



INTEGRITY TESTING

The valve regulated lead acid (VRLA) battery has several components (Ref. Figure 1), all of which can deteriorate with storage conditions and normal as well as abusive use conditions. For example, it is common that during normal use, over a period of years, the positive plate lead alloy grid and active material will gradually deteriorate while the gelled or absorbed electrolyte may dry somewhat. This deterioration is greatly accelerated by abuse charging conditions and elevated operating temperatures. Other types of phenomenon which can occur in the battery include degraded intercell connections, conductor corrosion, paste shedding from the positive plates or shorts between the positive and negative plates.



All of these conditions affect the battery's performance capability (its capacity) and in some situations may render the battery not serviceable or even hazardous. There are several convenient, inexpensive tests which can be performed on the VRLA battery to assure its integrity and serviceability. While these tests do not determine or assure the battery's actual capacity, they may indicate a need for replacement or a complete performance capacity test.

Various forms of the integrity tests which can be performed include:

1. Open Circuit Voltage Test
2. On-Charge Current Acceptance Test
3. On-Charge Float Voltage Test
4. Momentary Load Test

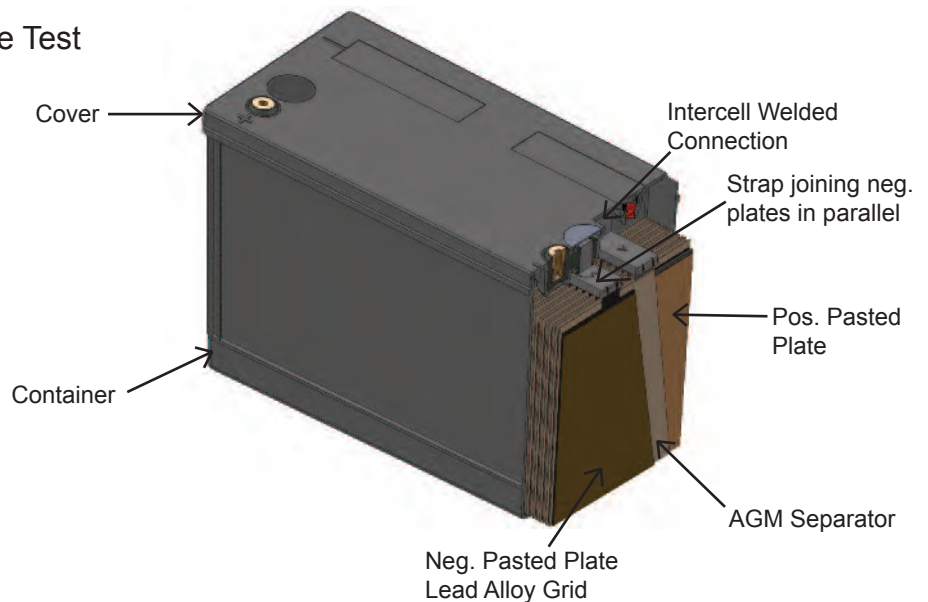


Fig #1 - VRLA Battery Components

OPEN CIRCUIT VOLTAGE TEST

The open circuit voltage of a cell, 24 or more hours after charging, is related to the cell's electrolyte specific gravity which is an indication of the state of charge. The cell OCV is approximately equal to the specific gravity plus the number 0.84. For example, a fully charged cell with a specific gravity of 1.300 would have an OCV of 2.14 VDC (1.300 + 0.84). A different design of cell with a fully charged specific gravity of 1.280 would have an OCV of 2.12 VDC (1.280 + 0.84).

During storage, the VRLA battery will experience a gradual decline in electrolyte specific gravity as sulfuric acid in the electrolyte is consumed and the lead sulfate forms on the plates due to self discharge. As this occurs, the OCV declines proportionally. As a result, the OCV of the open circuit battery gives an indication of its state of charge.

