beijing, China.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=749&id=22&aid=7206

Original Research Article

Received 2nd September 2014
Accepted 28th November 2014
Published 15th December 2014

ABSTRACT

Aims: To determine the distribution of battery life for batteries that often are used to power smoke alarms.
Place and Duration of Study: Pacific Institute for Research and Evaluation, Calverton Maryland, USA, between June 2007 and September 2009.
Methodology: We recorded the life of 167 9-volt zinc-carbon batteries and early failures among 60 alkaline batteries that we installed in ionization smoke alarms that, like all US smoke alarms, came equipped with battery test buttons and battery charge monitors. We tested two brands of batteries of each type. We also used a Radio Shack digital multimeter to test 100 unused zinc-carbon-batteries 7 months prior to their expiration date.
Results: Among zinc-carbon batteries, 25% of one brand and 12% of a second failed in less than 100 days. These batteries had a wide, disturbingly flat lifetime distribution, with 40% of the brand with the most early failures but only 1% of the second brand lasting more than 500 days. In a 9-volt battery eight-pack, one or two batteries are likely to be problem batteries that would not last for three months in a low-draw device like a smoke alarm. In this relatively undemanding application, the majority lasted less than the nominal one-year life reported by battery manufacturers. Among

**Corresponding author: Email: miller@pire.org;*

alkaline batteries, 2 of 60 failed within three months and 2 more failed between 21 and 24 months. Among unused batteries, 7% were dead 7 months before their expiration date.
Conclusion: Nine-volt batteries, especially zinc-carbon batteries, need better quality control. Consumer protection is lacking around this problem. Unless using longer-life batteries, changing smoke alarm batteries at every clock change makes some sense. Most will not last a year. Nevertheless, that advice may not be optimal for people pressed for cash. Depending on brand, a third of the batteries will last for 18-24 months. And alkaline batteries that are not defective should last more than two years.

Keywords: Smoke alarm; consumer protection; zinc-carbon; alkaline; battery life.

1. INTRODUCTION

Recently we tested a health education program designed to induce people to keep working batteries in their smoke alarms [1]. Our protocol included hanging more than 100 alarms in our offices in order to ascertain when to return to homes to see if new batteries had been installed in alarms that we hung. That approach surfaced serious issues about battery life. This article reports on the distribution of battery life for 9-volt zinc-carbon batteries installed in smoke alarms.

The United States has a grand tradition of testing consumer products and reporting on their performance, with brand names openly disclosed (e.g., [2,3]). Despite that, the literature is virtually silent about how battery life varies among batteries. Lee [4] documents that one brand of defective 9-volt lithium batteries with an advertised 10-year life entered the marketplace, with numerous batteries failing in 3-5 years.

2. MATERIALS AND METHODS

We purchased new Kidde model 0916 ionization smoke alarms in 2005. This alarm has a round face roughly 15 centimeters in diameter and is 3 centimeters deep. It operates on one 9-volt battery. Like all battery-operated smoke alarms in the US, each alarm has a built-in battery test button on the front. It also internally monitors battery charge and according to manufacturer's specifications [5] begins a high-pitched chirping at roughly 3-minute intervals when 6% of battery charge remains.

Our order explicitly specified that the alarms should be shipped with fresh batteries. Kidde [5] states that a fresh battery should last for one year under normal operating conditions. That suggests the smoke alarm draws an average of 0.057 milliamps per hour including weekly testing (500 milliamp battery/8,760 hours per year).

All alarms were numbered and mounted on plasterboard that was stored in our offices in the Washington, DC suburbs, which are climate-controlled during the week but usually not on weekends and holidays. Batteries generally were tested in new bulk-purchased alarms except that 11 alarms where batteries failed within 20 days were equipped with a second battery to check that an alarm defect had not caused early battery demise. Batteries in two alarms with defective test buttons were transferred to new alarms.

Two groups of batteries were tested: 32 Powercell 1604P zinc-carbon 9-volt batteries (manufactured in China by Gold Peak Industries, LTD) that came with the alarms and had expiration dates of June 2006 or April 2007 and 135 Rayovac D1604 heavy duty 9-volt zinc-carbon batteries that were purchased in bulk and had an expiration date of April 2010. We purchased the Rayovac batteries because the first few test alarms we installed in our offices in 2005 with the included batteries failed in less than a month. We also collected two years of data on 30 Energizer Max 9-volt alkaline batteries and 30 Duracell Coppertop 9-volt alkaline batteries, recording early failure rates.

