Alkaline Batteries

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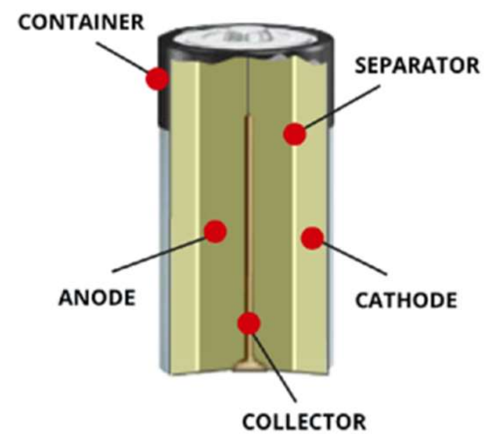
Parts of a Battery

- Seven different components make up a typical household battery [1]
  1. Container
     - Steel can that houses the cell's ingredients to form the cathode, a part of the electrochemical reaction.
  2. Cathode
     - A combo of manganese dioxide and carbon, cathodes are the electrodes reduced by the electrochemical reaction.
  3. Separator
     - Non-woven, fibrous fabric that separates the electrodes



Parts of a Battery [1]

Parts of a Battery (concluded)

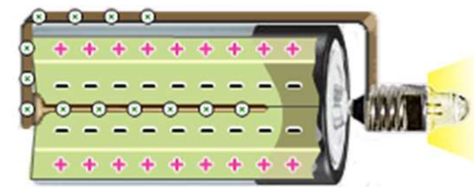
- Seven different components make up a typical household battery [1]
  4. Anode
     - Made of powered zinc metal, anodes are electrodes that are oxidized
  5. Electrodes
  6. Electrolyte
     - Potassium hydroxide solution in water, the electrolyte is the medium for the movement of ions within the cell. It carries the iconic current inside the battery
  7. Collector
     - Brass pin in the middle of the cell that conducts electricity to the outside circuit

Battery Construction

- Container [2]
  - Battery container is an empty steel can
- Cathode Mix [2]
  - Finely-ground powders of manganese dioxide and conductors that carry a naturally-occurring electrical charge are molded to the inside wall of the empty container
- Separator [2]
  - Separator paper is inserted to keep the cathode from touching the anode
- Anode [2]
  - Anode, which carries a negative electrical charge, plus potassium hydroxide electrolyte are then pumped into each container
- Collector [2]
  - Brass pin, which forms the negative current collector, is inserted into the battery, which is then sealed and capped

How Batteries Work

- Chemical Reacts [2]
  - Chemical reaction starts when a battery is inserted into a device – and complete the circuit



Interior View of Battery [2]

- Device Responds [2]
  - Electrolyte oxides the anode’s powered zinc
  - Cathode’s manganese dioxide/carbon mix reacts with the oxidized zinc to produce electricity
- Voltage Drops [2]
  - Interaction between the zinc and the electrolyte produces reaction products, which gradually slows the cell’s action and lowers its voltage

Battery Chemistry

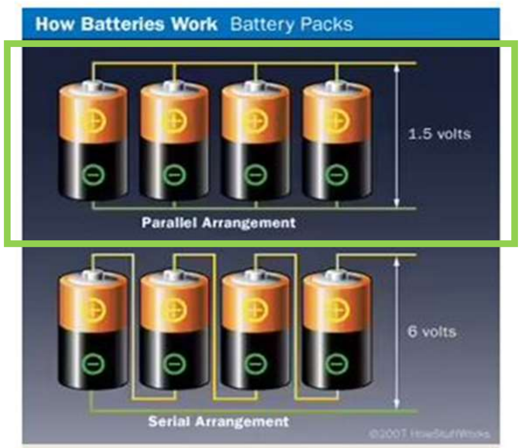
- Battery chemistry that powers an alkaline battery is a precise combination of zinc, high-density manganese dioxide, and potassium hydroxide [3]
- An alkaline battery produces electricity when the manganese dioxide cathode is reduced and the zinc anode becomes oxidized [3]
- Equation for a simple alkaline cell reaction: [3]
  - $Zn + 2\,MnO_2 + H_2O \rightarrow ZnO + 2\,MnOOH$
- During this battery chemical reaction, water (H_2O) is consumed and hydroxyl ions (OH^-) are produced by MnO_2 cathode under the following reaction: [3]
  - $2\,MnO_2 + 2\,H_2O + 2\,e \rightarrow 2\,MnOOH + 2\,OH$
- At the same time, the anode is consuming hydroxyl ions and producing water: [3]
  - $Zn + 2\,OH \rightarrow ZnO + H_2O + 2\,e$

