Design, Operation & Safety Overview of VRLA Batteries For Telecommunications Applications

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Abstract

For many years, FIAMM has been manufacturing and distributing Valve Regulated Lead Acid Batteries (VRLA) for a large spectrum of applications. As of today hundreds of thousand of cells and modules have been deployed around the world particularly in telecom installations. The proposed paper summarizes this experience and analyzes three main critical areas: Design, operations and safety. Issues like choice of manufacturing materials, acceptance testing and installation procedures are analyzed and discussed.

The paper reports also the results of some battery testing, with particular reference to ohmic measurements for acceptance and warranty claims.

VRLA Design

AGM Technology

AGM batteries feature a microfiber glass mat separator which is able to retain an amount of liquid electrolyte almost equal to its volume (saturation coefficient $\cong 1$) while allowing the flow of oxygen gas. As a result the electrolyte, which is still liquid, is totally absorbed into the active materials and the separator: there is no free liquid electrolyte. It is worth noting that, in comparison to conventional batteries, the lack of free liquid electrolyte implies a lower volume of electrolyte in the cell. As the electrolyte participates to the charge/discharge reactions and a certain amount of sulfuric acid is necessary to achieve a given capacity, the electrolyte volume limitation of AGM cells is usually compensated by an increase in its concentration.

AGM technology does not mean simply the adoption of a special separator. Other design and construction features must be adopted to enhance the recombination capability and avoid chemical and mechanical side effects. The most important are:

- the use of special grid alloys to limit gassing for parasitic reactions;
- the sealing of the cell from the environment and especially from atmospheric oxygen which can alter the electrochemical balance;
- the use of a pressure-relief valve to limit the internal pressure to an acceptable level;
- special containers designed to withstand the increased internal pressure without appreciable deformations.

As the separator provides the supply of electrolyte during charging and discharging, it must be in close contact with the plates. The plate/separator group must be kept at a specified compression in all the operating conditions. This is the reason why AGM batteries are constructed with flat plates. Tubular plates with a gauntlet as a retainer of the active material are not suitable to this technology as the gauntlet limits the supply of electrolyte.

Gel Technology

Gel batteries do not greatly differ from conventional batteries. Most of them are basically derived from the conventional types with the modification dictated by this technology: special grid alloys, extremely porous separators, one-way valve. The critical issue is the production process of jellifying the electrolyte, which is very important to ensure a uniform distribution of the gel inside the cell. Regarding the plate type, the gel technology is more flexible, in the sense that they can be used with both flat and tubular plates.

Comparison of the Technologies

Gel batteries are normally designed with an electrolyte reserve or excess of electrolyte. This is a major difference with the AGM technology where cells are designed "electrolyte starved" being it just enough to deliver the capacity requirements. In AGM batteries, the migration of the oxygen from the positive to the negative plate is mostly dictated by the porosity of the separator. In GEL batteries the same reaction is conditional to the development of micro-cracks over time during battery operation. From this point of view, the recombination efficiency in AGM batteries is prompt and more "controllable" as the porosity can be managed through either the choice of the separator type and/or the amount of electrolyte (level of starvation).

For VRLA batteries the separator not only provides electrical insulation between the plates while allowing the ions to migrate from one electrode to the other but also fulfills the following important purposes:

- It holds the amount of electrolyte necessary throughout the expected lifetime of the battery;
- It retains the active material that otherwise would gradually shed.
- It provides a mean to enhance the migration of the Oxygen from the positive to the negative plate.

Considering the functions listed, a separator must be highly porous, have mechanical strength and maintain great electrochemical stability in a hostile environment.

Loss of plate group compression was claimed for many VRLA battery failures. This effect occurs when the plate group formed by the positive and negative plates with the separators in between, is not hold together with the appropriate pressure. The principal effect of loss of compression is the formation of gaps between the separator and the plates that increase the internal resistance of the battery and reduce the available capacity. This is why the material used and the design of the case assumes a very important role in the functionality of VRLA batteries. The case must be capable of maintaining plate group compression in a wide range of operating conditions. After comparing the different alternatives, FIAMM decided to use containers made of thick ABS with reinforcing ribs that maintain suitable group compression without the use of any external jacket that would reduce the heat transfer. Besides making the container stronger, the ribs prevent the batteries to be packed too closely allowing air circulation in between the blocs. Not always the proposed material is flame retardant *(what do you mean?)*. If the installation requires flame retardant materials it must specified and verified that they comply with the Standard.

