QUICKER ASSESSMENT OF LIFETIME OF PV BATTERIES (QUALIBAT)

Ph. Malbranche[1], S. Métais[1], F. Mattera[1], J. L. Martin[1], D. Desmettre[1],
C. Protogeropoulos[2], N. Vela[3], F. Fabero[3].

[1]GENEC, CEA Cadarache, 13108 Saint-Paul-Lez-Durance, FR. Email : philippe.malbranche@cea.fr.
phone : 33 4 42 25 66 02, fax : 33 4 42 25 73 65.
[2]CRES, 19th km Marathonos Av., 190 09 Pikermi, Athens, GR. Phone 301 603 99 00
[3]CIEMAT, PVLabDER, Avda. Complutense, 22. 28040 Madrid, ES. Phone : 34 91 346 6745

ABSTRACT : In the frame of the Qualibat project, damaging mechanisms of batteries belonging to photovoltaic systems have been studied. Irreversible sulphation is the most observed degradation type, some batteries showed shedding and the presence of a corrosion layer. Then, three test procedures corresponding to each type of degradation have been developed and validated. The efficiency criteria has been studied, it seems to be an interesting criteria, beyond the lifetime criteria, to choose a battery.
Keywords : Glasgow Conference - 1: Storage - 2 : Batteries - 3 : Test procedure

1. PURPOSE OF THE WORK

The Qualibat project concerns the development of test procedures of batteries for PV systems. This project involved three European laboratories (GENEC-France, CIEMAT-Spain, CRES-Greece) and two industrial partners (OLDHAM-France and CHLORIDE-England) during thirty months.

The main purpose of this project is to develop appropriate testing methods which reduce the number and the duration of the experimental tests to be performed and consequently to enable the wisest possible selection of the most appropriate batteries for PV applications.

1. APPROACH AND RESULTS

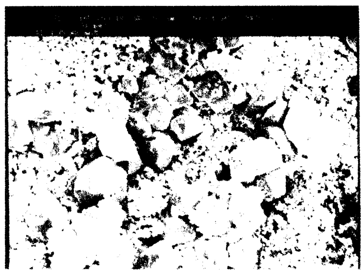
1.1. Photovoltaic batteries degradations

The first task was to study the damaging mechanisms of the batteries. Therefore, seven batteries were accurately characterised by electrical measurements, chemical titration in several location of the active mass, electrolyte analysis and finally S.E.M. observations of the grid and the active mass.

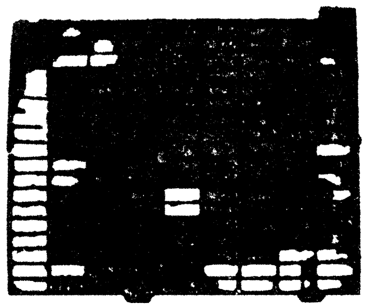
The main observed defect is the irreversible sulphation of active material with higher lead sulphate rates in the positive active material [1]. Moreover, stratification of the electrolyte is developed by the absence of significant gassing and this phenomenon is linked with the presence of irreversible sulphation (Figure 1a).

Loss of connection (shedding) between active material and the grid is observed, characterised by the presence of active material in the bottom of the container (Figure 1b).

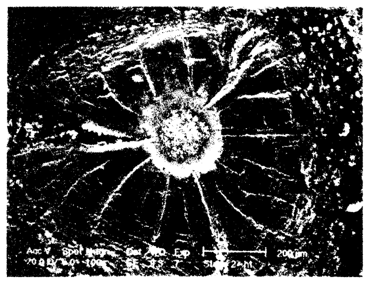
The presence of an insulating barrier of lead oxide in the grid - active mass interface which could hinder the exchanges between the collector and the active mass can be observed (Figure 1c).



(a)



(b)



(c)

Figure 1 : Observation of positive plates.

(a) : S.E.M. photography of positive active material (Lead sulphate crystals).
(b) : Photography of a positive flat plate (Shedding).
(c) : S.E.M. photography of positive plate grid-active mass interface (Loss of connection of active mass).

1.2. Test procedures and results

The development and the validation of the test procedures which allows quicker degradations have been studied.

The work has been focused on four issues : shedding, irreversible sulphation and the recovery from deep discharges, corrosion and efficiency.

① The cycling or shedding test is based on high currents and quick cycles (three per day) (Figure 2).

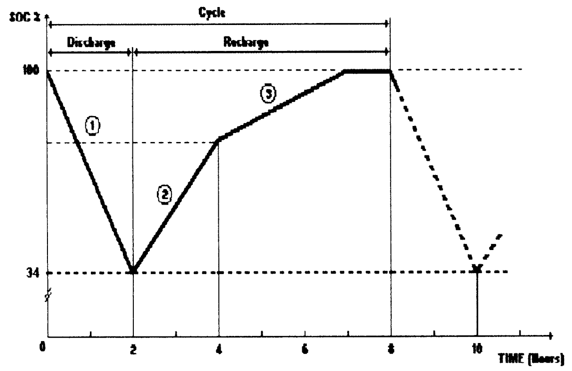


Figure 2 : Shedding test procedure.

For flooded batteries :	For VRLA batteries :
Discharge (1) : 2h at 0.33 C/10	Discharge (1) : 3h at 0.22 C/10
Recharge (2) : 2h at 0.25 C/10	Recharge (2) : 10h at 0.19 C/10 up to U=2.28 V
(3) : 4h at 0.071 C/10	(3) : 3h at 0.01 C/10 up to 2.28 V
Overcharge ratio : 1.2 1.25	Overcharge ratio : 1.05-1.25

A validation on four different batteries show that this procedure is around three times quicker than the usual ones, Figure 3 show the comparison of the results obtained with Qualibat test procedure with the ones obtained with a procedure developed in Genec, called "Moroccan procedure".