Battery Chemistry (concluded)

- Electrons (e) generated during the reaction are used to power devices [3]
  - Efficiency of the reaction depends on the quality of the raw materials and availability of water and hydroxyl ions during reaction
- Each battery is designed to keep the cathode and anode separated to prevent a reaction [3]
  - Stored electrons will only flow when the circuit is closed. This happens when the battery is placed in a device and the device is turned on – same principle as turning on
- When the circuit is closed, the stronger attraction for the electrons by the manganese dioxide will pull the electrons from the zinc anode electrode through the wire in the circuit to the cathode electrode [3]
  - Battery chemical reaction or this flow of electrons through the wire is electricity

Battery Voltage and Current

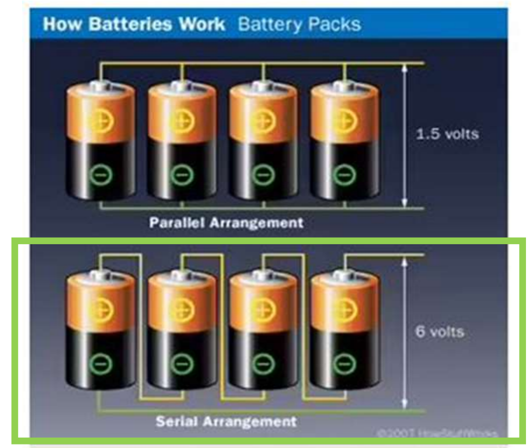
- Batteries are grouped together in serial arrangement to increase the voltage or in a parallel arrangement to increase current [4]
- Parallel Arrangement [4]
  - Batteries in parallel will together produce the voltage of one cell, but the current they supply will be four times that of a single cell
  - Current is the rate at which electric charge passes through a circuit and is measured in amperes
  - Batteries are rated in amp-hours or milliamp-hours (mAH)
    - Generally speaking, batteries with higher amp-hour ratings have greater capacities



Battery arrangement determines voltage and current. Check out serial battery arrangements, parallel arrangements and what maximum current is about.
HOWSTUFFWORKS.COM [4]

Battery Voltage and Current (concluded)

- Serial Arrangement [4]
  - Batteries in series will together produce the current of one cell, but the voltage they supply will be four times that of a single cell
  - Voltage is a measure of energy per unit charge and is measured in volts
  - In a battery, voltage determines how strongly electrons are pushed through a circuit
    - Most AAA, AA, C and D batteries are 1.5 volts
- Batteries shown in the diagram are rated at 1.5 volts and 500 milliamp-hours [4]
  - Four batteries in parallel arrangement will produce 1.5 volts at 2,000 milliamp-hours
  - Four batteries arranged in a series will produce 6 volts at 500 milliamp-hours



Battery arrangement determines voltage and current. Check out serial battery arrangements, parallel arrangements and what maximum current is about.
HOWSTUFFWORKS.COM [4]

