Just how "BAD" can a flashlight battery be?

Robert L. Nuckolls, III
EAA 205021
March 27, 2002

If you watch much television, you've seen ads for the latest-and-greatest formulation of a battery that claims to "run hard and last forever." Okay, you've seen the high-dollar ads about how good a battery can be, but have you ever wondered how bad a battery can be? All of my hand-held aviation devices use AA size cells. If all my radios were with fitted with products advertized on television and purchased at retail prices, I would be understandably reluctant to change out batteries until I'd sucked them completely dry.

Background

In the accident investigation business about fifteen years ago it took only one embarrassing occurrence of battery failure during a kilodollars-per-hour test program to instill the wisdom of starting every new task with fresh batteries. It wasn't uncommon to charge a client $20-30 for batteries . . . a

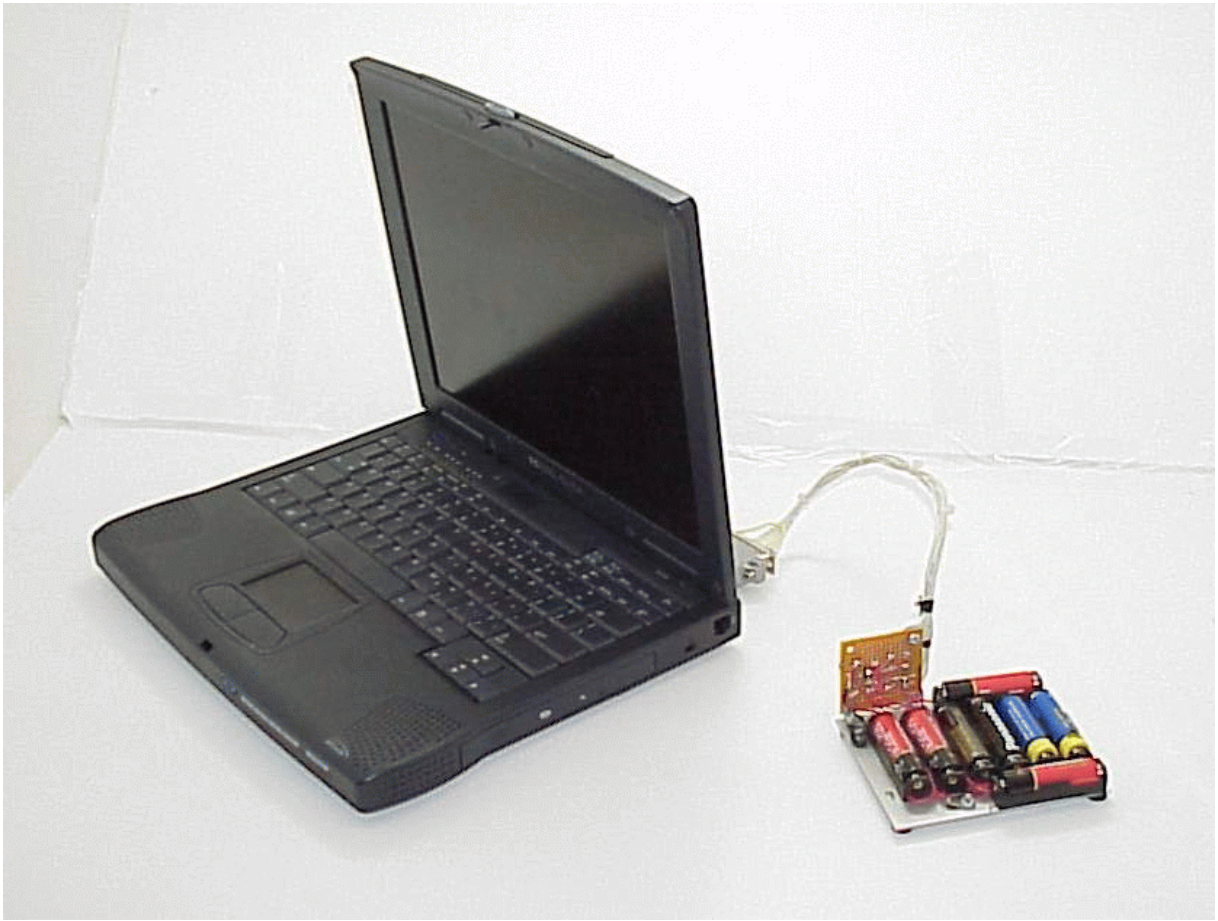


Figure 1. Bob's Computer Driven Battery Killer.

trivial sum that insured system reliability when the cost of doing tests would run thousands of dollars.