For example, the AGM battery typically has a fully charged electrolyte specific gravity of 1.300 and an OCV of 2.14 V/C (6.42 and 12.84 VDC for 3 and 6 cell batteries respectively). As the battery continues in storage, the open circuit voltage will decline as noted below:

% Charged	AGM Electrolyte S.G.	Cell OCV	3 Cell OCV	6 Cell OCV
100	1.300	2.14	6.42	12.84
80	1.260	2.10	6.30	12.60
75	1.250	2.09	6.27	12.54
50	1.200	2.04	6.12	12.24
25	1.150	1.99	5.97	11.94
0	1.100	1.94	5.82	11.64

The gelled electrolyte VRLA batteries typically have a fully charged electrolyte specific gravity of 1.280 and a resulting OCV of 2.12 V/C (6.36 and 12.72 VDC for 3 and 6 cell batteries respectively). Their OCV would decline as follows during storage:

% Charged	Gelled Electrolyte S.G.	Cell OCV	3 Cell OCV	6 Cell OCV
100	1.280	2.12	6.36	12.72
80	1.240	2.08	6.24	12.48
75	1.230	2.07	6.21	12.42
50	1.180	2.02	6.06	12.12
25	1.130	1.97	5.91	11.82
0	1.080	1.92	5.76	11.52

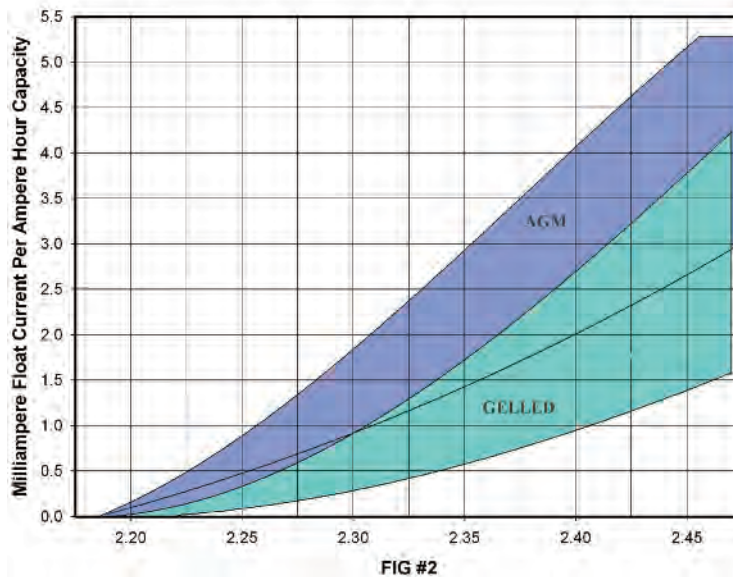
When batteries have been in storage, or otherwise not connected to a charger, they should be given a freshening charge when they have lost 20% of their capacity due to self discharge. This will assure they will be fresh and serviceable when installed. When batteries are allowed to self discharge to a low OCV and are not given a freshening charge, they may eventually experience shorted cells or an otherwise irreversible loss of capacity.

Batteries which have been in service and have an OCV of less than 5.7 or 11.5 VDC for 3 and 6 cell batteries respectively should be assumed to have a shorted cell. New 3 and 6 cell batteries with OCV's of less than 6 and 12 volts respectively should also be considered to have one or more shorted cells. Batteries with these very low OCV's should not be charged or further tested with a load. If the short should open while current is flowing in the battery, a spark could be generated which could ignite the normal gasses in the cells.

ON CHARGE CURRENT ACCEPTANCE TESTS

The value of the current acceptance of a battery at a specified charging voltage, temperature and presumed state of charge can provide critical information related to the condition of the battery. For example, the normal current acceptance of fully charged AGM and gelled electrolyte batteries, with 1.300 and 1.280 specific gravity respectively, is shown in Figure 2 for charging voltages from 2.25 to 2.50 V/C at 25°C.

For example, when a 6 cell AGM battery is fully charged and at an average of 2.30 V/C (13.8 VDC) it should be accepting a “float” current of between 0.75 and 1.75 milliamperes per ampere-hour of rated capacity. That is, one or more batteries rated at 90 ampere-hours connected in a series should normally be accepting between 67 and 158 milliamperes at 25°C.



If the current acceptance is significantly higher than anticipated (3 to 4 times) and it is known the batteries are fully charged, there is a possibility that one or more of the batteries have shorted cells. This may be verified by a low OCV of the shorted battery when removed from the charging circuit. When the battery is one of several in a series connected string, very low charging voltage may appear across the shorted cell as compared to the other batteries in the string. Batteries that are suspected of having a shorted cell should not be further charged or load tested and should be removed from service for safety reasons.

