OHMIC TESTING

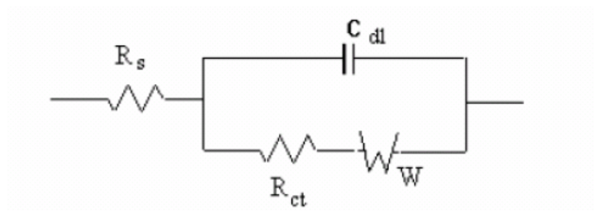
How Ohmic Testing Works

A battery is a series of cells containing two plates or different metals that are separated by an insulator. These cells are submersed in an electrolyte. The voltage of each cell is depended upon the chemistry of the cell. Cells can be connected together in series to create higher voltage batteries. These are called battery jars.

For example in an automobile you will have a 12VDC battery. This is a jar that consists of 6 lead acid cells in series.

The amount of current a cell can deliver is dependent on the surface area of the plates; the greater the surface area the greater the available current, the greater the capacity of the battery. This also means the greater the surface area of the plates the lower the battery impedance; therefore, the greater the capacity the lower the impedance of the battery.

In 1959, Willinhganz[4] suggested an electrical schematic for a battery. It is shown below:

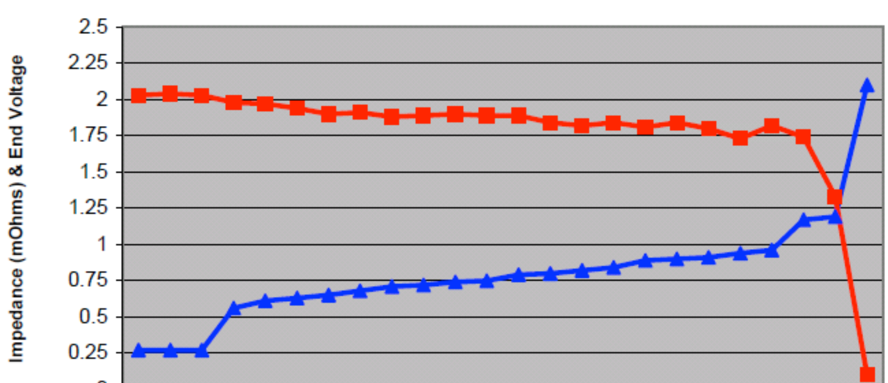


From the schematic above we can see that a battery has capacitive and resistive qualities. The battery will also contain inductive qualities when the terminals are taken into account.

Ohmic testing measures the battery resistance and / or impedance. This value will change as the chemistry of the battery changes. The battery chemistry will change from use, maintenance or age.

- As a battery ages the plates will corrode which causes loss of active material on the plates, causing the impedance to rise.
- As a battery discharges the plates sulfate which causes loss of active material on the plates, causing the impedance to rise.
- Impedance testing is not an absolute measurement of battery capacity; however a battery's impedance does have a correlation to its capacity. As the battery plates lose active material due to corrosion of sulphation it also loses capacity.

Ascending Impedance with Corresponding End Voltage



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Imp	0.27	0.27	0.27	0.56	0.61	0.63	0.65	0.68	0.71	0.72	0.74	0.75	0.79	0.8	0.82	0.84	0.89	0.9	0.91	0.94	0.96	1.17	1.19	2.1
End V	2.03	2.04	2.03	1.98	1.97	1.94	1.9	1.91	1.88	1.89	1.9	1.89	1.89	1.84	1.82	1.84	1.81	1.84	1.8	1.73	1.82	1.74	1.33	0.1
Cell #	11	15	16	3	18	22	13	24	10	14	23	20	5	9	6	4	21	8	1	12	2	17	7	19

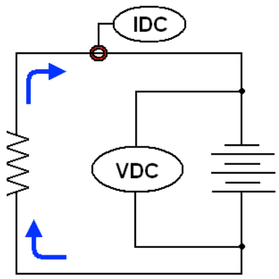
As active plate surface area is lost the impedance goes up and the capacity goes down

Ohmic testing is not an absolute test. The measured value is not compared to a standard known good value to determine if the battery is good or bad. (Ohmic testing is NOT a GO / NO GO Test) Ohmic testing is a relative test. The measured value is compared to the previously measured value to see how much it has changed. The percentage change indicates how much the battery chemistry has changed; which is an indicator of the batteries State Of Health. (SOH).

