Caring for your starter battery

The most failure-prone part in a car

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No other part in a vehicle is as failure-prone as the starter battery. According to ADAC (Allgemeiner Deutscher Automobil-Club), battery problems have quadrupled between 1996 and 2010. ADAC, Europe's largest automotive club, says further that each third breakdown involves either a discharged or defective battery. The report published by the German "Motorwelt" in May 2013 also states that only few starter batteries reach the average age of five years, and this applies to all cars. The statistic was derived from more than four million breakdowns that the ADAC car club typically receives in a year. The study only includes newer cars; service-prone vehicles more than six years old were excluded.

Battery problems are not limited to Germany, a country that produces some of the finest cars. Japan also says that battery breakdown is the largest single complaint among new car owners. Low charge leading to sulfation and acid stratification is a common cause of failure. This is especially apparent in congested Japanese cities where motorists only drive an average of 13km (8 miles) per day. North America may be shielded from these battery problems in part due to long-distance driving.

Battery manufacturers are exploring the high failure rate and the results are mystifying. A leading German battery maker checked 400 starter batteries that had been returned under warranty and found that 200 of them had no problem. Another battery manufacturer revealed that genuine factory faults on warranty returns amount to only 5–7%. Something does not add up.

When Cadillac introduced the starter battery in 1912, the main purpose was to provide starting, lighting and ignition functions. Today, the battery also assists in steering and breaking, besides comfort-adding features such as heating and cooling. Simply opening the driver door causes 20A to flow, not to mention power assisted side doors and tailgates. Start-stop function is a new demand that stretches the flooded lead acid battery beyond its capability. All this leads to capacity loss and premature failure.

Li-ion starter batteries are now being offered. Their small size and light weight are striking but when asked if these batteries are trouble-free, a German manufacturer of sports cars said that in spite of the high price, the Li-ion starter battery is not without trouble. Longevity is similar to lead acid.

Capacity is the leading health indicator of a battery. Measured in Ah (ampere-hours) or RC (reserve capacity in minutes 25A discharge), capacity reflects how much energy a battery can hold. CCA (cold cranking amp) is responsible for power delivery and relates to the internal battery resistance. Figure 1 reveals CCA as a free-flowing water tap and capacity as liquid in a container. The intruding rock content demonstrates irreversible capacity loss.

Figure 1 Graphic illustration of a starter battery

CCA represents power delivery for good motor cranking; capacity is energy storage illustrated as liquid.

Capacity fade does not affect cranking noticeably, and most starter batteries perform well until the engine won't turn one morning. A battery does not die suddenly; it simply runs out of capacity. This is similar to a galloping horse that keeps its spirited performance until the eventual collapse of exhaustion.

The large number of warranty returns and high road failure is in part to blame on lack of reliable battery testers. Most testers read only CCA; capacity, the leading health indicator, is unknown. As the capacity diminishes with use and age, the internal resistance remains low. This renders resistive measurements unreliable as a state-of-health and end-of- life indicator. This leads to wrong diagnostics in which a good battery is being replaced in error and one with low capacity is passed, only to fail on the road.

Test Methods

The health of a battery cannot be "measured," only estimated. Much like a doctor examining a patient, or the weatherman forecasting the weather, battery test results are only *predictions* relating to state-of-health and end-of-life. A dead battery is easy to predict and most testers give 100% accuracy. The challenge comes when measuring a working battery in the 70–100% capacity range. Besides capacity, other attributes also come to play, and these are internal resistance, sulfation and self-discharge. No single device can assess all battery characteristics in a short-test on the fly.

One of the early battery testers was the *carbon pile*. The battery passes if the voltage stays above a set threshold with a load applied for a given time. The carbon pile test reflects lifelike conditions and a skilled technician can attain a reasonably good evaluation, however, the device cannot distinguish between low charge, high internal resistance and lost capacity.

Single frequency AC testers inject a 1000-hertz sinusoidal signal or square wave pulses of 80–90 Hertz. These non-invasive methods work on a *scalar* level by comparing data from a single reference point and measuring the internal resistance. Multiple frequencies have been tried, but the so-called *vector* method only adds to complexity without significant improvement. Capacity estimation remains beyond reach.

Battery scientists believe that the future of battery testing lays in *electrochemical impedance spectroscopy* (EIS). EIS has been around for many years but high equipment cost, long test times and the need for trained experts deciphering data have kept this technology in laboratories. Figures 2, 3 and 4 illustrate the most common battery test methods in use today.

