Homeland Security
Science and Technology

TechNote

Rechargeable Batteries

Emergency responders rely heavily on battery-powered equipment to accomplish their job. To ensure that potentially life-saving equipment is ready to use when needed, it is important for responders to keep the right batteries for their equipment on hand.

Batteries convert stored chemical energy to electrical energy when the battery is used within a device. When the stored energy in a rechargeable battery is depleted, a battery charger is used to apply electrical energy to the battery, which restores the chemical energy inside. Rechargeable batteries can be used and reused many times.

The capacity of a battery is its ability to maintain a usable voltage, at a set current, for a period of time and is given in amp hours (Ah) or milliamp hours (mAh). The capacity of a certain type of battery increases as its physical size increases (see Table 1 for battery types). For instance, a D-size battery will have more capacity than a C-size battery of the same type due to its larger physical size. Batteries with higher capacities will last longer and perform better in high-drain devices.

Rechargeable Battery Performance

The performance of a rechargeable battery is largely determined by its *runtime* and *cycle life*. Runtime refers to the length of time a battery will power a device, is an indication of capacity, and varies based on the device it is used in. Cycle life refers to the number of times a rechargeable battery can be discharged and recharged and still deliver at least 50 percent of its rated capacity. A sign that a rechargeable battery is at the end of its cycle life is decreased runtime, which limits the device's use.

Over time, all rechargeable batteries experience *capacity fade*—a permanent loss of capacity that limits runtime and cycle life. Capacity fade results from damage that occurs with normal use during the charge and discharge cycles. The rate of capacity fade accelerates when batteries are charged more often than necessary, overcharged, undercharged, or stored in elevated temperatures.

Battery capacity is also affected by *self-discharge*—a temporary, inevitable loss of capacity that occurs over time in all batteries, whether they are used or not. Rechargeable batteries have higher self-discharge rates than single-use batteries. However, unlike single-use batteries, self-discharge is not permanent in rechargeable batteries and charging them will restore capacity. Warmer storage temperatures will speed up the rate of self-discharge, so batteries should be stored in a cool, dry place.

Rechargeable Battery Types and Applications

Lead-acid, nickel cadmium (NiCd), nickel metal-hydride (NiMH), and lithium-ion (Li-Ion) are common types of rechargeable batteries (see Table 1 for a comparison of these battery types).

Lead Acid batteries are available in 2-volt (V), 4-V, 6-V, 8-V, and 12-V. Lead-acid batteries are not practical for use in small devices, but are often used in high-drain applications, such as automobiles, defibrillator/electrocardiograph monitoring equipment, uninterruptible power supply (UPS) devices, and rechargeable 6-V flashlights. Lead-acid batteries left in a discharged state or used below 20 percent of their capacity experience an increased rate of capacity fade, which adversely affects performance. Therefore, lead-acid batteries should be charged when not in use. Battery testers can be used to determine exact capacity.

U.S. Department of Homeland Security

SAVER

System Assessment and Validation for Emergency Responders

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts unbiased operational tests on commercial equipment and systems and provides those results along with other relevant equipment information to the emergency response community in an operationally useful form. SAVER provides information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL).

Information provided by the SAVER Program will be shared nationally with the responder community providing life- and cost-saving assets to federal, state, and local responders.

The SAVER Program is supported by a network of technical agents who perform assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?"

For more information on this and other technologies, please see the SAVER Web site or contact the SAVER Program Support Office.

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NiCd and NiMH batteries are available in standard sizes, including AAA, AA, C, and D, and are oftentimes interchangeable as a set within a device, although the appropriate charger for each battery type may vary. They are frequently used in portable blood pressure monitors, large or mid-sized flashlights, and digital cameras. NiCd and NiMH batteries undergo a specific type of capacity fade known as the memory effect, which occurs when batteries are repeatedly charged prior to being fully discharged. These batteries will "forget" the remaining unused capacity that exists prior to recharging, resulting in a permanent loss of that capacity. To slow the memory effect, NiCd and NiMH batteries should be deep cycled—fully charged and fully discharged—every two to three weeks. NiMH batteries are lighter and safer for the environment than NiCd batteries, but are more expensive, have a higher self-discharge rate, and have a significantly higher minimum operating temperature.

Li-Ion batteries are available in a wide variety of shapes and sizes and designed to fit the device. Li-Ion batteries can hold a constant voltage while under a heavy load and suggested applications include thermal imaging cameras, mobile phones, laptop computers, portable printers, and other high-powered, frequently-used devices. Traditional Li-Ion batteries are made with lithiated cobalt dioxide and are common replacements for NiMH and NiCd packs because they offer higher voltage in a smaller package, weigh less, and have lower self-discharge rates. However, Li-Ion batteries may explode if overcharged or exposed to extreme temperatures. Therefore, the Department of Transportation has issued special guidance for air travelers with Li-Ion batteries. Before traveling with Li-Ion batteries, travelers should check for the latest guidance.

Nano Li-Ion batteries, a newer technology, contain iron phosphate and are a safer, less expensive alternative that deliver a higher current than Li-Ion and lead-acid batteries. Nano Li-Ion batteries are quickly becoming the preferred battery for many applications, replacing Li-Ion and lead-acid batteries. Uses include electric and hybrid vehicles, power tools, and other consumer electronics.

Optimizing Battery Performance

To optimize the life of a rechargeable battery, it is important to follow manufacturer charging instructions, use the appropriate charger, and maintain a charging history (when the battery was used last, when it was charged last, and so on). Equipment functionality should be checked regularly, and batteries must be recharged or replaced when device performance is inadequate, especially in seldom used equipment. In devices that require multiple batteries, battery replacement should be done in complete sets, using batteries of the same brand and type. If changed individually, batteries with differing properties will adversely affect the total voltage and/or capacity available to power the device. Newer or more powerful batteries may also attempt to charge weaker ones. In extreme cases, this can result in leakage, smoke, or fire as batteries overheat.

When to Use Rechargeable Batteries

For devices that are frequently used each day, rechargeable batteries are the best economical choice—offering a lower cost per use than disposable batteries. However, due to higher self-discharge rates, rechargeable batteries are not always the most dependable choice for emergency equipment or devices used less frequently. Devices that use standard-sized rechargeable batteries can also use disposable batteries; which should be kept on hand and readily available for use in mission critical devices in case of rechargeable battery failure.

Battery Disposal

Federal regulations require the chemical composition to be marked on batteries, since they can contain heavy metals such as cadmium in NiCd batteries, and improper disposal may contaminate the environment. Disposal should be in accordance with federal, state, and local environmental regulations. Some states regulate battery recycling due to environmental concerns. There are a growing number of recycling companies and battery retailers that will accept used rechargeable batteries. When government regulations cannot be confirmed, battery manufacturers are a good source of information on proper disposal.

Table 1 Rechargeable Battery Characteristics

Battery Type	Lead-acid	NiCd	NiMH	Li-Ion	Nano Li-Ion
Operating Temperature Range (ºF)	-40 to 149	-22 to 122	14 to 122	-40 to 140	-22 to 140
Cycle Life	500	1500	1000	1200	2000+
Self-Discharge Rate/Month	3 – 4%	~20%	20 – 30%	5 – 10%	5 – 10%
Advantages	High current capabilities, low self-discharge rate	High cycle life, charge quickly	Lightweight, long runtime between charges	High voltage, very lightweight, low self-discharge rate	High current capabilities, very lightweight, high cycle life
Disadvantages	Heavy, large, and not practical for use in small devices	Heavy, high self-discharge rate, contain toxic heavy metal	High self-discharge rate	May explode when exposed to heat or overcharged	Limited availability (new technology)