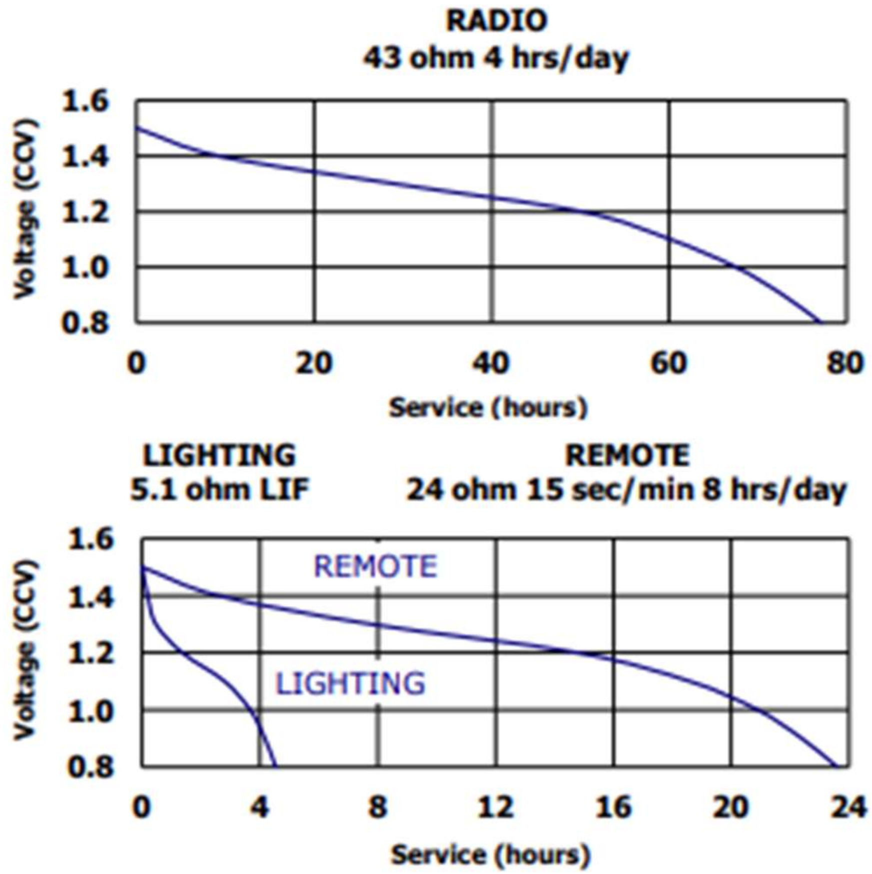
Decay of Voltage and Current

- Effective Battery Energy Capacity is affected by Temperature and Discharge Current [5]
  - Larger discharge currents consistently led to lower measurable starting voltage and faster overall drain
  - Higher resistance led to a lower overall current draw, which provided more optimal performance and efficiency as long as the draw is not too low

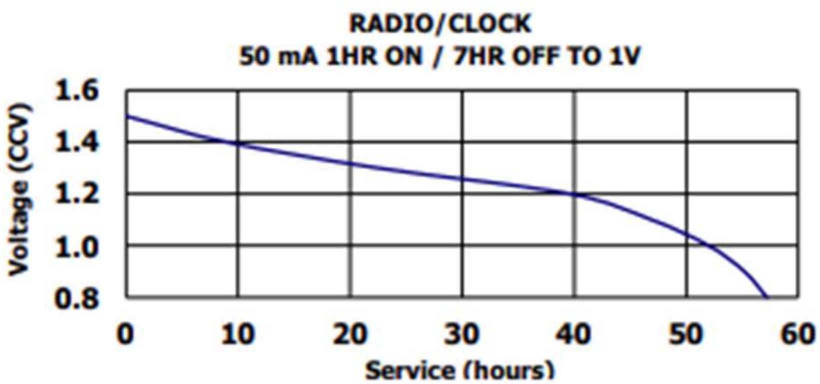
Decay of Voltage and Current (concluded)

