A Primer on Battery Charging

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ADVANCED CHARGER TECHNOLOGY

A PRIMER ON CHARGING

The standard OEM or consumer-priced battery charger is a "constant current trickle charger." *Trickle chargers* operate by delivering a steady, low-level, positive current for as long as it is connected to a power supply. Energy-storing ions are generated at one electrode in a battery cell and must move to the other electrode. If the current is sustained over an extended period of time, the ions concentrate on one side and create polarization, which causes heat generation, inadequate charging capacity, and a shorter life for the battery. Although they are an inexpensive consideration when purchasing a two-way system, they are NOT cost-effective*. They can significantly increase the cost of operating and maintaining the system*.

These slow, "overnight chargers" charge a battery in approximately ten hours and rely on the user to stop them when the battery has reached its maximum capacity. They are inexpensive and simple to design, but do not optimize the performance of the battery -- in fact, they actually contribute to its premature disposal. The low charge rate allows the chemical reactions to localize on the electrode surface, leading to dendrite growth. There is a high likelihood of overcharging, and, in the case of NiCd and NiMH, if the battery isn't discharged first, voltage depression, or "memory effect" begins to occur.

Memory effect is often responsible for the early demise of batteries. When NiCd batteries and, to a lesser degree, NiMH batteries are recharged before they are fully discharged, electrodes passivate, decreasing the ability of the cells to accept a charge. When a battery is repeatedly charged without being fully discharged, operating time and performance deteriorate and it appears to die before its time. Most radios will stop operating before the battery can reach a low enough per-cell voltage to recover the voltage depression, so even if a user thinks the battery has been "run down," few batteries actually are fully discharged before they are recharged. This practice and the standard OEM constant-current "drop-in" chargers combine to sabotage NiCd and NiMH battery performance. Radio Maintenance Engineers try to compensate for this problem by periodically discharging, or conditioning, the batteries on special equipment. Conditioning helps, but it is time-consuming, and batteries never recover completely from repeated abuse.

Most OEM-upgrade *fast chargers* operate by *increasing* the constant current rate, charging the battery in only two or three hours. They usually have basic circuitry that terminates when the battery is fully charged, or decreases the charge current when the battery reaches a certain voltage, usually about 80%-90% charged. However, charging at a high constant current rate ignores the electrochemical process within the battery, which, over time, causes significant deterioration, similar to, or worse than the trickle charger. The result is reduced capacity with each charge, untimely wear-down and fewer charge/discharge cycles for the battery. Although these one-to-three-hour chargers are significantly faster, they require that the battery remain in the bay for an additional 30-60 minutes after the battery is charged.

Pulse-charging, introduced in the 60s, was the first improvement to the constant current trickle charge. *Pulse charging* operates on the principal of surging power into the battery in "pulses" of electrical current. One-second pulses of power are interspersed with rest periods, lasting just a fraction of a second. Interrupting the pulse current gives ions a chance to diffuse and distribute more evenly throughout the battery and return to normal levels routinely, thus reducing some of the negative effects of trickle charging. While developed to address the chemical process of batteries, pulse charging still ignores the chemical reaction and physical phenomenon taking place in the battery, and the likelihood of the battery not being fully discharged. It provides short-term fixes, i.e. charged batteries, but the costs are heavy -- shortened battery life and reduced charge capacity, which translates to batteries not lasting a shift between charges, or a year out of the box.

The *second generation of pulse charging* emerged in the 1970s to counter the problem of recharging batteries that aren't fully discharged. This method, which is only used in a few high-end chargers, augments the rest period by adding a very short negative discharge pulse (depole pulse) interspersed with the positive charging pulses. The depole pulse is 2.5 times as strong as the charge pulse and is followed by another rest period. For many, this method seemed to solve some of the problems of traditional charging. Batteries return to balance more quickly -- speeding up charging rates to as little as one hour for a 700 mAhr battery -- and improving performance. The shortcoming to this approach is that the ion transport problem gets progressively worse as the battery is charged. The single discharge pulse method can only gain limited information about the state of the battery and the charge current cannot exceed the level which is acceptable at the end of the charge, when conditions are most limiting.

Even the OEM conditioners do not discharge the voltage low enough to recapture *all* the hidden capacity lost to memory effect. However, a new algorithm [pattern of current], discovered by Yury Podrazhansky and patented by ***ACT***, discharges to the *lowest possible* level to return hidden memory capacity. Podrazhansky, a Russian immigrant with a background in electrical and radio frequency engineering, was busy searching for a solution to the problems plaguing his rechargeable batteries when he developed ***ACT***'s patented enrev technology. This unique battery operating system sets the ***ACT***ivator apart from other chargers.

Podrazhansky, Vice President of Research at Advanced Charger Technology (***ACT***), discovered that single, high-magnitude negative pulses cause ion transportation problems in the reverse direction, as well as excessive discharge of the battery, which increases charge time.

Podrazhansky also found that applying even shorter, multiple negative pulses with a much higher magnitude eliminates charging problems and actually *benefits* battery chemistries. The larger magnitude discharge pulses are inherently focused in the area of dendrites and help to remove them. When allowed to build up, dendrites can short-circuit a battery's electrodes. The brief, high currents rapidly balance the ion concentration and improve the crystalline structure of the electrodes. In NiCd batteries, they momentarily pull the battery voltage down, resulting in the *reversal of voltage depression*. The improved balancing of ion concentration leads to a highly efficient charge process that enables a much higher charge current, yielding the shortest charge times possible and uniquely conditioning batteries as they are charged, eliminating the need to discharge first. Podrazhansky patented his discovery – a dynamic, charging waveform which uses real-time feedback to intersperse variable length positive charging waves with multiple negative discharge waves and brief rest periods to allow energy dissemination.