I really like to navigate using GPS. In a Sport Aviation article a few years ago, I described an outstanding value in small GPS receivers available from many sporting goods and department stores (***"If You Can't Afford a Nailgun, Will a Hammer Do?" Sport Aviation, November 1996***). Since that article appeared, I don't believe I've even turned a VOR receiver on much less used one to navigate. I still have the Magellan GPS2000 featured in the article. It saddles up right next to a Magellan GPS310 purchased at Walmart for less than half the cost of the GPS2000.

Because it's portable and stored in my flight bag, I'm able to enter a few waypoints as needed before leaving for the airport. Both radios use AA cells. Even if the airplane is fitted with a panel mounted GPS or Loran receiver, I like to perch the hand-helds on the glare shield held down at the base with Velcro and supported against the inside of the Plexiglas with a small gob of malleable windshield sealant.

I power up both radios and set them in place during pre-flight. By the time we're ready to launch, both radios have figured out where we are located and are ready to navigate.

The older GPS2000 uses four, AA cells; the GPS310 only needs two. For maximum reliability, I choose to put fresh cells in both radios before launching on a long trip. If I had to buy AA alkaline cells at a convenience store, they could cost as much as $1.50 per cell. A full set of cells for the radios would be $9.00. Hmmmm . . . a round trip of batteries for the hand-helds could be as much as $18.00.

Batteries, batteries - so many choices

A few years ago, I noticed a number of stores carry house brand or lesser brand alkaline AA cells at attractive prices. A local Dollar General store offers house-brand AA-cells at $1.50 for a package of six - 25 cents per cell. Nice price . . . but how do they stack up against "pink bunny" or "copper top" batteries? A scavenger hunt through several stores yielded an assortment of AA cells that consisted of the following: Duracell "Ultra" ($0.80/cell), Energizer e2 Titanium ($0.75/cell), Panasonic ($0.38/cell), Eveready ($0.38/cell) and Dollar General's Energy Super+ ($0.25/cell).

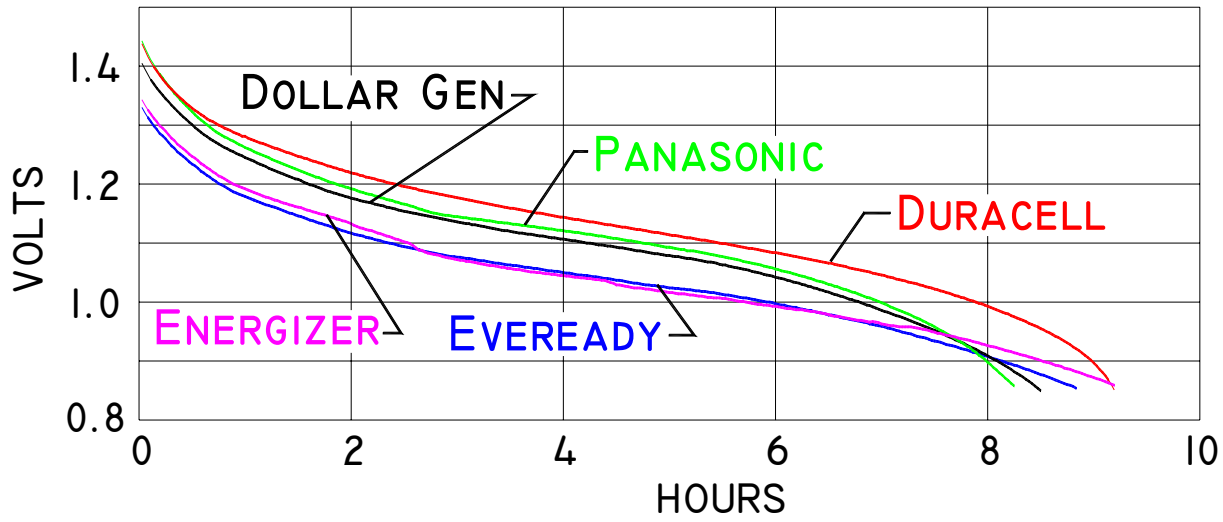
Evaluating the Competitors

Published engineering test data for various AA-cell products commonly cite performance in hours required discharge a cell to "end-of-life" voltage with some value of load resistance.

I built a battery-killer to hold eight AA-cells and connected 5-ohm resistors across each cell. 5 ohms produces an initial load on each cell of approximately 260 milliampers. The battery killer plugs into a computer driven data acquisition module shown in Figure 1.