Acceptance Procedures

Very often we find that the numerous Standards that were developed for acceptance testing purposes, are only applied for large battery plant installation, leaving the rest of the smaller installations uncovered. This is unfortunate, as testing should be related to the importance of the application and not to the dimension of the purchase. With the right tools and properly trained people, a simple acceptance procedure can be developed to at least identify the major problems.

1. Verify the material against the packing slip
2. Verify when the battery was last charged. This date with other manufacturing stamps to identify the production lot should be easily identifiable and provided by the battery manufacturer.
3. Perform voltage and ohmic measurements and verify that they comply with the manufacturer suggested value (remember to take into account the battery temperature while doing this). On the next page, table 1 summarizes the FIAMM values for the most commonly used battery blocs (1).
4. The measurements performed at point three will help in developing a base line to compare the behavior of the different blocs during the life of the battery. On the next page, table 2 summarizes ohmic values for FIAMM batteries that when fully charged, have either capacity lower then 80% or are questionable (1).

Table 1 "Suggested Acceptance Values at 25°C"

Battery Type	Resistance Range [μΩ] (2)	Conductance Range [Mhos] (3)
12SLA25	10,000 - 14,000	400 – 600
12SLA30	9,000 – 13,000	450 - 600
12SLA50	6,000 – 8,000	800 – 1,000
12SLA75	4,000 – 5,500	1,000 – 1,500
6SLA100	2,000 – 3,500	1,200 – 1,600
6SLA125	2,500 – 4,500	1,100 – 1,600
6SLA160	2,500 – 4,500	1,500 – 2,000
4SLA150	1,500 – 3,500	1,700 – 2,200
2SLA300	350 - 600	2,400 – 3,000
2SLA1000	200 - 400	3,800 – 5,000

Table 2 "Suggested Values for questionable cells at 25°C"

Battery Type	Resistance (2) higher than [μΩ]	Conductance (3) lower than [Mhos]
12SLA25	21,000	250
12SLA30	19,500	300
12SLA50	12,000	500
12SLA75	8,250	650
6SLA100	5,250	800
6SLA125	6,750	700
6SLA160	6,750	1,000
4SLA150	5,250	1,100
2SLA300	900	1,600
2SLA1000	600	2,500

This simple procedure can dramatically reduce a large number of problems that often occur with VRLA batteries.

1. It avoids that batteries are installed with the wrong hardware.
2. It avoids that batteries that have not been charged for a long time are installed without further investigation.
3. It identifies suspected blocs that have unusual ohmic readings.

Installation Procedures

Every company that is involved with the installation of battery systems, should develop an installation procedure with the main focus being:

1. Safety and the use of proper tools;
2. Setting of the proper torque;
3. Voltage and Temperature compensation settings;
4. Thermal Management;

The use of a torque wrench to tighten the connections is highly recommended as it improves battery reliability and reduces the risk of damaging the terminals. If the intercell connections are not properly installed they may be over-torqued or under-torqued with stress applied on the terminals and possible leakage during the battery life and/or possible overheating during discharge. There are not fixed torque values so the battery manufacturer should recommend the proper torque setting.

A test conducted on a FIAMM battery with 8mm studs and a standard 80mm connection made of lead plated copper, using the Albertcorp Cellcorder is summarized in the following table 3 and graph. The test was conducted using lead-plated nuts and stainless steel Belleville washers. The use of the Belleville washer slightly increases the value of the electrical resistance especially when the torque setting is below 70 inch-lb. On the other side the Belleville washer increases the reliability of the installation as it reduces the risk of loose connections during the battery life. The graph shows also that the use of higher torque values than those suggested by the manufacturer (FIAMM suggests 70 inch-lb.) does not reduce the electrical resistance but just increases the stress on the terminal posts.

The setting of the right float voltage will make the difference between a long lasting battery and one with a very short life. It is not unusual that the charging voltage is set on the base of previous experiences instead than what suggested by the manufacturer of the specific product. Even if similar VRLA batteries from different manufacturer are not the same and often they require different charging voltages.