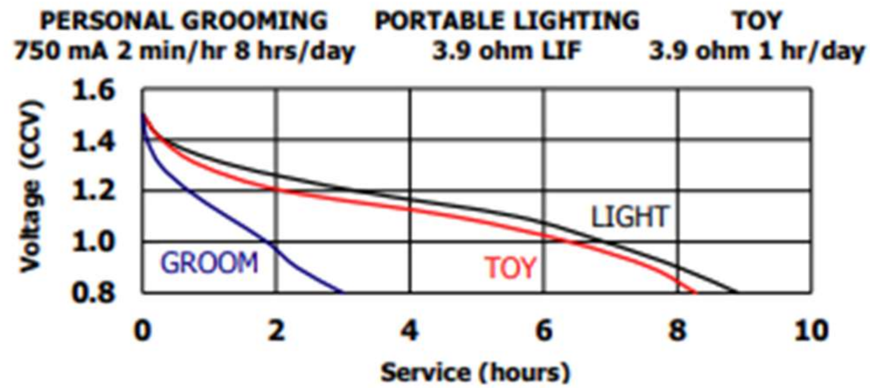
- Environmental temperature influences the rate of voltage drop [5]
  - In lower temperature, the battery voltage dropped faster and reached lower voltage values much faster
  - Hotter temperatures seemed to provide more efficient energy – supporting the conclusion that hot environments (50°C) provide the most optimal total energy output
  - Colder temperatures led to lower total power output when compared to room temperature and hot data

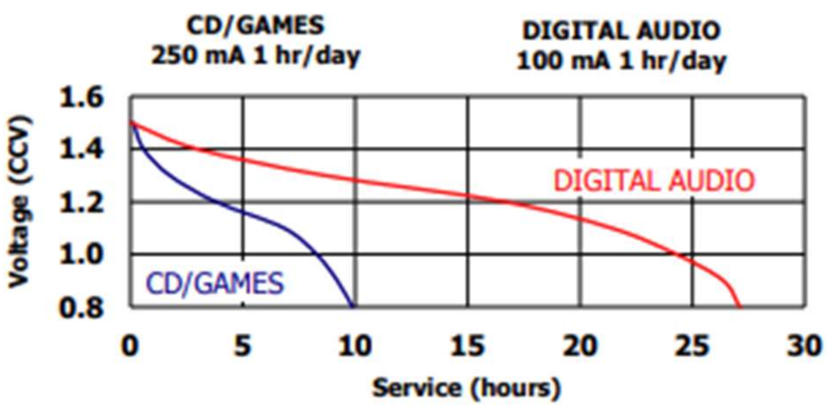
Decay of AAA Batteries [6]

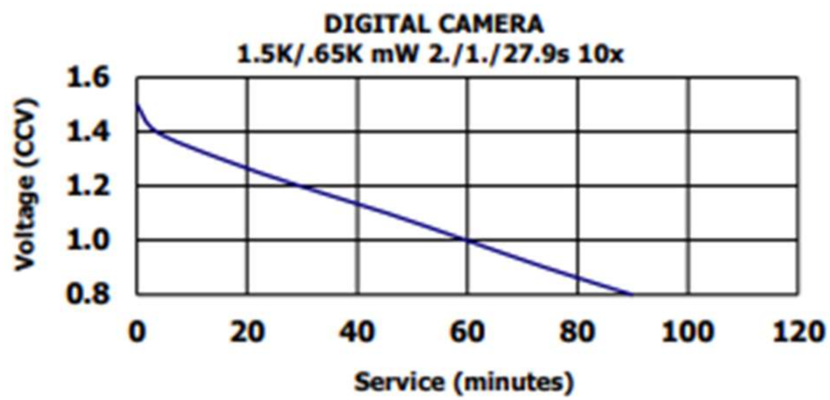


Decay of AA Batteries [7]