Methods of Ohmic Testing

There are several methods of ohmic testing; these include Resistance, Conductance and Impedance.

- Resistance testing is performed in different ways by different companies. Some use a pulsed DC to measure the voltage drop across the battery. Some will just place a resistor across the battery. Alber basically measures the DC voltage across the battery cell then places a low resistance resistor across the battery to draw a high current from the battery, they then measure the current and DC voltage. By using ohms law they are then able to calculate the resistance.



This method has a flaw. A battery is not a resistor. As can be seen in the below image there is a capactive characteristic to batteries as well as resistive. The resistive method ignores the capacitive characteristic of the battery.

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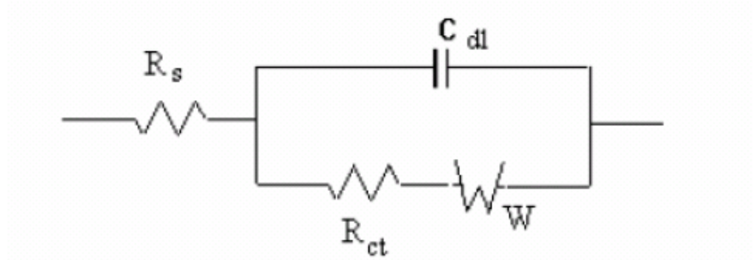
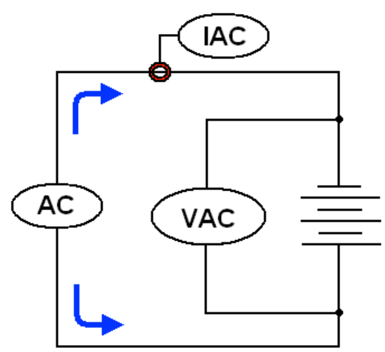


- Impedance testing injects a low frequency AC signal through the battery. This frequency is typically at 50Hz or 60Hz. (Opposite the line frequency to reduce the influence of noise from the line) The AC Current and AC Voltage are then measured. By using ohms law the impedance can then be measured. This value is inclusive of the capacitive characteristics of the battery as well as the inductive characteristics as well.



In addition a battery string is connected to a charger which converts AC voltage to DC voltage in order to keep the battery string charged. This AC to DC conversion is never 100% efficient. There is always some AC voltage remaining, this is referred to as AC Ripple voltage. AC ripple voltage has a higher frequency than the injected current we use for impedance testing. Since the impedance testing is done at a lower frequency, even larger values of AC ripple has little effect.

Conductance testing also injects frequency AC signal through the battery. This frequency is typically at approximately 1KHz. The AC Current and AC Voltage are then measured. The reciprocal of impedance, admittance is then measured. This value is typically referred to as conductance, but this is an incorrect terminology. Conductance is the reciprocal of resistance and therefore a DC value. Since AC is used it is actually admittance that is measured. This value is also inclusive of the capacitive characteristics of the battery as well as the inductive characteristics as well. However since the conductance testing is done at a higher frequency, AC ripple can have an affect on it.

Analyzing Ohmic Data

Ohmic testing; which includes resistive testing, impedance testing and conductance testing is a relative test that provides comparative data that can be analyzed in 3 ways.

- **Short Term:** Ohmic values of each cell comprising the string are compared to the strings average ohmic value. This is useful in identifying weak cells within the bank. The flaw in this approach is if the majority of cells in the bank are in poor quality then the string average will be poor. Baseline data comparison can aide in identifying if the average value is within reason.