The same is true for the voltage compensation slope. Table 4 and the attached graph, show the difference between the FIAMM's temperature compensation characteristic and another manufacturer A.

Table 3 "Resistance Vs. Torque Setting"

Torque Setting [inch lb]	Connection Res. w/ Belleville washer [μΩ]	Connection Res. w/o Belleville washer [μΩ]
25	112	54
30	101	61
35	94	63
40	83	53
45	80	53
50	77	52
55	77	55
60	74	54
65	71	51
70	69	52
75	68	51
80	68	51
85	68	52
90	60	51
95	65	55
100	65	51

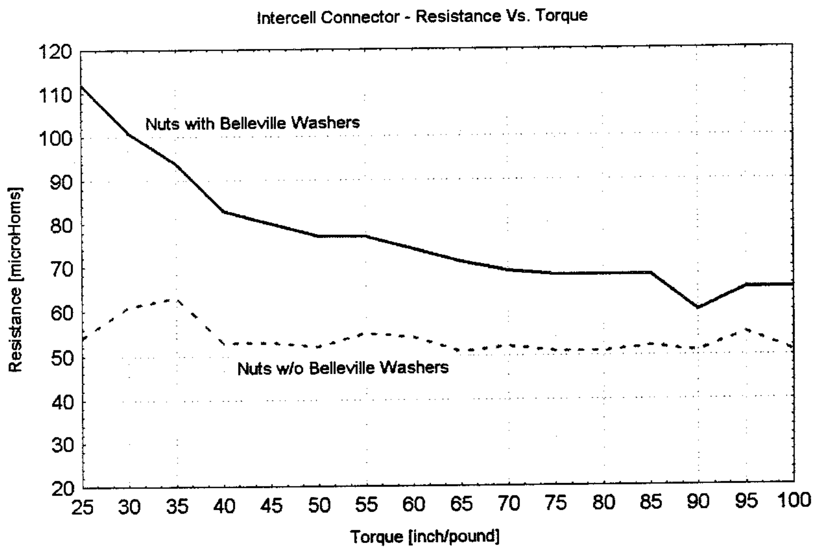
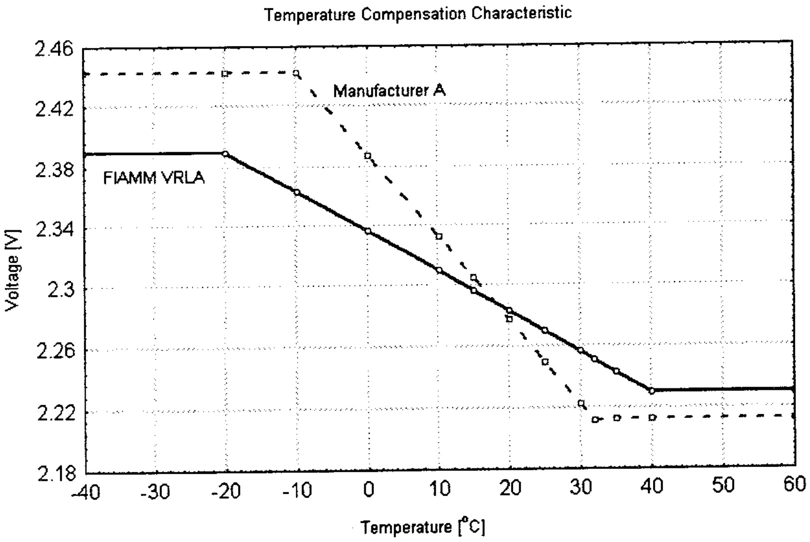


Table 4 "Temperature Compensation Setting"

Temp. [oC]	FIAMM VRLA [V]	Manufacturer A [V]
-20	2.390	2.443
-10	2.363	2.443
0	2.337	2.388
10	2.310	2.333
15	2.297	2.305
20	2.283	2.278
25	2.270	2.250
30	2.257	2.223
32	2.251	2.212
35	2.243	2.212
40	2.230	2.212



It is extremely important that the temperature compensation probe is placed in a significant place so that the measured temperature is the actual temperature of the ambient surrounding the batteries. In most cases if the charger does not allow the use of the temperature compensation characteristic specified by the manufacturer, is better to disable it. Many papers[1,2] and books[3] offer a detailed explanation on the charging process were presented to provide a good understanding of the electrochemical mechanism that rules the charging process and they may be used as a reference. However, when in doubt: stick to the basics and follow the manufacturer specs or call for further explanations.

