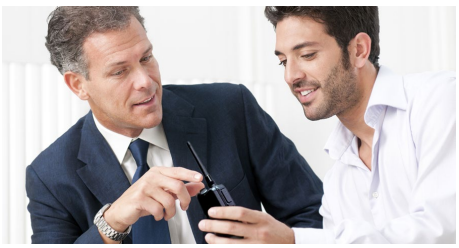
Battery Technology: **White Paper**

Principles of Power

Battery Technologies Employed in Icom's Portable Two-Way Radios


A white paper prepared by Icom America Inc.
Manufacturers of high-performance,
award-winning radios for over 55 years.

Principles of Power

Battery Technologies Employed in Icom's Portable Two-Way Radios

Selecting the right portable two-way radios starts with answering obvious questions about how and where they will be used. There are always considerations of features, capabilities, size and price. Often overlooked is the other technology that makes wireless communication possible: the battery.

Highlights:

- All About Chemistry
- Keeping the Power On
- Leading the Charge

Advances in battery technology have helped make two-way radios and plenty of other electronic devices dramatically smaller and more powerful. And while the lithium-ion battery first sold commercially less than 25 years ago has become the industry standard, it is not the only choice. Understanding the available options will help guide customers to the right battery for their particular needs. Informing them of a few simple rules will extend battery life an improve radio performance.

All About Chemistry

Reliability in the two-way radios comes not just from the people who make the devices but also from the people who use them. It's up to users to make certain the radios have the power they need; and that means knowing about the batteries inside. The learning process shouldn't begin after the radios are delivered but during the selection and buying process. While that process is often dominated by discussions of features, capabilities and pricing, there should be consideration of the battery and how well it will meet the needs of the user group.

"There is no perfect battery and each pack is tailored to a given use," says Cadex Electronics, a leader in battery testing. "All batteries have one thing in common: they run for a while, need charging, progressively fade with each cycle and eventually need replacement."

Alkaline: Still a Dependable Backup

All batteries produce electricity from a chemical reaction. And almost any discussion of the various battery chemistries begins with the ubiquitous alkaline battery as it is manufactured by the millions to power all manner of electronic devices. The alkaline battery, which delivers power through the reaction between zinc and manganese dioxide, gets its name from its alkaline electrolyte of potassium hydroxide, which is used in place of the acidic ammonium chloride or zinc chloride electrolyte of zinc-carbon batteries.

Single-use alkaline batteries have a reliable shelf life and provide high energy capacity. They do not need to be charged before use, which makes these batteries ideal as a backup source. Radios such as Icom's IC-T70A Sport and IC-V80 Sport accommodate a battery case for six AA alkaline cells. These amateur handheld radios are often found in emergency response kits, but can also be used in recreational, outdoor settings where power outlets are not readily available.

Nickel Cadmium: Rugged but Largely Replaced

An alkaline battery can hold a charge for a long time, but it remains a singleuse device and has only one life cycle before it is discarded. This ongoing need to replace this kind of battery is expensive for users in the long run. Single-use batteries are more appropriate for flashlights and clocks used at home than two-way radios used at work. Predictably, most radio batteries are rechargeable.

The first rechargeable batteries were the lead-acid batteries we still see in motor vehicles. In 1899, a Swedish inventor developed a battery with nickel oxide in its cathode, a cadmium compound in its anode, and potassium hydroxide solution as its electrolyte. Physically and chemically superior, it was the best option available for decades. When astronauts landed on the moon in 1969, the camera they carried was powered by two nickel-cadmium batteries that advanced the film and cocked the shutter.

Nickel-cadmium (NiCd) batteries are more difficult to damage than other batteries and tolerate deep discharge for long periods. Typically, they last longer than other rechargeable batteries. However, cadmium is toxic and requires special care during disposal. This eventually prompted restrictions on their use. In the European Union, for instance, the sale of consumer NiCd batteries has been banned except for use in medical devices, alarm systems emergency lighting and portable power tools.

Nickel-Metal-Hydride: Less Toxic with Higher Specific Energy

Getting rid of toxic cadmium led to the nickel metal hydride (NiMH) battery, which uses a hydrogen-absorbing alloy in its negative electrode. NiMH batteries, developed in the late 1960s, can have two to three times the capacity of an equivalent size NiCd and they deliver a near-constant voltage until they are almost completely discharged. Compared to alkaline batteries, they deliver more electron flow, or current. It's not surprising they quickly replaced single use alkaline and rechargeable NiCds in everything from cameras to cars.

NiMH batteries are widely available and inexpensive, but they are not as durable as their nickel cadmium predecessors and are more difficult to charge.

Battery Basics

- **Voltage:** Batteries are marked with nominal voltage. Before connecting a battery, always check that the value on the battery matches the one on the device.

- **Specific Energy:** Specific energy, as measured in ampere-hours (Ah), is the load a battery can deliver over time. A battery with a higher Ah delivers a longer runtime. This value, also known as capacity, declines over time as the battery is repeatedly charged and discharged. A lithium-ion battery, for instance, was shown in one study to deliver only 75% of its original capacity after 200 charge cycles. This inevitable decline is referred to as battery fade; and while it can't be stopped, it can be slowed.