- **Mid-Term:** Comparison of ohmic values to baseline values. This method assists in establishing if average values are within reason for the cell type being tested. Comparing the string average to the baseline helps establish the overall health of the string. Baseline values should be established by the end user. Manufacturer's baseline values as well as test equipment manufacturers baseline values have limited value. This is because the odds are they are not using the identical equipment and probe and the measurements are from individual batteries not from strings as well as temperature differences and other influencing factors.
- **Long Term:** Trending of ohmic values and observing the percentage of change from one test period to the next test period is ideal for establishing an approximate rate of aging. This data is useful in forecasting future needs. It will also display trends of battery strings that are aging pre-maturely. This can be an indicator that the wrong type of battery is being used for the application or there may be a maintenance or environmental issue with the batteries.

Baseline Data

Establishing a baseline line value is important in testing battery strings. It is not recommended to acquire baseline values from battery manufactures or battery test equipment manufacturers. This is because battery ohmic measurements are in micro-ohms. Many factors can affect these measurements. For example, the following criteria will affect the reading taken.

1	Cell Type	Different Chemistries and different capacities.
2	Battery Charge	As a battery discharges the plates sulfate.
3	Temperature	The higher the temperature the faster the internal reaction.
4	Make and Model of Instrument	Different instruments take different readings. $Z = 1/(2\pi fc)$ As frequency changes so does the reading.
5	Probe Type	Different probes have different impedances, these affect the reading.
6	String length and configuration	Different configurations can affect test current path flow.
7	Load	Some loads can draw current or add ripple.
8	Charger	Ripple from chargers can affect readings.
9	Measurement Location	Readings in different locations can add or reduce micro-ohms from readings in different locations. (Posts are recommended)

IEEE does recognize this as of the Ohio meeting 2007 and IEEE450 will be modified to reflect this. For this reason baseline data from battery manufacturers as well as instrument manufacturers has limited value. The battery manufacturer as well as the test equipment vendor may not be using the same make and model tester. In addition they may not be using the same type probes. They are measuring individual cells not strings, so there is no load or charger. The temperature of the test locations could be different. All of the above criteria will affect the actual readings recorded.

Proper Method of Ohmic Testing

Ohmic testing is a relative test. This means that the accuracy of a battery ohmic value is a moot point. Different instruments can give different readings just because of the frequency they perform the test at. A relative test compares the present reading to previous readings this means that repeatability is key. In order to maintain good repeatability a certain test methodology must be performed.

1. Battery string needs to be fully charged.
2. The user must use the same make and model instrument
3. The same probe type needs to be use from one test to another.
4. The measurements need to be taken at the same point. (Posts are the preferable location)

Establishing New Baseline Data

In general, in order for a user to establish a baseline they just need to run a test on the battery string. The first set of results can be used as baseline data to be referenced on consecutive tests.

For new battery strings baseline needs to be established after formation has been completed. For VRLA batteries this is typically after about 3 months of use. For flooded batteries it is after their first full charge. Once formation is complete perform an ohmic test. This can be used as baseline data.

To establish new baseline data for existing string perform a discharge test to verify the capacity of the cells. This can be done with a Torkel unit. Then after re-charging the string, test the string with the new instrument to establish a new baseline.

The above applies to ALL ohmic testing, resistive, impedance as well as conductance.

Initial Limits

As a battery ages its chemical properties will change. This will cause a change in the batteries impedance. How the battery chemistry changes will depend on several factors. Some of these factors are shown below.

1. The type of battery
2. The environment which the battery is exposed
3. The maintenance the battery receives.
   a. Electrolyte levels
   b. Strap conditions
   c. Charger settings
   d. Charge status
4. The operating conditions which the battery is exposed.
   a. Load
   b. Cycling
   c. Ripple

Since many conditions will affect the chemistry of the battery it is not possible to give an exact warning and alarm values. These need to be determined by the end user. Below is a table that provides rough initial warning and alarm values for different chemistry batteries.

	Percent Variation from String Average	Percent Variation from String Average	Percent Deviation from Baseline	Percent Deviation from Baseline
	Warning	Alarm	Warning	Alarm
Lead-acid, Flooded	15	30	30	50
Lead-acid, VRLA, AGM	10	30	20	50
Lead-acid, VRLA, Gel	20	30	30	50
NiCD, Flooded	10	20	15	30
NiCD, Sealed	10	20	15	30
Inter-cell Connections (Straps)	15	20		