If the current acceptance is significantly less than expected or virtually nonexistent, and the battery has been on charge for more than 48 hours, an open circuit in the battery should be suspected. Again, the suspect battery should not be further charged or load tested and should be removed from service for safety reasons.

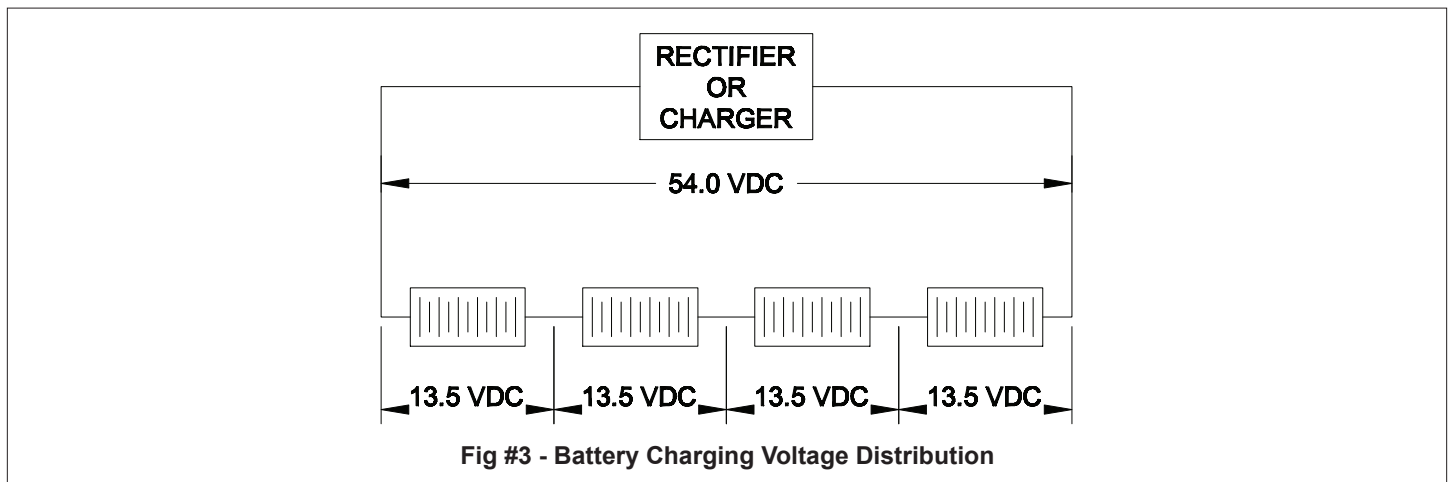
There are two situations in which a battery placed on charge may initially appear to have an internal open circuit:

1. When a VRLA battery has been severely discharged, for example to 0 or to 1 V/C, almost all of the sulfuric acid in the electrolyte will have been consumed and it is not available to provide ionic current carriers to accept a significant charging current. Actually, there is a very small charging current flowing through the battery, perhaps lower than the sensitivity of the monitoring current meter, and following an extended period, a measurable charging current will flow and be accepted by the battery. If the current acceptance does not rise to near normal within 24 hours after initiating the charge, the battery should be removed from service. If the battery does not appear to recover from this abusive condition and accepts a near normal current, it should be closely monitored for possible eventual shorted cells.

2. When a lead acid battery has remained idle for an extended period and has not been charged on a periodic basis to offset the affects of self discharge, the sulfate on the plates will eventually “harden” and cannot be converted to the original active materials. In this instance, the “hardened” sulfate acts as an insulator and the battery will not accept a charging current. In this case, again, the battery should not be placed in service and no further attempts to salvage it should be pursued.

ON CHARGE VOLTAGE TESTS

When cells (or multi-cell batteries) are connected in series and placed across a charging circuit, the charging voltage is distributed across all the cells (or multi-cell batteries) and the same charging current passes through all the cells. The voltage measured across each cell will be a function of its state of charge, impedance and the degree to which the oxygen recombination reaction is occurring within the cell. This is illustrated in Figure 3. However, the voltage across each unit is not an indication of the unit’s capacity.