All batteries in this study were installed in 2007, mostly in June-September. As Fig. 1 illustrates, the battery boards were monitored for chirping and each alarm was tested using the alarm push button every one to three weeks. We recorded the time to chirping or test failure and computed the days between installation and failure. In September 2009, we used a Radio Shack 29-range digital multimeter to test 100 additional Rayovac batteries newly removed from a previously unopened bulk purchase box.

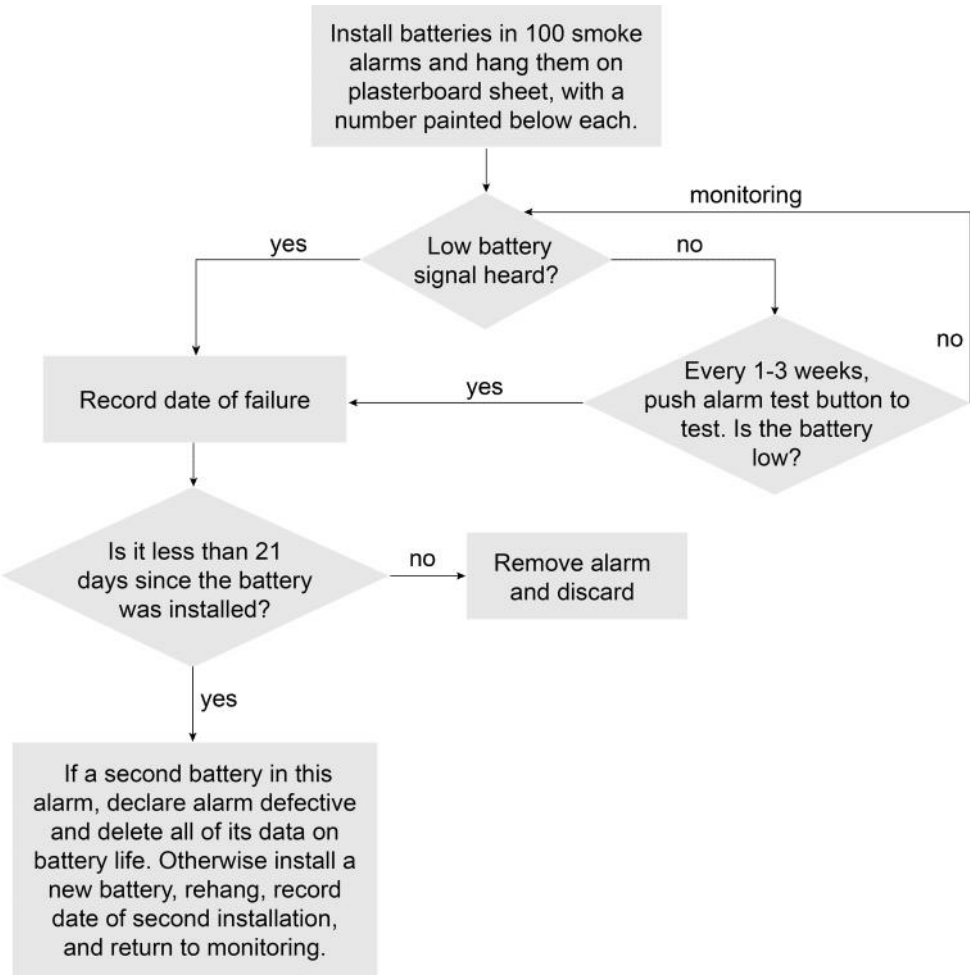

Fig. 1. Flow chart summarizing the test procedures

3. RESULTS AND DISCUSSION

Table 1 describes the battery life distributions of the two sets of batteries, separately and pooled. Figs. 2 and 3 display the distributions. The distributions are far from normal and differ markedly from one another as well. The Powercell distribution is essentially hyperbolic, while the Rayovac distribution is virtually flat. Both sets of batteries have a tendency toward early failure, a problem that was so common with Powercell's we tried to use in 2005 that we bought Rayovac replacements before even starting our fieldwork. At the same time, despite being installed near or beyond their expiration date, more than 30% of the Powercell's outlived all of the Rayovacs.

