Giving batteries a second life

Isidor Buchmann, CEO & founder of Cadex Electronics Inc.

Are batteries replaced too soon or too late? The answer lays in reliability concerns, service strategies and economics. While most batteries are replaced too late, Dr. Imre Gyuk, manager of the Energy Storage Research Program at DOE, says that every year roughly one million usable lithium-ion batteries are sent in for recycling with most having a capacity of up to 80%.

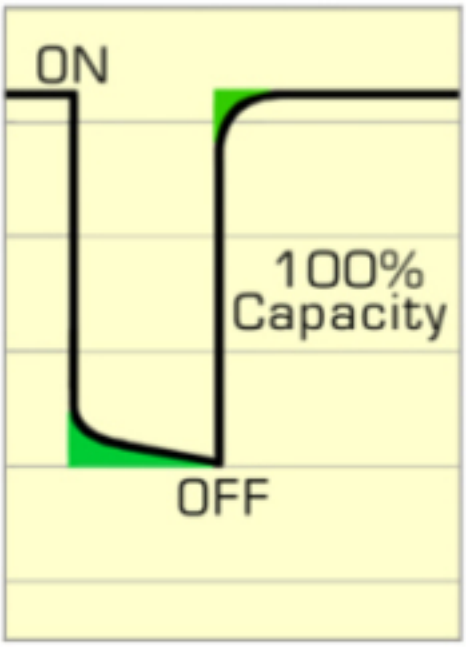
Dr. Gyuk is not alone. Mobile phone providers learned that 90% of returned warranty batteries have no problem. Packs are being replaced on the slightest complaint without testing; installing a new pack seldom resolves the perceived problem. Batteries in the medical industry are often replaced through date-stamping regardless of condition; some are hardly used and still in excellent health. A leading battery manufacturer discovered that 200 of 400 returned starter batteries had no problem when checked. These organizations question the reason for the returns and query the test methods used.

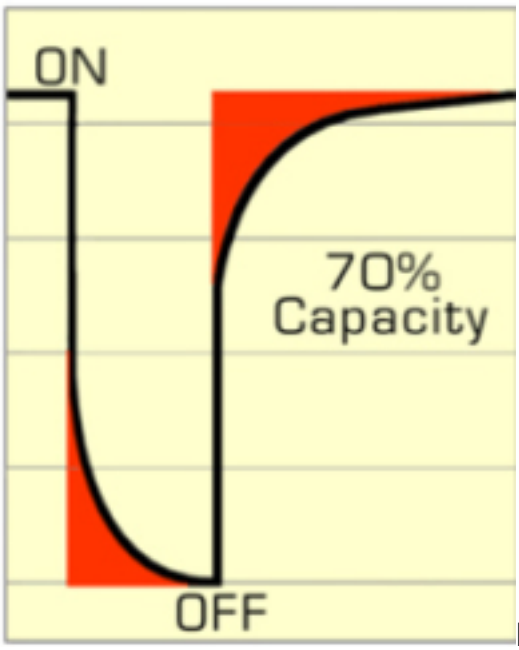
While lead and cadmium-based batteries pose the largest environmental concerns, lithium-ion is for the first time being added to the list of pollutants. This chemistry was classified as only mildly toxic, but the sheer volume of Li-ion batteries in consumer products requires tighter scrutiny.

Ingenious entrepreneurs have discovered a business model in giving discarded batteries a second life. Refurbishment centers have sprung up in the USA, UK and Israel. A service center in Texas handles up to 700,000 mobile phone batteries per month. They purchase surplus batteries by the ton and check them with battery analyzers. Reports reveal that customers using these B-Class batteries serviced by Cadex battery analyzers have identical performance records to new packs; there are no recorded increases in returns. Figure 1 shows a box of incoming batteries to be serviced.