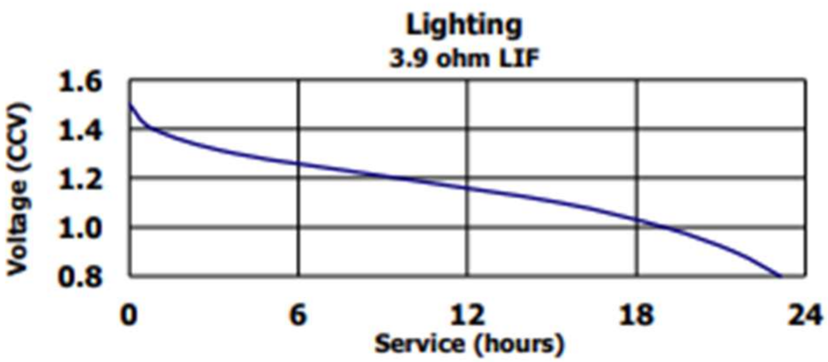


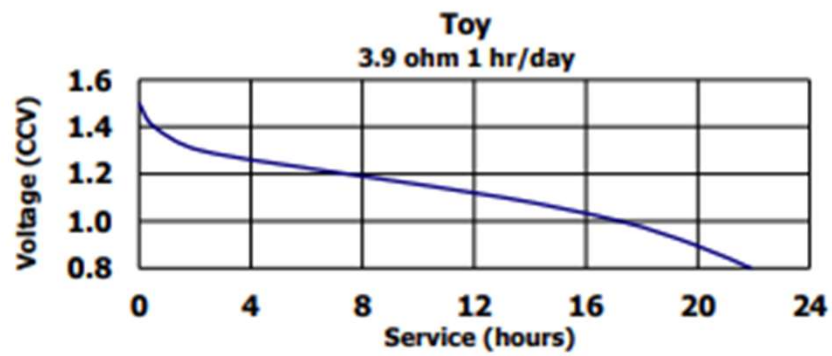