The battery tester revealed that 7 months before their stamped dates, 5 of 100 Rayovac batteries were essentially dead in the package; 2 others were unable to generate a full 9-volts of charge. These deficiencies are consistent with the findings from the smoke alarm tests.

As for the alkaline batteries, 1 out of 30 of each type failed within 6 months and a second of each type failed between 21 and 24 months. So again, some batteries essentially were defective in the package.

3.1 DISCUSSION AND CONCLUSION

Although the Powercell batteries were out of date at the time we systematically tested them, their average life exceeded that of the Rayovac batteries by 68 days. Moreover, they were in

date when we abandoned tests on an initial set because the early failure rate was so high we could not use them in the alarms we were preparing to install. That early failure rate was consistent with the subsequent formal testing reported here. In 2005, we pulled alarms from a dozen boxes, removed the plastic from the battery terminals, installed the batteries, and heard several chirp within a week. It was only on discovering that other batteries were failure-prone too that we decided to undertake testing with a broader purpose than determining how long to wait before checking if residents had changed their dead smoke alarm batteries. Nevertheless, the Rayovac early failure rate may be the more reliable.

In addition to revealing the wide variability of battery life, our broader study underlined rules for handling batteries. Batteries rapidly discharge if their terminals come into prolonged contact with another battery or a surface that can act as ground. If one drops several batteries in a bag and carts them around the house, they probably will die. Batteries are best stored at a moderate temperature in their original packaging or standing up next to one another in a cardboard box.

Table 1. Battery life distribution parameters (in days) by brand of battery and pooled across brands

	Powercell	Rayovac	Pooled
Mean	344.6	276.4	289.5
Median	357.5	294	308
Standard deviation	260.04	127.92	162.98
Kurtosis	-1.616	-0.848	-0.335
Skewness	-0.103	-0.257	0.200
Minimum	6	8	6
Maximum	732	581	732
LT 100 days	25.0%	11.9%	14.4%
100-199 days	12.5%	20.0%	18.6%
200-299 days	3.1%	18.5%	15.6%
300-399 days	12.5%	28.9%	25.7%
400-499 days	6.3%	20.0%	17.4%
500-599 days	12.5%	0.7%	3.0%
600-699 days	21.9%	0.0%	4.2%
GE 700 days	6.3%	0.0%	1.2%
Cases	32	135	167

