BZI Training Course
Advanced Impedance Measurements Module #201

This course helps you understand some of the more advanced concepts relating to measuring impedance of motive battery cells in the field. After completing this training course, you will be able to identify the major causes of the changes in impedance in an individual 2-volt motive battery cell.

> "Cell Impedance" is determined by applying an alternating current source, of known frequency, voltage and amperage to the cell, then measuring the output and comparing the input and output values. This differential is a measure of the internal resistance or impedance, caused either by sulfation or other means within the battery. Low impedance means low internal resistance and high probable battery output power. High impedance means high internal resistance and low probable output power.

A battery cell has voltage within it, so the resistance of the cell cannot be read using a regular ohms setting on a multimeter. The impedance tester creates a small, precise alternating (AC) current that is then applied to the battery cell positive and negative terminal plates. The difference between the amount of the applied AC current that is measured out of the cell compared to what was induced into the cell, is the cell impedance.

Impedance readings, like the readings of a voltmeter, are simply measurements. When you rent a car at the airport, you trust the gas gauge, so you will have to learn to have trust and confidence in impedance as you do your voltmeter or the gas gauge in your car. The problem of course is that the understanding of impedance is not as simple as the measurement of voltage. It will take some experience and patience on your part to gain that trust.

That being said, there is some difference in the way that impedance can be applied to a tubular designed battery vs., a flat plate battery. Because of the design structure of tubular batteries, they are less responsive to the measurement of impedance than a flat plate design.

While there may be regional or brand differences with respect to tubular batteries, the USA based batteries we are familiar with generally range from .5 milli-ohms of impedance when new to no greater than 2.0 milli-ohms, as a general rule. Flat plate battery cells by contrast, range from 0 milli-ohms when new to 1000 mill-ohms on extremely bad cells.

Typically a flat plate battery will perform at it's optimum, all other factors remaining constant, when the impedance is between 0 and .6 milli-ohms.

Actually a high range of .5 to 1.0 may be acceptable depending on the battery type and other factors. Motive Flat plate batteries are seldom serviceable above 2.0 milli-ohms per cell.

Typically tubular batteries that range from .5 to 1.0 milli-ohms of impedance, and the serviceability of the batteries, all other factors remaining constant, would be in the range of .5 to 1.5 milli-ohms.

We here at BZI have more field impedance data than anyone else in the world because we have one of the few devices that can accurately read 2-volt cell impedance, the Model 1200 impedance tester. Secondly, we have made it the basis for sulfation elimination to all of our dealers and operators, therefore, we have collected more field data than any other company. Even the manufacturer's themselves have learned about field impedance measurements and the corresponding internal condition of the battery, from BZI research.

Flat plate and tubular batteries increase in impedance as they age in a relatively linear manner, all other constants remaining the same. This is caused by sulfation (either stratified or evenly placed sulfation), mechanical damage, corrosion, or oxidation (deterioration of the grid to paste conductive surface). An offset to higher impedance with age is the accretion of shorting, either mossing or sedimentary, on the plates of the battery. Thus, sulfation, mechanical damage, oxidation, and corrosion increase impedance, shorting reduces impedance.

While gradual shorting of the cells may offset the normal increase in measured impedance values, the lowered measured impedance does not increase the performance of the battery. Therefore, unusually low impedance cells in older batteries (those batteries older than 5 years as a rule), or batteries with high cycles or previously high amp-hour consumption and re-charging rates, fall outside the normally distributed bell shaped curve of battery restoration probability. Simply stated, batteries with heavy use and abuse may have low impedance values after sulfation elimination, without a corresponding increase in their capacity.

The specific gravity of the electrolyte will also affect the impedance readings. For example, a cell with a low SG reading of let's say that of water, will read slightly higher impedance than a battery with the correct acid of let's say 1.285. This may also account for a difference in the before and after measured impedance of the cell.

The grid to conduction paste surface can be viewed as a super highway, and as the batteries age and cycle, the super highway looses the ability to handle as many cars going as fast as they once did. While sulfation is one of the components of impedance measurements and it is expected (and it is normally true) that the removal of sulfation should lower impedance, there are some exceptions. A battery that sat idle for several years, would be expected to provide results in that category.

Why is it on older batteries that the impedance will increase after de-sulfation?

Depending on the battery, if the battery sat for an extended period of time, then it has heavily sulfated (and stratified) with what we call Level 3 sulfation, and under the layer of sulfation the battery chemistry is permanently damaged on a molecular basis. Since active areas of the battery plate have been INACTIVE for such a long period, the plates are covered and stratified by this Level 3 crystalline form of sulfation, which has chemically changed the plate affected by that sulfation.

One factor, or theory, as to why impedance in older batteries may be expected to increase after sulfation elimination is because the battery was operating "around the heavily sulfated areas," and now that the battery can allow the use of those surfaces again, the impedance will go up as more "less conductive" (higher impedance) surface area is useable. The cell composition is changed in that same area, so it is not as good a performance as an identical cell without the previous damaging Level 3 sulfation, thus it has higher impedance.

A second factor is that as the area of the paste to grid contact area is oxidized during the charging process, or corroded by the mere fact that acid is in contact with that area, then the super highway conductance (impedance is the opposite of conductance), is decreased. This is a natural and somewhat linear relationship. As the plate to grid area is oxidized, the oxidized material causes an increase in impedance. This increase in impedance may be somewhat offset by sulfation and the removal of the sulfation then increases the impedance. Another possible contribution is that as the process of sulfation elimination is being applied, it also removes a layer or an "oxidation bridge" between the grid and the paste, thus increasing the impedance of the cell.

Some companies view sulfation as a "daily" or "permanent" comparison. Daily sulfation and permanent sulfation are from the same source, the difference is the time that you allow it to stay on the plates. The longer a chemical problem, such as sulfation, is allowed to go unresolved, the more permanent damage will result. If you wait too long after the battery is sulfated, then you will have less positive results.

Thus, a battery that sat sulfated for 2 years will have permanent damage, which is evident as a higher impedance value, than a battery that has been in continuous use, all other factors remaining constant. Whether that value is higher or lower after sulfation will be dependent upon the condition of each cell prior to the de-sulfation attempt, and not the sole reflection of the reduction of sulfation. The removal of sulfation normally is indicated by the reduction of impedance, however, when the impedance of the battery cell increases after de-sulfation, you have NON sulfation related, additional and permanent cell damage.

The BattRecon system simply re-ionizes the sulfate molecules back into the electrolyte solution. The battery should then either be placed back into service where it is charged and discharged during normal operation, or in the case of heavily sulfated batteries, manually charged and discharged perhaps using a constant current or constant potential charger. During the de-sulfation process, on the normally distributed 80 percentile of batteries we encounter, the lowering of impedance is a measurement of sulfation elimination. In the batteries outside the normal distribution, sulfation has been eliminated and performance increased, yet other factors within the battery outside of our control or repair capability can exist causing the impedance to rise rather than diminish. This does not mean that the sulfation has not been eliminated, rather, it means that the offsetting factors in the cell opposing sulfation impedance measurements, have a greater proportional effect than the sulfation induced impedance factors. This is always an indication of a distressed cell and the client should be advised that this cell must be monitored more closely in the future, if it is even serviceable. Normally, cells that have a rise in impedance after de-sulfation, have a very low life remaining expectancy.