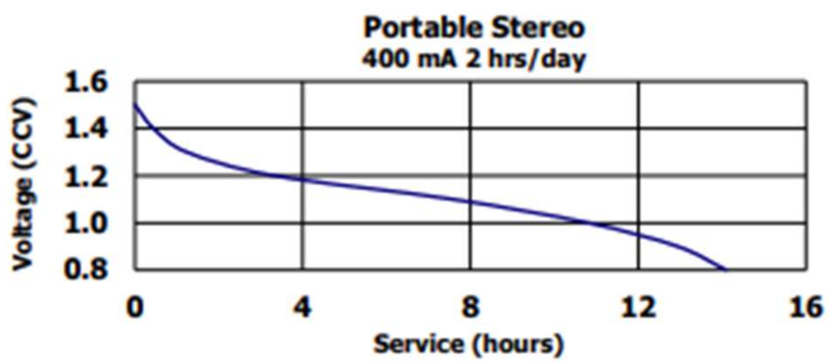




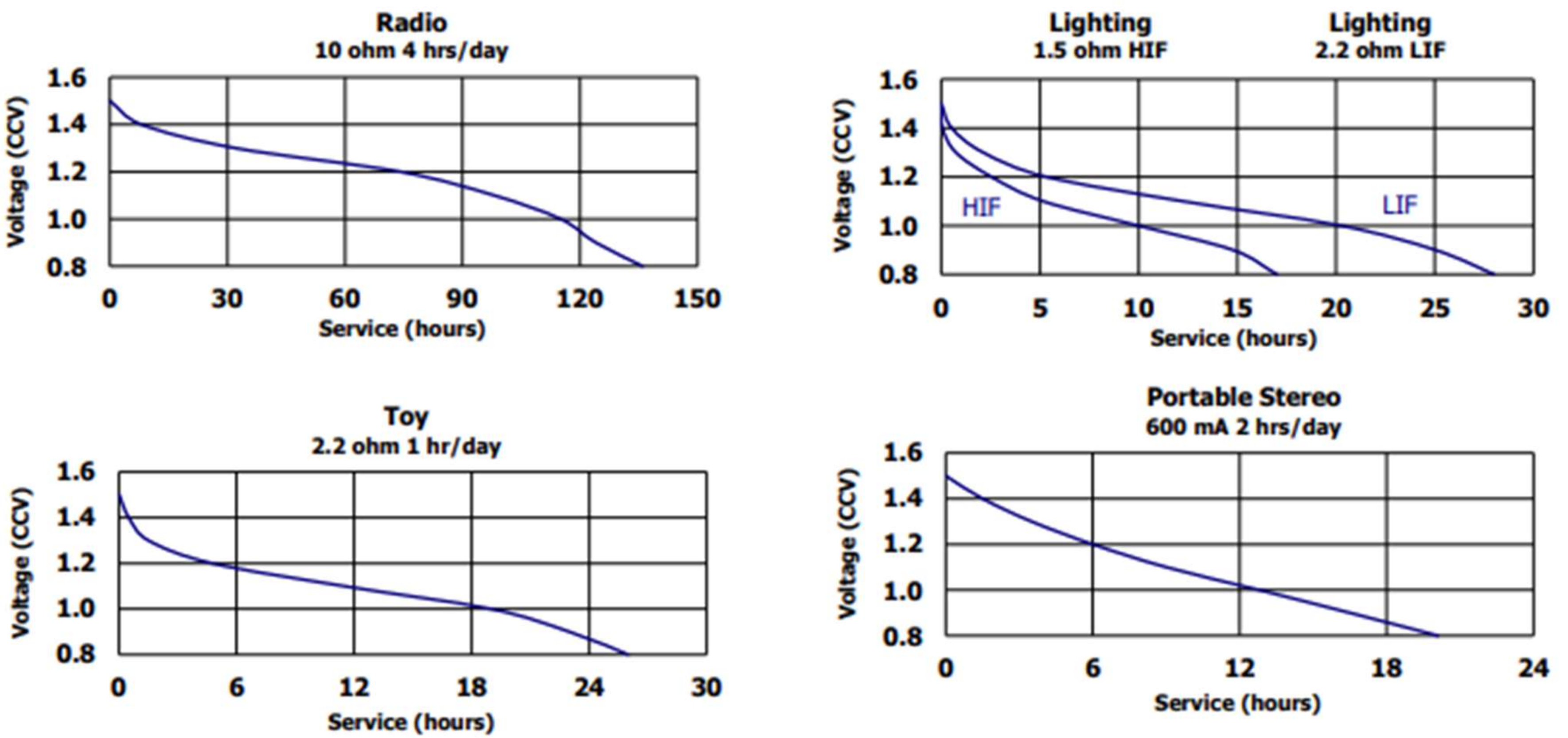
Decay of C Batteries [8]