With the advent of the electric powertrain, more batteries are becoming available for refurbishing. Although less than the full 100% capacity, these rugged industrial batteries have plenty of life left to serve less demanding applications. GM and ABB are already using Chevrolet Volt battery packs to store electrical energy for grid use. A medical technician working in a large Michigan hospital uses spent batteries from patient heart pumps to cut the grass with an electric lawn mower. This makes green energy even greener.

The leading health indicator of a battery is *capacity*. Capacity determines the energy a battery can hold and suggests the price a refurbished battery should fetch. Even if faded, an otherwise healthy Li-ion battery has a higher capacity than a new lead acid. Li-ion batteries for industrial use have a specific energy of about 120Wh/kg; lead acid is only at 40Wh/kg. A Li-ion battery dropping from 100% to 60% still has 72Wh/kg, a capacity that is substantially higher than lead acid. Furthermore, Li-ion will outlive lead acid if continuously cycled in a renewable energy application.





Battery test methods

Battery diagnostics has not advanced as quickly as other technologies and appears to dwell in medieval times. No instrument is capable of estimating the state-of-health of a battery in a single measurement. Similar to a doctor examining a patient, or the weatherman forecasting the weather, battery testing entails looking at multiple attributes to get a clear health assessment. Although capacity is the leading health indicator, internal resistance and self-discharge also play a role. Deploying suitable test equipment and understanding battery behavior are essential in making a refurbishing business viable.

Rapid-testing would be most desirable, but this only works for a designated battery population for which a matrix has been developed. A matrix is a multi-dimensional lookup table against which readings are compared. Research continues to test larger packs using *Time Domain* and *Frequency Domain* methods. Time domain applies a series of pulses and observes the rate of recovery. A good battery has as a quick recovery; a faded one is slow. An analogy can be made with a dry felt pen that still writes but needs rest to replenish the ink. Figure 2 compares a good battery with quick recovery against a faded one that is sluggish.

Frequency domain is based on *electrochemical impedance spectroscopy* (EIS) and involves scanning a battery with frequencies ranging from several kilohertz down to millihertz. High frequency reveals the resistive qualities of a battery, also known as bird-eye’s view, and low frequencies provide insight into unique battery characteristics, including capacity estimation with a suitable algorithm.

Evaluating batteries at sub-hertz frequencies adds to the test time. At one millihertz, a cycle takes 1,000 seconds and several data points are required to assess a battery with certainty. Clever software simulation can shorten the duration to seconds by applying prediction models.

Research laboratories have been using EIS for many years to evaluate battery

characteristics, but high equipment cost, long test times and the need for trained professionals to decipher reams of data have limited this technology to laboratory environments. In spite of its complexity, battery scientists believe that advanced battery testing will evolve around this very technology.

Not all batteries can be checked with rapid-test methods. For the broad population of larger batteries, battery analyzers are recommended to first establish if a battery is functional or not. A final capacity reading must always be known, and the most reliable method is through a full charge and discharge cycle. This method works well for deep-cycle lead acid, as well as nickel and lithium-based batteries, but should be avoided for starter batteries.

Choose a programmable battery analyzer with redundant safety features to allow servicing batteries that are known to be faulty. Connecting batteries has always been a challenge and some manufacturers offer clever battery adapters that make battery interface easy. Watch for wattage ratings and PC compatibility.

Summary

Battery diagnostics and monitoring techniques are not advancing as rapidly as the global battery market demands. Much work lays ahead but progress is being made. These incremental improvements will help extend battery life without sacrificing reliability, as well as protect our environment by being able to fully utilize the life of each battery. Battery refurbishes will embrace these advancements.

About the author

Isidor Buchmann is the founder and CEO of Cadex Electronics Inc. For three decades, Buchmann has studied the behavior of rechargeable batteries in practical, everyday applications, has written award-winning articles including the best-selling book “Batteries in a Portable World,” now in its third edition. Cadex specializes in the design and manufacturing of battery chargers, analyzers and monitoring devices. For more information on batteries, visit www.batteryuniversity.com [1]; product information is on www.cadex.com [2].

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