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Testing...Testing...How Good are the Batteries in Your Stock?

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For participants in the expanding market for rechargeable batteries of all types, one major concern is the current "condition" of their inventory. Batteries are a great market to be in, but the shelf life consideration can give anyone gray hairs. Being aware of self-discharge and its causes, then taking the proper steps to combat it, is still most of the battle. But there is that one thing no one seems to know; how do you determine the battery condition?

Concern with this issue should start with the way the battery inventory is stored. The two great enemies of batteries are heat and time. Excessive heat accelerates the self-discharge of SLA's (Sealed Lead-Acid). It is imperative to recognize that self-discharge starts the minute a battery is first charged, not when it is first received. It is also important to realize that self-discharge is not linear. At 25°C, a battery may discharge from 100 percent charge down to 90 percent charge in just a few weeks, but the rate begins to slow thereafter. Normal self-discharge of VRLA (Valve Regulated Lead-Acid) batteries is around 3 percent of total capacity per month at 25°C[1]. For every 10°C above that level, the self-discharge rate doubles every month. If your inventory is stored at 100°F (38°C), the self-discharge is close to 7 percent per month[1]. The relationship of time to this issue is obvious, so the best defense of inventory becomes recognition of this situation, and recharging your inventory when voltage gets down to about 2.08 volts/cell (12.5 V fro 12 V battery). This open circuit voltage represents a charged condition of about 50 percent. The importance of maintenance recharging cannot be overstated! If a sealed lead-acid battery is allowed to self-discharge below 2.0 volts/cell, recharge becomes more difficult, and at 1.75 volts/cell, the recharge characteristics actually change for the worse[1]. It's a fact of the battery business, perishable inventories can't be ignored. Even small retailers must acknowledge this fact and act accordingly.

Battery Testing Methods

If you are in the SLA business, the VRLA battery is a "black box" of unknowns, due principally to its "sealed" construction. We can't see inside; we can't check the water; we can't measure the specific gravity of the electrolyte. So, how do you know if the battery is all right, or not? Our only view into the battery's health is through the positive and negative output terminals and that's a pretty narrow view.

With this said, it doesn't take a genius to conclude that some test method or instrument is needed to do the checking for us. In times past, one of the more common devices for analyzing battery condition was the variable load bank, a large tester that sat on a roll-around cart, and cost six months profits! Due to the bulk of the load bank itself, the tester was cumbersome, heavy and hard to use; though it could give an accurate evaluation of a battery. But today, everybody wants something light to carry, quick to use and accurate for battery condition.

Given the criterion of "light", "quick" and "accurate", some inventive people began the search for a means to meet those demands. Since there are only the two output terminals connecting the battery to the outside world, the solution had to come through those terminals. With this limitation, it was considered that the "Internal Impedance" of a battery could be accurately measured from the terminals. This is the internal resistance of a battery to the flow of electrons, measured in thousandths of an Ohm, or milli-Ohms. It is a very important indicator; but it must remain in context and be evaluated in concert with numerous other factors from the same source. That source is the individual battery.

One of the most valuable uses of the internal impedance reading is found in monitoring UPS system battery banks. The individual batteries in these banks are carefully chosen by manufacturer, purpose (standby), lot number or date code and size. Some strings are even impedance-matched before they are installed. They are mounted in a controlled atmosphere (temperature and sometimes humidity), and are under constant trickle charge from a dedicated charger/inverter. The key in this application is consistency in the individual batteries of the bank. It is worth noting that the batteries are very carefully selected and the environment is closely controlled. When the bank is first installed, an initial internal impedance reading is taken for **each battery** and recorded. As the life of the bank proceeds, periodic readings of each battery (and noting of the internal impedance) gives a precise condition of a specific battery and identifies the batteries most likely to fail. The ability to identify a battery beginning to falter, before it actually fails, offers the opportunity to change the battery for a new one, keeping the UPS system un-interrupted. The important thing to note is that individual battery “condition” is determined from a baseline taken from that same battery. A baseline from another battery, or a published chart, is of no real significance.