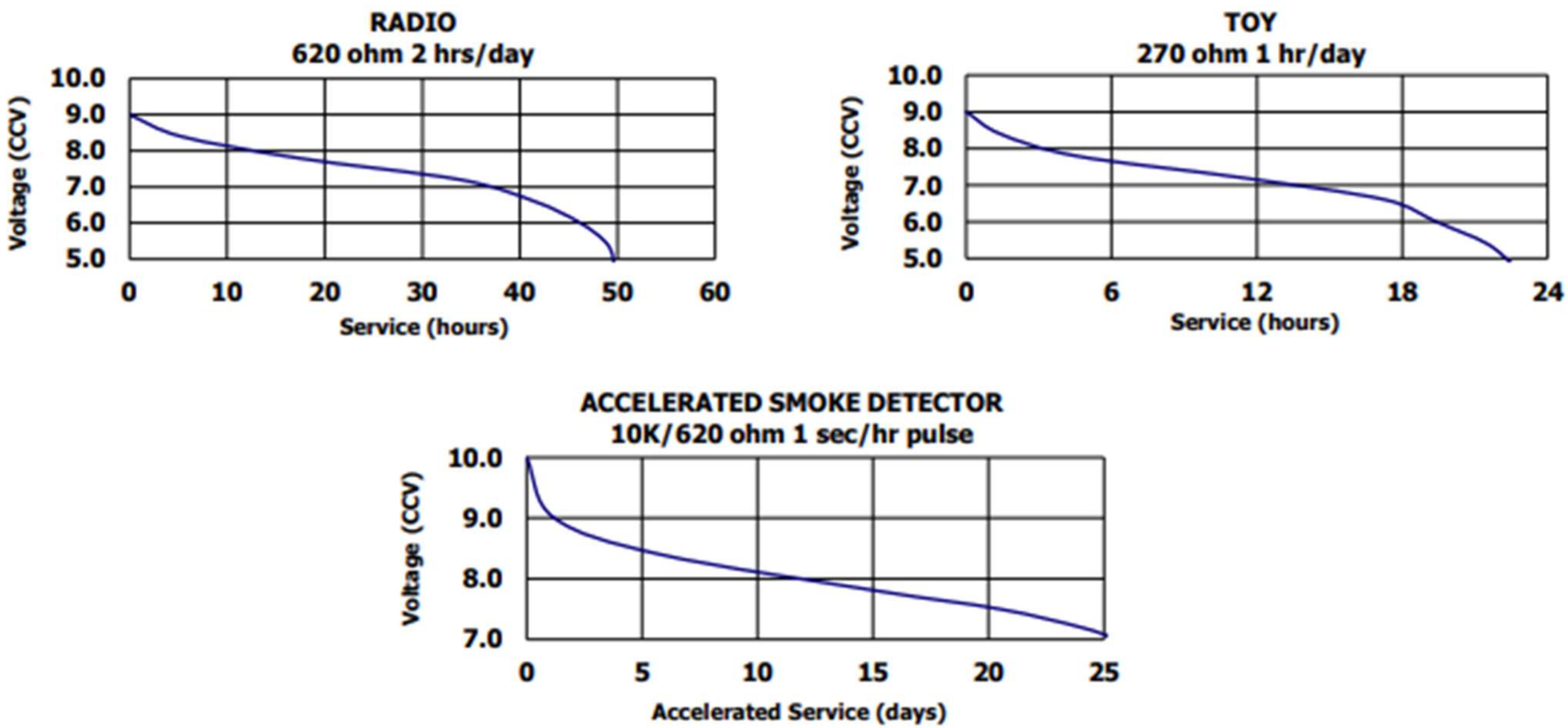




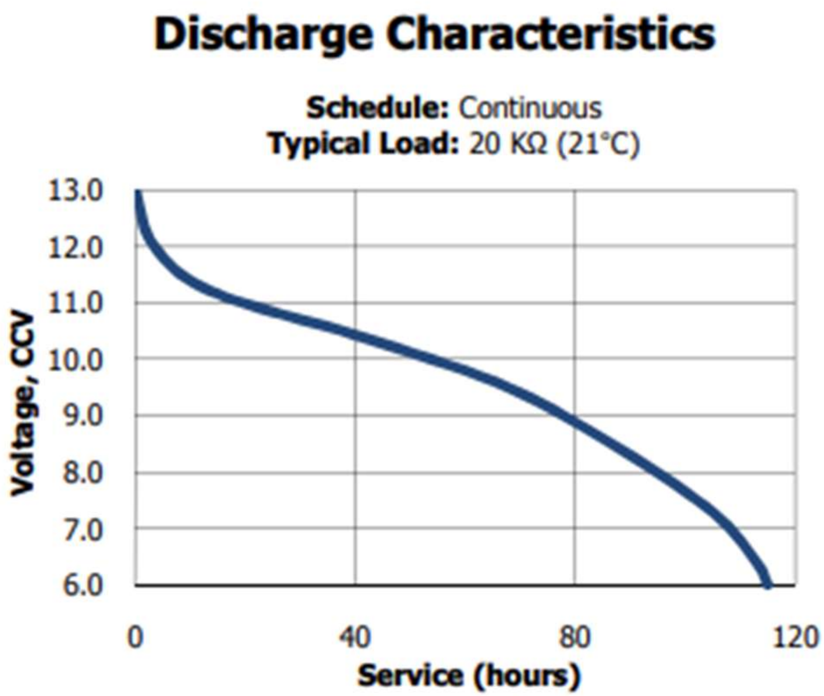
Decay of D Batteries [9]