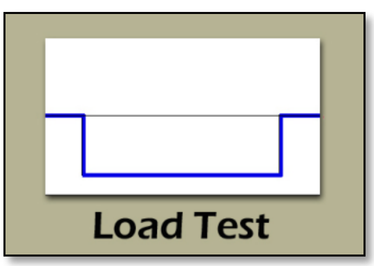

Figure 2: Load Test applies a load while reading the voltage. Confirms functionality but cannot read low charge, high internal resistance and low capacity.

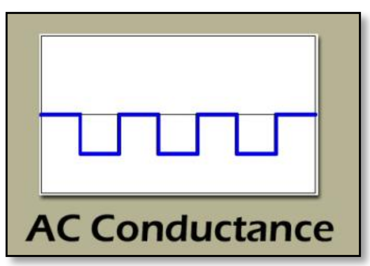

Figure 3: Load Test applies an AC signal to measure internal battery resistance. Testers are non-invasive, fast, stay cool, but cannot estimate capacity.

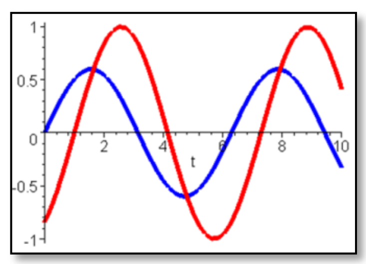

Figure 4: EIS scans the battery with frequencies. Nyquist plot needs expert to decode. Long test times reserves EIS mostly to research labs.

Scanning a battery and plotting a Nyquist curve with EIS is relatively simple; the complexity arises in evaluating the data. Cadex took the EIS technology a level higher and developed *multi-model electrochemical impedance spectroscopy* or *Spectro*™ in short.

Built in an elegant handheld device, the Spectro CA-12 scans the battery with a 20–2000 Hertz signal as if to take the topology of a landscape. The heart of the system is the algorithm that compiles 40 million transactions and delivers CCA and capacity readings in 15 seconds. The CCA accuracy is +/-5%, but its strength lays in capacity estimation with an accuracy of +/-20%, resulting in a correct prediction of 8 out of 10.

The industry will ask for higher accuracy in capacity measurements and improvements in matrices will achieve this in part. The user must appreciate that a battery fault can only be diagnosed if measurable indicators are present. A new battery that has not yet been formatted or has been in storage for a long time can give false results. Low capacity and partial charge produce similar pointers that must be recognized to get correct results. For unknown reasons, reversible (soft) sulfation does not display readable symptoms and the battery may receive a clean bill of health in spite of the anomaly. Only permanent (hard) sulfation that can no longer be corrected agrees with the result. A comparison can be made with a patient who has a unique illness that defies medical instruments.

As with all advanced systems, Spectro™ requires infrastructure and these are matrices, also known as pattern recognition algorithms. A matrix is a multi-dimensional lookup table against which readings are compared. Text recognition, fingerprint identification and visual imaging operate on a similar principle. Cadex is in the process to build a matrix library that includes various battery types. Generic matrices are most practical as these service a broad range of batteries by sorting on a capacity threshold.

Summary

Battery diagnostics and monitoring have not advanced as rapidly as the battery industry desires but incremental progress is being made. Batteries are complex beasts and test methods must distinguish between low charge and faded capacity, symptoms that are different to the outside but have similar diagnostics qualities. Battery characteristics also change after charging and prolonged storage.

Capacity is the leading health indicator that determines the end-of-battery-life. A starter battery should be replaced when the capacity drops below 40%. With the resistance-based method, the capacity is unknown, and many batteries may be replaced on a false assumption. There is also resistance to replace a battery that still cranks but is dangerously low on capacity. A battery does not die suddenly but runs out of capacity, and this occurs mostly during a cold spell. Driving with an expired battery is like a corroded bridge that has been closed to traffic but still stands.

German luxury car makers want to remove the word *breakdown* from the dictionary. Capacity-based diagnostics will assist in this effort that will also lower statistical records of ADAC road assistance. Improved battery testing will also benefit non-automotive industries. Capacity estimation of UPS batteries will lead to better valuations and possible longer service lives. Extended life will benefit the pocketbook and protect the environment as fewer batteries will be discarded.

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; product information is on www.cadex.com.