Conductance Testing

With research and inventiveness, some test equipment companies have established internal impedance measurement as a generalized method of declaring the overall capability and condition of a battery. Many of the units of measure employed by these manufacturers are derivatives of internal resistance (such as Mho's or Siemens numbers, the reciprocal of internal impedance, also referred to as Conductance). Other old terms from the automobile industry such as CA (Cranking amps), CCA (Cold Cranking Amps), MCA (Marine Cranking Amps) are also being referenced. These units of measure are valid because they are either directly related to internal impedance, or derive their evaluation from it. But like internal impedance, the variables must be controlled to validate the readings. When used correctly, these testers offer results that are accurate, but only if an initial internal impedance figure was established for that battery, and recorded for future reference. Without this comparative reference, the readings are not relative.

Other tester manufacturers have chosen the "Battery Good" or "Battery Bad" unit of measure, which is much more speculative with serious credibility problems. Also, very close scrutiny is warranted when any type tester is offered to the market by a battery manufacturer; as the test results versus other battery brands, using XYZ's battery tester, may bear more resemblance to a marketing tool than an analytical one.

Conductance Validity

The resulting testers have been “light”, “quick” and “accurate”? Well, maybe we had better delve into this a little further. If a determination of battery condition is going to be based on one factor, then the stability of that factor against outside influence must be strong. Well, internal impedance in a battery has very little stability. There are numerous variables that influence the battery impedance, and cause it to read widely, even in just one battery. It might be very helpful to determine exactly what does affect the internal impedance reading, and if that issue can be subsequently classified as "low quality" of the battery?

There are many influences that stem from the construction of the battery (either mechanical or chemical), that are not applicable to a judgment of battery condition. There are also external influences that must be considered, that have nothing to do with the battery is capability:

1) The alloy of the lead grids.
2) The area of plate surface.
3) The measurements of the plate shorting-bars.
4) The porosity of the separators.
5) The specific gravity of the electrolyte.
6) The state-of-charge of the battery.
7) The temperature at which the measurement takes place.

The first five of these factors are built into the battery by the manufacturer, and make that battery suitable for its intended application. There are "starting" batteries, "standby" batteries, "deep cycle" batteries, and even "general purpose" batteries. All are different, each with its own mechanical and chemical make-up that prepares it for its intended purpose. These factors are not variable; but neither can they be generally evaluated by an internal impedance reading.

Let's consider these factors individually:

The alloy of the lead grids is directly related to electrical resistance. Regardless of why certain battery manufacturers choose the lead alloy they do, pure lead has the lowest impedance; and any alloy, depending on how much is incorporated into the lead, will raise the plate resistance. If the plate resistance is raised, the internal impedance of the battery will rise; but that does not equate to a standard battery.

The area of plate surface, in conjunction with robust plate shorting bars and output connections, will also result in lower resistance to the movement of electrons from the battery. Some battery manufacturers practice a method of manufacturing called TPT (Thin Plate Technology). This increases the plate area by using thinner lead grids, and more of them in each cell. This is outstanding for a battery whose primary usage will be for engine starting. This construction reduces the internal impedance reading upon which conductance testers base their analysis, which makes this battery appear better than standard construction, when it is not. It has just been maximized for a particular application.

The robustness of the shorting bars the manufacturer uses in his batteries has already been mentioned, but this construction fact bears repeating. Heavier shorting bars lower the internal resistance of the battery with the same results on conductance testers as noted above.

The separators used to build a battery also have their effect. If the porosity of one material is greater than that of another material, it will allow for greater ion movement between the plates during charge or discharge. This freer movement of ions equates to lower internal impedance. It must be noted that a more porous material is not always desirable, and does have its faults, just as other component variations mentioned previously.

Another closely related component to the separator is the electrolyte. This is a solution of sulfuric acid, the specific gravity of which is usually between 1.200 and 1.300, depending upon the application for which the manufacturer intends that particular battery. A higher specific gravity will cause a more active condition of the battery's electrochemical process, and this will manifest itself in apparent lower resistance to ion movement. To a conductance tester, this appears as a lowering of the internal impedance of the battery, and an improvement in the battery's health. Here again, this is not the case. Higher specific gravity is accompanied by faster depletion of the active material, faster corrosion of the grids, and shorter service life. These are not desirable traits, but rather chosen to accomplish an end.