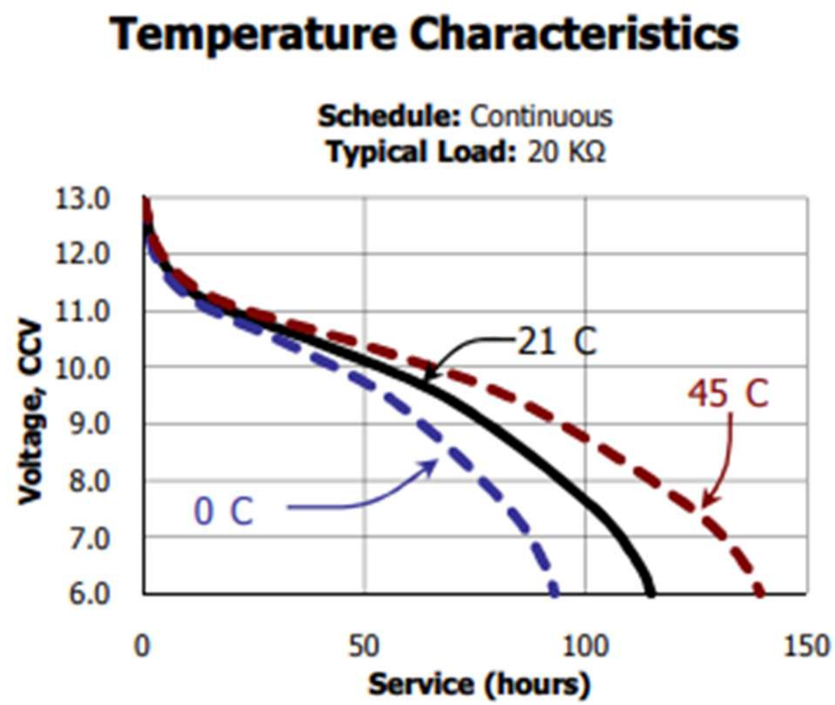


Decay of 9 V Batteries [10]



Decay of 12 V 23A Batteries [11]





Power Remaining When Batteries Stop Working

- Disposable batteries have 80% power remaining when appear to be dead [12]
  - Batteries start off with 1.5 volts of energy
  - Voltage goes down as the batteries are used up
  - When the batteries dip below 1.35 volts, they appear to be dead

Are Alkaline Batteries Really Dead?

- Different devices stop working at different low / cutoff voltage levels [13]
  - Cutoff voltage could be 1.3V in a halogen flashlight – but only 1.0V in a clock or 0.8V in a radio or remote control
  - When an alkaline batteries dies in a high-demand device like a flashlight, it could have a second life in a lower-demand device like a remote control or a clock.

Are Alkaline Batteries Really Dead? (concluded)

- All batteries in an arrangement (set) do not die at the same time [13]
  - When the batteries in a device appear to go dead, there is a good chance that only one is really dead
  - Some batteries may still have sufficient voltage remaining for some applications

Wasted Energy

- Environmental Protection Agency reports that Americans throw away more than three billion batteries each year! [14]
  - More than 86,000 tons of these are single use alkaline batteries (AA, C and D cells)
  - Placed end to end, these dead alkaline batteries alone would circle the world at least six times
- At 1.35 V per battery, 4,050,000,000 volts of unused energy are thrown away each year!

Uses for Secondary Materials Recovered from Batteries

- Iron in all battery types is recovered to make new goods [15]
- Manganese oxide inside alkaline batteries is processed in a rotary kiln to recover the zinc oxide, which can be used as an additive in numerous products including plastics and ceramics [15]

Discarded Batteries for Recycling [15]

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