When the VRLA battery is new it shouldn't be paid to much attention to the float voltage spread among different blocs unless it is unreasonable (spread between the lower module and the higher greater than +/- 0.20 V/Cell). If the blocs have been matched before shipping the spread should be very limited (0.0 - 0.10 V/Cell) and the end user may compare those values with the ones provided by the manufacturer. At any rate if the battery was stored for a long time before recharging (over 2-3 months), it may be possible that the spread can be wider. Unless the manufacturer so suggest it is pointless to use an equalizing charge to try to bring the blocs in line as this increases water consumption without any major benefit.

Safety Issues

One of the merits of the VRLA battery technology is that made possible the installation of Lead-Acid batteries in locations that were unthinkable with the traditional vented technology. Because VRLA batteries are easy to install and handle, users have the tendency to forget that they may become dangerous devices.

On this respect is important that the battery manufacturers take great attention to make these batteries as safe as possible. On the other hand, users should focus on the safety features that are offered with such products.

The use of flame retardant case materials complying with the UL 94V0 standard may certainly improve the safety of the system. The case has also the important function of containing the internal pressure under extreme conditions such as too high temperatures and external short circuit. Under those abuse conditions, very high temperatures may be reached and if the materials sustain the fire, great risk may be imposed to the installation and the people involved. A permanent short circuit test was conducted on a 6V 100Ah battery to record the effects of such an event on a VRLA bloc. The test is summarized on the following table 4 and graph.

We think that the values of current and temperature reached during the test are self-explanatory. Never underestimate the risks that are correlated with a battery.

Other components that should always be present in VRLA batteries are the flame arrestors. The flame arrestor has the function of avoiding the "propagation" of any external source of ignition inside the battery, thus greatly reducing the possibility of battery explosions due to sparks or flames present outside the battery.

Few things need to be in the minds of those who handle VRLA batteries:

- They are capable of very high short circuit currents. A battery with a capacity of 100Ah, may deliver up to 3,000 A (30 x C_8).
- They generate Hydrogen that may explode if reaches a concentration level greater than 4%. Under practical conditions, it is difficult to assure a uniform concentration, this is why normally a 2% threshold based on average concentration is to be considered highly dangerous.
- They contain chemicals that under extreme conditions may spill or generate dangerous gasses.

Acknowledgments

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Notes

(1) Data collected testing an average of 100 modules/type. The testing activity is ongoing and data are subjected to minor changes.

(2) Measures @ 77°F/25°C with Albercor CellCorder – Model CLC 200

(3) Measures @ 77°F/25°C with Midtronics – Micro Celtron

(4) The battery temperature was measured at the negative terminal post

References

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Table 4 "Results of the Short Circuit Test"

Time [s]	Current [A]	Temperature [°C] (4)
0	2580.0	14
5	2116.0	16
15	1750.0	19
30	874.0	30
45	495.0	35
60	322.0	38
120	163.0	44
180	134.0	41
240	124.0	38
300	128.0	37
360	134.0	35
420	144.0	35
480	156.0	36
540	171.0	36
600	188.0	36
660	205.0	36
720	222.0	36
780	237.0	36
840	238.0	36
900	230.0	36
960	212.0	40
1020	193.0	42
1080	173.0	43
1140	154.0	45
1200	132.0	46
1260	109.0	46
1320	89.5	45
1380	74.6	46
1440	64.0	46
1500	58.9	47
1560	55.7	47
1620	54.9	47
1680	55.1	47
1740	55.4	47
1800	55.1	47
1860	52.8	46
1920	52.4	46
1980	50.0	45
2040	50.0	45
2100	52.0	46
2160	51.0	46
2220	53.0	47
2280	53.0	47
2340	53.0	47
2400	52.0	46
2460	52.0	45
2520	54.0	45