I discharged several sets of scavenger hunt batteries down to 0.85 volts and averaged the results. Figure 2 is a graphical representation of the test results. As you can see in the graphical data, there are no striking differences between the various products tested. For each of the brands, one may cite an endurance of 8.5 to 9.2 hours for discharge to 0.85 volts with a 5-ohm load. Given that virtually every product tested reached the 0.85 volt endpoint in 8-9 hours, one might conclude that there is very little difference in the various products. As engineers, we're

FIGURE 2. VOLTAGE VS. TIME PERFORMANCE



often more interested in the area under the discharge curves as opposed to the single data point describing hours to end of life.

Data to plot the curves in Figure 2 was collected by measuring and recording cell voltage at 10 second intervals. I wrote an analysis program to plot voltage with time (Figure 2) and to calculate total delivered energy in watt-hours. Each voltage sample was squared, divided by the load resistor (gives us watts) and then multiplied by 10 to yield watt-seconds for that measurement interval. These energy packets were accumulated for the duration of the test and converted to more convenient watt-hours. Numerical results of this study are shown in Table 1 with tested products ordered top to bottom in order of performance.

Table 1. Numerical Performance Data

Brand	Depletion to 1.0V w/5 Ohm Load		Depletion to 0.85V w/5-Ohm Load		
	Time (Hours)	Energy (Watt-hours)	Time (Hours)	Energy (Watt-hours)	Cost $/watt-hour
Duracell Ultra	7.95	2.13	9.24	2.36	$0.33
Panasonic	6.99	1.87	8.27	2.09	$0.18
Dollar Gen	6.78	1.78	8.50	2.08	$0.12
Eveready	6.46	1.63	8.88	2.05	$0.19
Energizer	4.45	1.14	6.22	1.99	$0.37

Results

Inspection of graphical and numerical data suggests first that there are no great differences in performance of the cells tested. Duracells came out the hands-down winner in terms of performance with Energizer and Eveready at the bottom of the heap. Interestingly enough, my favorite el-cheapo cell is right in the middle of the pack.

I'll suggest there is a BIG difference in value across the spectrum of products. I'll support that assertion as follows:

Real battery performance depends on how your battery powered cockpit accessory uses the energy. A pocket flashlight doesn't differ very much from a resistor. Every battery in the test would power a light bulb for about the same interval (defined as some fixed point of light output too low to be useful). All five products might be considered ties in a dead heat if you discount the fact that Energizer and Eveready deliver fewer total lumen-seconds of light over their discharge cycle.

Other devices may experience tremendous variations in performance depending on how the critter is designed. For example, if my battery powered cockpit accessory goes belly up at 1.0 volt/cell then Duracell Ultras come in on top at 7.95 hours. Energizers are last at 4.45 hours. Referring to the graphical data, let's see what happens if your cockpit electro-whizzy dies at 1.1 volts per cell. In this case, Duracells will run the appliance for about 5.5 hours, Energizers go belly up at 2.5 hours.

Some products use switchmode power supplies that will take advantage of every last drop of store energy in a power cell. Here the numerical data provides the best portent of battery performance. A switchmode powered radio would certainly function down to 0.85 volts per cell if not lower.

Energy outputs over the range of products tested ran from 1.99 to 2.36 watt hours per cell. Not a big spread.

Time to Talk Value . . .

I opened this article with the not-very-attractive notion that lacking the benefits pre-planning and good information, I could spend as much at $18.00 per trip to power up my favorite nav aids.

Cell cost divided by energy contained produces a figure of merit for value. The last column of Table 1, shows the cost per watt-hour of products tested. While all products produced energy outputs within 12% of average for the group, their cost for energy delivered varied over a 3:1 ratio!

In Summation

From this simple experiment and analysis of data, I conclude that:

(1) the use of house brand batteries in my GPS receivers drops the cost of fresh cells to $3.00 per round trip. Fresh cells in my GPS receivers means that I'm never having to fish around for batteries and change them out while airborne. Because I fly for fun,. the cost of batteries comes right out of my entertainment budget. This experiment demonstrates that I can enjoy the reliability of fresh cells for outbound and return legs of a long trip without breaking the bank. In fact, my total battery budget for a long trip wouldn't buy a hamburger, fries and a Coke!

(2) a more subtle conclusion comes from an observation of plotted data. If your battery powered device cannot use all available energy from the battery, performance variations between brands can be very striking depending on where the powered accessory is designed to quit functioning.

(3) if your accessory uses a modern power supply, then simply measuring time to end-point voltage is not a fair evaluation of battery performance - total energy yield to end-point is the true measure of a battery's ability.

(4) there is very little difference in the performance of the various alkaline-cell products irrespective of television advertising hype to the contrary. If you want to enjoy the reliability and convenience of continuous performance of battery powered devices in the cockpit, the modus operandi is simple:
"Buy cheap and change often."

You are invited to access additional articles by Bob at www.aeroelectric.com