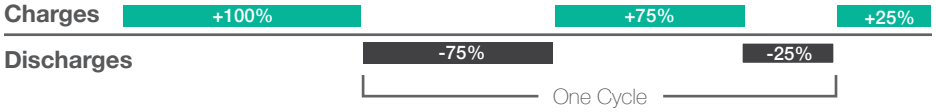
- **Specific Power:** Specific power, sometimes referred to as gravimetric power density, is a battery's ability to deliver power. Batteries for power tools are made for high specific power. Two-way radios obviously do less physical work that power tools.

NiMH also did not completely solve the memory effect that causes a loss of capacity when batteries are not given a periodic full discharge cycle. The batteries still appeared to remember the previous energy delivered and once a routine had been established did not want to give more.

Lithium Ion – The New Industry Standard

Lithium is the light metal, has the greatest electrochemical potential, and delivers the largest specific energy per weight. Work on lithium batteries began more than a century ago. But lithium is unstable; and electrical shorts in lithium metal batteries caused fires. The answer to this problem was a nonmetallic solution using lithium ions.

Lithium-ion (Li-ion) batteries are now reliable sources of power for two-way radios, laptops and many other devices. They are so widely used because they have a high energy density, resulting in a much lighter weight than other rechargeable batteries. Li-ion batteries have other advantages too. They hold their charge well, losing about 5% of their charge per month as compared to about 20% for nickel-metal-hydride batteries. Li-ion batteries have no memory effect, so recharging them before they are completely discharged is not an issue.



One Charge Cycle: Discharging 100% of the Battery

Li-ion batteries can handle many recharges before the end of their useful life, though it is key to monitor the number of cycle charges and the age of the battery. These factors determine the proper time to replace and recycle units. Old batteries and batteries that exceed the number of charging cycles may cause increased internal resistance. These cases of chemical instability often result in excessive – and sometimes unsafe – heat generation.

It is important to remember that Li-ion batteries don't like high temperatures. If a Li-ion battery fails, it can burst into flames or even explode. However, the lithium-ion battery remains a superior rechargeable battery for two-way radio applications. With basic attention to their use and life, these batteries will perform well in Icom radios.

Li-ion batteries should be regularly tested for safety and capacity on a battery analyzer designed for lithium-ion batteries. If a Li-ion battery has 1,000 cycle charges or it is five years after date of purchase, it is well past the time to replace it. In fact, it is wise to replace a Li-ion battery every two to three years.

Keeping the Power On

Some of the rules for rechargeable batteries are universal and familiar. They should always be stored in a dry, cool and well-ventilated location. Batteries in storage for extended periods should be fully recharged before use.

Never use a battery that has been physically damaged or is generating excessive heat. Furthermore, never use batteries above or below operating temperatures of the radio. Water or any other conductor across the contacts can short circuit the battery, resulting in smoke or flame.

After five years, the battery chemistry can become unstable and use beyond this range is not recommended. Using a battery past its useful life increases the possibility of battery failure (generating excessive heat, smoke or flame). Any battery displaying signs of failure – excessive heat, smoke or flame – should be removed from the radio and disposed of properly.

Disposal guidelines vary. For information on battery recycling, go to www.call2recycle.com. CALL2RECYCLE® offers no-cost rechargeable battery and cellphone recycling solutions across the U.S. and Canada. The program is operated by a nonprofit public service organization and funded by battery and product manufacturers, and manages over 34,000 collection sites.

Extend Battery Life and Avoid Potential Dangers

Some of the rules for battery charging are familiar to most users: New batteries must be fully charged before their first use. Unless otherwise noted in the charger instructions, batteries should not be charged with the radio power on. Other guidelines include:

- Batteries should be removed from chargers when the charge cycle is complete as continuous charging shortens battery life
- Avoid deep discharges as they too shorten battery life
- Batteries should not be left in chargers in an unmonitored location
- Ultra-fast charging causes undue stress and shortens battery life, so it is best avoided
- Icom radio batteries should be charged only in Icom chargers.

Some battery chemistries have specific rules with respect to charging.

Nickel-Metal-Hydride

- Charge fully each time
- Condition* batteries to reduce the memory effect
- Can be stored completely discharged
- Increased temperature while charging is normal

Lithium-ion

- Should charge in 1-3 hours
- Partial charges are less of a concern than with Ni batteries
- Partial discharges and more frequent charging are preferred
- No trickle charging as Li-Ion cannot absorb the overcharge
- No charging in freezing temperatures
- Partial charge is best for storing
- Batteries typically stay cool while charging

Leading the Charge

Users should monitor the number of cycle charges as well as battery age, periodically testing for capacity and safety. Testing with a specified battery analyzer is recommended.

As battery technology continues to evolve, the dramatic improvements seen in size, weight, power density, and intelligence seem certain to continue. These advances will make battery considerations even more significant for buyers moving forward.

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