FLOAT VOLTAGE TESTS

The battery is said to be on float charge when the applied charging voltage is a constant regulated voltage just adequate to produce a current acceptance sufficient to compensate for the self discharge of the cells and recharge the battery within a reasonable period following discharge.

For AGM and gelled electrolyte VRLA batteries with an electrolyte specific gravity of 1.280 to 1.310 the recommended float voltage is from 2.25 to 2.30 volts per cell average. For example, a 48 volt string of 4 series connected 6 cell batteries could be float charged at 54.0 VDC. If all cells had identical characteristics, 2.25 VDC would be measured across each cell and 13.5 VDC across each of the 6 cell batteries.

Naturally, not all the cells and batteries have identical characteristics and the actual voltage measured from cell to cell will vary from the average. The VRLA cell will exhibit greater float voltage variations than the comparable vented (flooded) cell due to the affects of the oxygen recombination reaction; however, extreme variations may indicate a cell defect and the requirement for further investigation or even replacement.

The periodic check of the cell or multi-cell battery individual float voltages is the common and perhaps the most essential of the tests which is performed. A very low voltage may indicate a shorted cell while a very high voltage may indicate an open cell, both of which conditions may eventually lead to irreversible damage to the balance of the other cells and batteries in the series connected string and may be hazardous.

NOTE: Increased cell voltage variation is natural when a battery string is initially put on charge or has been disturbed (by individual battery replacement batteries). The guidelines presented below are for products that have been on charge for three months or more.

LOW VOLTAGE CELLS

Individual cells which measure below 2.16 VDC or 3 and 6 cell batteries which measure below 6.6 and 13.3 VDC respectively should be assumed to be shorted and replaced. The existence of a short can usually be verified with a voltage measurement being taken while the suspect battery is on open circuit for 12 to 24 hours.

If a shorted cell remains in the circuit and a high rate load is applied to the total battery, there is a risk that the internal short could fuse open, creating a spark which could ignite the gasses within the cell. Also, if a shorted cell or battery is not removed and replaced it will cause the float current flowing through the series connected string of cells to increase resulting in their overcharge, gassing, dry out and possible overheating and in thermal runaway.

Since there is a fixed voltage across the string of series connected cells and batteries, if some of the cells and batteries exhibit a somewhat low voltage on charge, others will have to show a somewhat high voltage – the total voltage remains fixed as the charging voltage as noted in Figure 4. When a high voltage is measured across a cell or battery it may simply be that there were other cells or batteries in the string that were shorted as noted in Figure 5. The low voltage cells should first be replaced and all the cell and battery voltages remeasured before condemning the previously high voltage cell.

