# THE INSPECTION IS COMPLETE. WHAT ARE YOU DOING WITH THE DATA?

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## ABSTRACT

Maintenance staffers responsible for measuring and recording battery operating parameters know they are supposed to be taken on a periodic basis. After years in the business, it is clear that little or nothing is frequently done with the readings post-inspection. Technicians think Engineering is analyzing the data. Or, is it that Engineering is supposed to be doing this? In reality, no one is doing anything with the data and, in the meantime, potential battery failure waits. When data *is* analyzed, it's frequently misinterpreted. So, what are you doing with the data? This paper will discuss commonly measured battery parameters, what the data mean and good sources of guidance for what the readings should look like.

## INTRODUCTION

Let's take a moment to review why parametric data is supposed to be collected, recorded and analyzed in the first place. Its purpose is to provide the user with insight into the general condition of the battery between scheduled performance tests. As the store of data continues to increase, trending should be conducted to determine if cell/unit voltage, internal ohmic values, temperature, etc. are maintained within specific operating limits. Here's the catch; if the data isn't being analyzed, you have no idea what's going on. I know this sounds incredibly simple, but the reality is many users don't know the condition of their battery because post-inspection data analyses aren't being done or are being done by persons with little or no understanding. The money crunch is on and battery test equipment is being placed in the hands of maintenance personnel who simply aren't up to the task. Not because they can't, but because they don't have the knowledge and skills – yet.

## TECHNICAL DOCUMENTATION TO SUPPORT YOUR EFFORTS

Reference documentation is frequently unavailable to service technicians and those responsible for determining battery condition. To the uninitiated, trying to figure out what the data mean can be a daunting assignment.

When reference documentation is required, one need not look very far for it is within easy reach of a computer and the internet. The primary sources for guidance are contained in battery manufacturer installation, operation and maintenance instructions as well as the IEEE recommended practices. Both are available as PDF downloads. That said IEEE standards are for-sale documents for a nominal fee. They are a bargain. The Annex sections of the standards alone contain significant educational value. When you take the time to read them, you will understand why they are great buy. The three listed below are the ones users should become familiar with and should be readily available in your electronic library.

- IEEE 450-2002 - IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications *(revised version pending at press time)*

- IEEE 1188-2005 - IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead- Acid (VRLA) Batteries for Stationary Applications

- IEEE 1106-1995 - IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications

While much information can be gleaned from these documents, technical support should be sought from the battery manufacturer if clarifications are needed. Additionally, basic training and understanding about batteries is highly beneficial to anyone responsible for their care and feeding.

## UNDERSTANDING THE BASICS OF MEASURED PARAMETERS

Basically, there are eight parameters that can be measured, trended and analyzed in a stationary battery system. Not all users measure all applicable parameters for a given type of battery. This can be due to equipment limitations maintenance program design, or battery construction. They include:

- Cell voltage
- Battery float voltage
- Float current
- AC ripple current
- Specific gravity
- Temperature
- Internal ohmic values (resistance, impedance, conductance)
- Interconnection resistance

### Cell Voltage

As you might expect, cell voltage is closely related to the applied charging system voltage and is discussed next. Interestingly, I have talked to people who think as long as a cell's voltage is at least 2 volts, the cell is healthy. Nothing could be further from the truth. As an example, a 1.215 lead-calcium vented battery made up of 60 cells is typically charged at 2.25 volts per cell (vpc). Given that, the battery voltage on float charge would be 135 volts. That's nowhere near 2 volts per cell which would indicate an improperly adjusted or failed charger or other system anomaly. Generally, cell voltage is permitted a range of +/- .05 - .07 volts per cell from float. Attention should be paid to cells whose voltage reaches critical levels. In the example case, 2.13 volts would be considered critical. Check operating instructions for specific values for your battery as they tend to vary between types.