The last two items on the list are widely variable, and may have the greatest impact of all. They can combine for a total change of the internal impedance reading of almost 90 percent. The first five factors are defined by the factory during production, while these two are controllable by the end user. State-of-charge and battery core temperature have a huge impact on the internal impedance.

When taking an internal impedance measurement, it is extremely important that the ambient temperature around the battery be the same as the factory established when they took the reading they publish. Internal impedance can increase by 50 percent between the temperatures of 30°C down to -18°C[1]. This demonstrates one fallacy of using a conductance tester as the sole indicator of battery condition.

State-of-charge has a similar effect on the internal impedance reading of any battery. The difference in resistance between a fully charged battery and a fully discharged battery can be an increase of 40 percent[1]. Here again, it is extremely important that this parameter be the same as the factory used when they took the measurement they publish. In the case of state-of-charge, it is even more important because a battery's natural self-discharge automatically increases the internal impedance reading. The tester will identify this as a degraded battery, rather than the fact the battery simply needs charging. Ask yourself, “How many battery resellers take the time to charge a battery before they test it with a conductance tester?”.

In summary, when these seven factors (five of which are not controllable by the end user) are taken into account, it is easy to appreciate the extreme difficulty of using internal impedance as an overall predictor of battery health. It is not possible to compare the internal impedance readings between two batteries constructed for different applications. Neither is it possible to compare two different manufacturer’s similar offerings using this criterion. Different factories choose different alloys, electrolytes, and mechanical construction; these differences alone account for enough variance in internal impedance reading to pass one battery while rejecting another. Throw in the fact that the individual using the conductance tester may not be considering the temperature, or charge-state of the batteries he's testing, and the readings of a conductance tester become highly suspect.

Where Do We Go from Here?

So, now we are still left with that initial question: "How do you know if a battery is good?" If we back up again to that old "load tester", the answer might be in view. There is nothing we can examine about the characteristics of the battery that were manufactured into it, because they are unknown. But, we can be sure that the battery we're testing is (1) fully charged, and (2) at a reasonable temperature. Any of the four constructions; starting, deep-cycle, general purpose, or standby will respond to empirical testing. The battery industry long ago established a testing formula for loading a battery at three times its rated capacity, and watching the voltage depression created by that load. For a 12 V battery, just a "good" battery (not a new one) should be able to take this load, with the terminal voltage stabilizing above 9 V in 10 seconds or less. A new battery should be able to take this load and stabilize above 10 V in 10 seconds or less. When testing a 6 V battery, just half those voltages. If the battery can't stabilize above the appropriate voltage, or keeps dropping; then there is definitely something wrong with that battery.

Alternative Testing

Variable load testers are available currently from several sources. They are reasonable size (about the size of a lunchbox), weigh just a couple pounds, and will give a correct analysis of any battery. They are actually variable carbon-pile resistors that can be adjusted from about 10 A all the way up to 500 A. Load accuracy is around +/- 5 percent, which is sufficient to achieve the desired results. Their only real limitation is the heat they absorb. When you measure 200 A for 10 seconds, something's going to get HOT! Earlier, it was mentioned that a load of 3X capacity was part of the formula. While this is true, even a load that is equal to C/1 will give a good indication whether a battery can cut-the-mustard or not

No matter how your battery inventory is being tested, by open circuit voltage, by load testing or even by conductance tester, be assured that the voltage is dropping, and how you respond to this will decide the battery condition. If you are not equipped to charge your inventory, then be sure that your inventory turns are fast. Or keep your inventory at a minimum level. Nothing can stop self-discharge of your stock. Only you can be sure you provide your customer base with fresh battery stock.

Footnote:

[1] David Linden, Thomas B. Reddy, “Handbook of Batteries” Third Edition, p. 24.45, Table 24.6b, 2002; p. 24.15, 24.16, 23.63, 2002; p. 24.15, 2002; p.23.41, Fig. 23.21, 2002; p. 23.42, 2002.

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