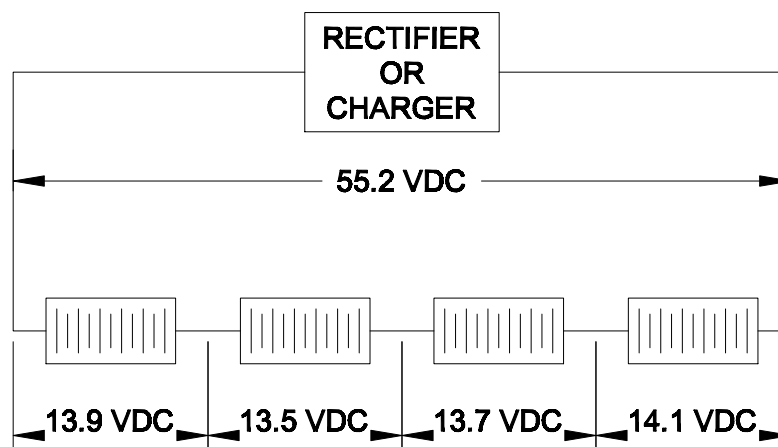


Fig #4 - Battery Charging Voltage Typical Distribution

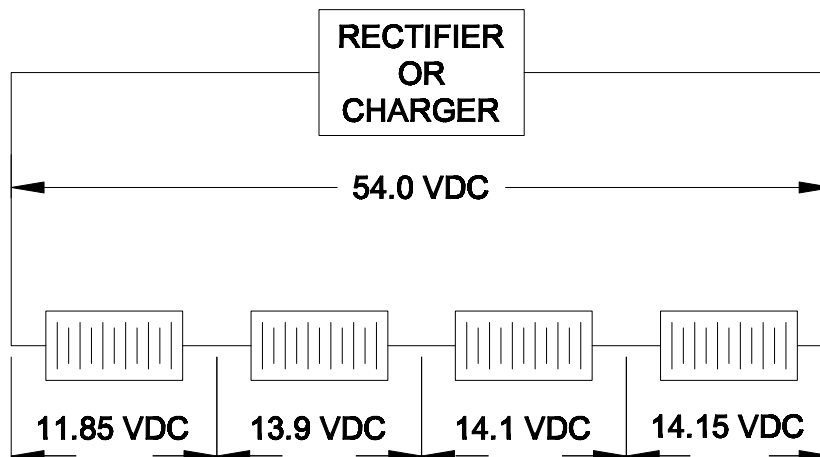


Fig #5 - Charging Voltage Distribution with a Shorted Cell

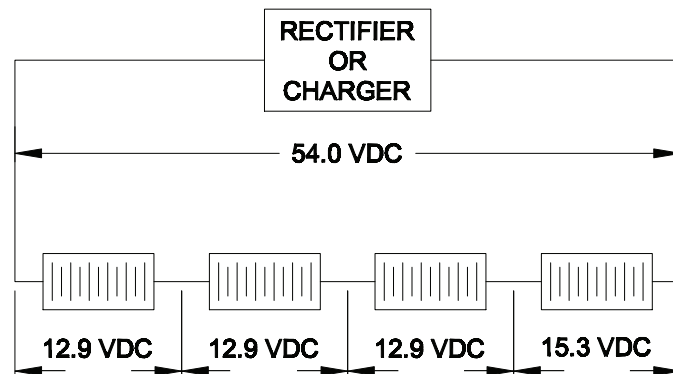
HIGH VOLTAGE CELLS

In an otherwise normal string of batteries being charged at the recommended float voltage, no cell voltage should exceed 2.47 VDC. Three and six cell batteries should not exceed 7.4 and 14.8 VDC respectively. Should these multi-cell battery voltages be exceeded, and the other batteries in the string are measured at near open circuit voltage, an open circuit in the high voltage cell should be suspected.

For example, note Figure 6. The 48 volt battery is being charged at 54 VDC and 3 of the batteries exhibit an on charge voltage of 12.9 while 15.3 VDC is measured across the fourth battery. This would indicate that no float current was flowing through the system and the three low voltage batteries are at their open circuit voltage while the fourth high voltage battery has an internal open circuit. It is also possible that a very high resistance exists in the cell (not a complete open) and a small but inadequate float current exists. In this case the 3 good batteries may exhibit a float voltage slightly higher than open circuit voltage while the defective one would still exhibit a high but lesser float voltage than that shown.

In either case, since inadequate float current is flowing, the three batteries will self discharge. The high voltage battery with the open circuit will prevent the system from providing power but more importantly, should a load be applied to the battery system, and a spark be generated in the “open” battery the gasses in the “open” cell could ignite.

Fig #6 - Charging Voltage Distribution with an Open Cell



MOMENTARY LOAD TEST

The momentary high rate load test assures the conductive path (terminals, plate grids, plate connecting strap, intercell connections and plate active material) are intact and will carry current at least up to the rate at which tested. This test does not replace a true performance capacity test but does give an indication that the battery is functional.

Typically this test is simply the momentary (3 to 10 second) application of a resistive load to the battery, which will result in a high rate discharge current. The terminal voltage of the battery is then measured to determine if it is a normal value. Usually this test current is a minimum of 2.5 times the rated ampere capacity of the battery (e.g. 25 amperes for a 10 ampere hour capacity battery) but may be considerably different for larger capacity VRLA batteries. The momentary high rate load test should only be performed on cells and batteries which exhibit normal open circuit and on charge float voltage. It could be hazardous to perform this test on a cell or battery that is suspected as being shorted or open.

WARNING: It could be hazardous to perform this test on a cell or battery that is suspected as being shorted or open. Sparks generated across shorted or open connections may ignite internal gases.



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