### Battery System Voltage

Overall battery voltage, as you might expect, is directly related to individual cell voltage based on the above discussion. When measuring this overall value, avoid using the battery charger panel meter as the sole source for the reading. Rather, consider using a calibrated digital volt meter and take the measurement at the battery main positive and negative terminals. The "three dollar panel meter" as a colleague puts it has been known to be terribly inaccurate. When divided by the number of cells in the battery, it tells you the average applied voltage per cell. Simple, I know, but many people don't get it. This is a measurement that is frequently recommended to be taken at monthly intervals. If it is observed to be out of range, adjust the charger as needed.

### Float Current

Considered to be the best indicator of state of charge, float current is a parameter that can be measured on a continuous basis or during periodic routine inspection activity. It is the current the battery requires to stay fully charged while in float service. This is a very low DC value, typically in the milliamp range and requires equipment designed to measure it. How it is measured and reported is a function of the type of equipment purchased whether incorporated into a monitoring system, as a hand held portable unit or a standalone monitoring solution.

Float current for properly operating vented lead calcium batteries should remain constant over their service life. In vented lead antimony batteries, it increases with age. For VRLA batteries, it increases as a function of dry out condition and should be monitored closely along with temperature. Generally, trends showing increases in float current and temperature should be cause for concern. To see a trend, however, you must look at these values over a period of time. Watch battery temperature and trend it along with float current. If you observe both increasing, contact the battery manufacturer for guidance. IEEE standards discuss float current in detail.

### AC Ripple Current

AC ripple current is a byproduct of rectification. The inverter in UPS systems also contributes ripple current because it is in parallel with the battery and the rectifier/charger. It is measured with a true RMS AC amp clamp. Generally, a value of 5 to 6 amps per 100 amp hours of 8 hour rated capacity is considered acceptable.

However when exceeded, the cause for increased values should be investigated. If you have a VRLA battery this measurement should be taken once per year. Unacceptable amounts of ripple current in a battery can cause a rise in temperature and premature failure due to heating and serious degradation to the internal components similar to those seen in excessive cycling of the battery.

**Temperature**

This discussion includes battery room (ambient) and battery cell temperature. Lead-acid batteries made in the U.S. are based on a standard temperature of 77 degrees, F. (25°C). Design life and performance are based on this temperature. Non-U.S. designs generally reference 68 degrees, F. (20°C). High ambient temperatures and batteries are much like oil and water; they don't mix. Keep you battery warmer than recommended on average and you'll be replacing it sooner than later. I will not chastise an owner for keeping a battery a *little* on the lower side of standard temperature.

Cell and ambient temperatures should be measured and recorded per the applicable standard with attention paid not only to the specific value, but also to the differential between ambient and cell temperature. These two should, for the most part, be the same unless there is an environmental issue causing one to be higher or lower than the other. The maximum deviation between the highest and lowest cell temperature within the battery as a system should not exceed 5 degrees, F. (3°C). These values should be measured and recorded and as with other operational parameters, evaluation of the measurements should be made against manufacturer recommendations. An unexplained increase in battery temperature could be due to increased float current. Crosschecking temperature and float current where both are available is highly recommended. With attention to historical data, make note of trends that occur and examine the potential cause for unexpected deviations from the norm.

**Specific Gravity**

As it stands today, if you operate a vented lead-acid stationary battery, specific gravity (S.G.) should be measured on a sample basis at random, quarterly and then taken on all cells once per year. It is looking as though that won't apply to lead-calcium or low antimony batteries in the next revision of IEEE 450 if a user is monitoring float current. If monitoring float current isn't going to be part of your maintenance program, keep the trusty hydrometer handy if you're going to follow the standard.

Before float current was used, determining state of charge was done with specific gravity readings. Actually, for the most part that's the way it is today unless you buy float current equipment. There are underlying issues that affect readings of S.G. that affect the true determination of a battery's state of charge. They do not tell the full story if there has been a recent discharge, or equalize charge or recent additions of water to the battery. Therefore, before you begin to analyze specific gravity you need to have a good understanding of how it is affected by these factors. That said if you are going to begin analysis of a full set of S.G. readings, keep in mind the variables mentioned here.