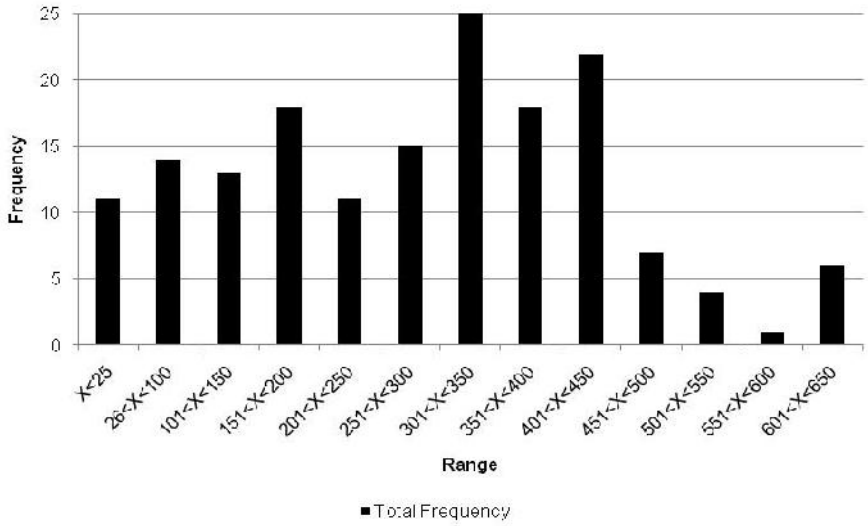

Fig. 2. Distribution of life for all 167 zinc-carbon batteries

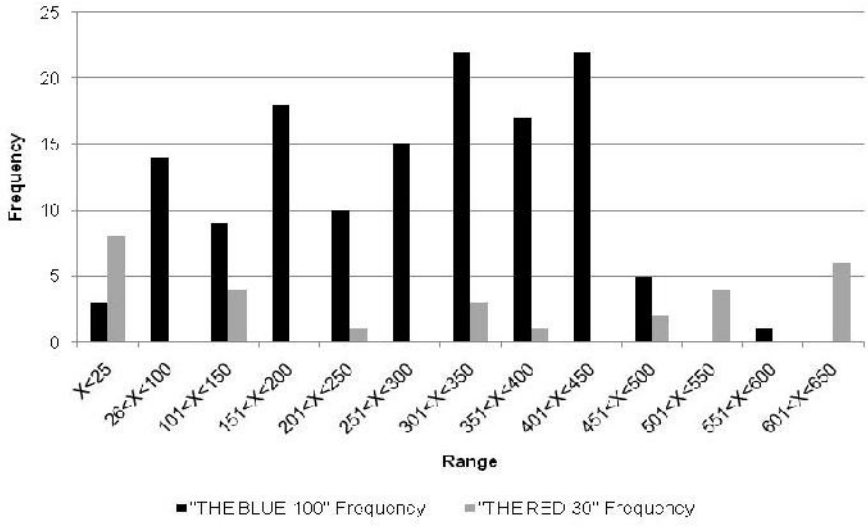

Fig. 3. Comparison of battery life by brand

When a consumer opens a 9-volt zinc-carbon battery eight-pack, depending on the brand, one or two batteries in the pack are likely to be problem batteries that would not last for three months in a low-draw device like a smoke alarm. Both brands of zinc-carbon batteries we tested had disturbing rates of very early failure and a very wide lifetime distribution. In this relatively undemanding application, the majority lasted less than the nominal one-year life reported by battery manufacturers. It seems likely that 9-volt batteries, especially zinc-carbon batteries, need better quality control.

This is not an isolated problem. Lee [1] found problems, ostensibly resolved by the manufacturer, with long-life lithium batteries. Alkaline batteries had very early failure rates of roughly 3%. Anecdotally, in 2009, the batteries died in the lead author's TV remote. He bought new alkaline Energizer batteries and the remote still did not work; the new batteries proved to be dead in the package. A week later, he noticed one of the still-working Maxell alkaline AAA batteries (expiration May 2013) in his electronic food scale was leaking. One wonders how often consumers discard "defective" electronics when the defective item instead is a newly purchased battery.

Consumer protection currently is lacking around this problem. No agency takes responsibility for assuring batteries are sold to specification or for regulating battery quality. Nor do consumer product testers test battery life of competing products.

As for smoke alarms, unless using alkaline or lithium batteries, changing the smoke alarm batteries at every clock change makes some sense. Most will not last a year. Nevertheless, that advice may not be optimal for people pressed for cash. Depending on the brand, a third of the batteries will last for 18-24 months. And alkaline batteries that are not defective should last more than two years.

CONSENT

Not applicable.

ACKNOWLEDGEMENTS

Funding for this project came from Centers for Disease Control and Prevention grant U49-CCU-323334. Thanks to Richard Bowen for hanging and tending the smoke alarms.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Miller TR, Bergen G, Ballesteros M, Bhattacharya S, Gielen A, Sheppard M. Increasing smoke alarm operability through

theory-based health education: A randomized trial. Journal of Epidemiology & Community Health. DOI:10.1136/jech-2014-204182. online ahead of print; 2014.
2. Diamond B (ed). Consumer reports 2014 annual buying guide. Yonkers NY: Consumers union of the United States Inc.; 2014.
3. Hershman LL. The U.S. new car assessment program (NCAP): Past, present and future. Paper 390 in 17th Proceedings, International Technical Conference on the Enhanced Safety of Vehicles. Available:http://wbldb.lievers.net/10067010.html, 2001.
4. Lee A. Final report on lithium batteries (Ultralife, ANSI 1604) used in residential smoke alarms. Bethesda MD: U.S. Consumer Product Safety Commission; 2002.
5. Kidde Fyrnetics. Smoke alarm users guide for models 0916, 440375. Rev B. Mebane, NC: Kidde, undated.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=749&id=22&aid=7206