Water additions are commonly found to be the culprit when an unwitting technician takes a full set of readings only to find the 1.250 S.G. rated cells were watered 2 days prior without the tech's knowledge. Even in small cells, 2 days isn't sufficient time to mix the added water fully with the electrolyte. Instead, for example, the technician is obtaining readings in the range of 1.200-1.220. Since a 1.250 S.G. rated cell would typically be allowed a point spread of +/- 10 points, the technician expects to see readings from 1.240-1.260.

When analyzing S.G., don't take the measurements at face value if they don't look right. If they appear to be out of range, you have to ask yourself a few questions to figure out of there are any recent events that would cause the condition. You have to become somewhat of a detective and look for clues to get the right answer.

**Internal Ohmic Values**

Use of portable and fixed ohmic measurement test equipment has become quite popular. Available equipment measures impedance, resistance or conductance. Numerous Battcon papers have been authored on the subject, technological advances, and operational theory has been discussed. Much data exists in the form of measured values and white papers.

What's important to the individual responsible for looking at the data? It starts at the baseline dataset. As batteries age, ohmic values deviate from their installation values and generally quite slowly over time. In the case of resistance and impedance, these values trend upward as the battery ages.

For conductance, they trend downward. In both cases, degradation of ohmic values is undesirable albeit inevitable and eventually results in poor performance leading to complete battery failure unless the problem is detected early and corrective action taken. Significant deviations in ohmic readings, 30%-50% for example from baseline should be considered cause for concern. Cells exhibiting values above that must be given serious consideration for replacement. Battery manufacturers should be contacted for further guidance.

With all the information that is available, I still talk to people frequently who have some type of ohmic equipment, make measurements, log the data and *still* experience battery failures.

Why? The reasons are numerous, but the more popular ones are:

- Failure to understand batteries on an ohmic level
- Incorrect use of test equipment
- Inconsistent use of test equipment
- Insufficient instrument training
- Failure to analyze readings

If you're having trouble, get in touch with your ohmic test equipment manufacturer and obtain some guidelines on establishing baseline datasets and thresholds to identify problem cells. Track and trend the readings over time and look at what is happening to these values. Become familiar with your specific test equipment and become proficient in its use. Know its capabilities as well as its limitations.

**Interconnection Resistance**

Lastly, there is the need to closely track and trend the DC resistance of bolted interconnections throughout a battery. Note that not all battery designs provide for measurement of this parameter due to their construction.

While a battery used in a low drain application may easily survive a less than perfect connection, the chances of that happening in a high drain system are a lot less likely. High drain applications include UPS, telecommunication central offices and electric generating station batteries where current can easily reach 1000 amps or more during a discharge event. Here, you cannot afford to have a connection let go. It's just not an option.

Baseline connection resistance values should be established at installation. These values are measured in micro-ohms. All future resistance readings are compared to those values. If a connection has exceeded its installation value by more than 20%, the first response is to re-torque the affected connection and retest. If that does not correct the condition, the connection must be disassembled, cleaned, remade and retested.

The presence of electrolyte on connections will accelerate corrosion and subsequently, high resistance. This is one of several reasons batteries should be kept as clean as practical.

## SUMMARY

Going through the motions of battery maintenance and completing the punch list is part one of a successful routine inspection program. Part two is just as important and includes performing the required analysis of the readings taken. Part three involves taking any corrective actions that were indicated that came out of the analysis. Failure to do any of this is setting you up for a battery failure. Take the time to do it right. Remember, when a battery is specified for an application it is because an interruption in power cannot not be tolerated. A stationary battery is the first line of support when normal power is lost. Its proper maintenance deserves your strict attention.

If you are not familiar with batteries, get some help from the battery manufacturer. Talk to fellow attendees at industry conferences like Battcon. Network with other users. Attend IEEE meetings. For more information to go http://www.ewh.ieee.org/cmte/PES-SBC/. Get involved in the industry and be more than a user. IEEE members are always in attendance at Battcon. Seek them out, ask questions and learn!