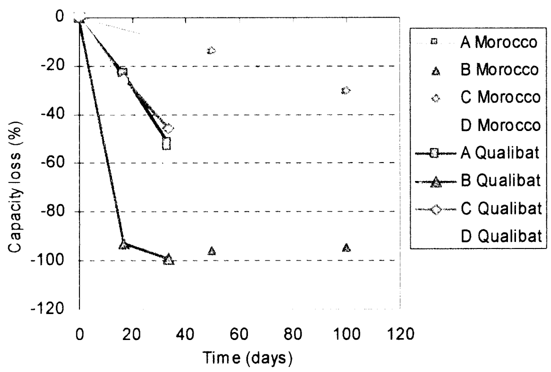


Figure 3 : Capacity loss changes of four identical batteries with Moroccan and Qualibat test procedure.

The use of this procedure on more than fifteen types of batteries results in an easy discrimination of the behaviour of the batteries in few months (Figure 4, Figure 5 and Figure 6).

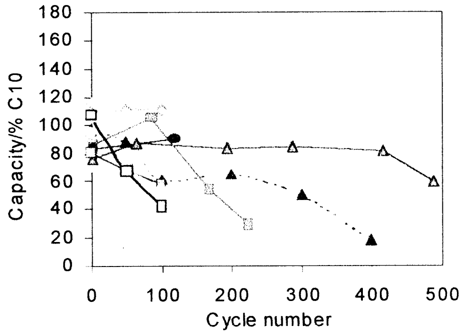


Figure 4 : Capacity value changes recorded during cycling tests performed on flooded flat plates batteries

The flooded flat plate designs show variable performance with most dropping below 70% capacity after 100 cycles (Figure 4).

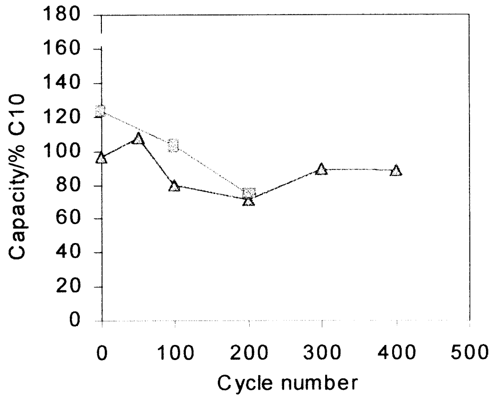


Figure 5 : Capacity value changes recorded during cycling tests performed on flooded tubular plates batteries

The flooded tubular designs are giving stable capacities at up to 400 cycles. One battery shows a gradual reduction in capacity over 200 cycles, this was identified as a short due to a paste lump in one cell.

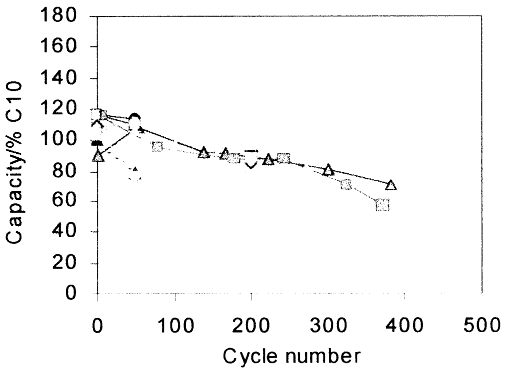


Figure 6 : Capacity changes during cycling tests performed on VRLA batteries.

Some of the valve regulated designs have reached 70% of rated capacity after 350 cycles.

Positive active material shedding and softening of the paste has been observed in the failed batteries, validating the test procedure. Moreover, this test allows a reduction of test duration.

② The irreversible sulphation process was then studied. Influences of temperature, voltage and time duration have been determined, helping in the development of the test procedure. This test procedure is presented Figure 7.

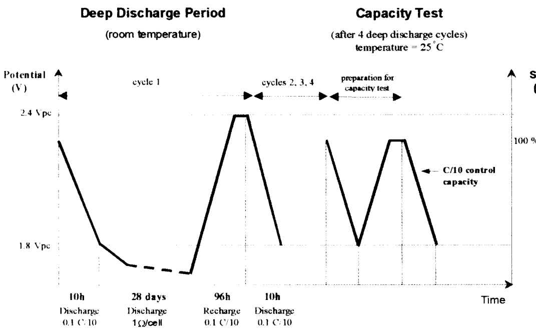


Figure 7 : Deep discharge test procedure.

This test procedure have been applied on three batteries, the results (Figure 8) show the importance of the recharging conditions. Indeed, after the first deep discharge period, two batteries have higher capacity results than their initial value. These observations lead to the fact that the accelerated characteristic in this testing procedure was not satisfactorily achieved. The main reason for not experiencing the sulphation effect on battery performance is the 96 hours recharge. During the charge, lead sulphate was transformed into lead dioxide, because the charged capacity was in some cases more than three times the nominal C/10 capacity value of the battery.

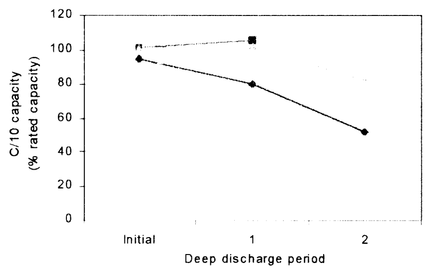


Figure 8 : Comparison of capacity test evolution

The accelerated procedure for assessing the effect of deep discharge on battery performance has been modified into a recovery from deep discharge, with a limited recharge (1.5 C/10) (Figure 9).

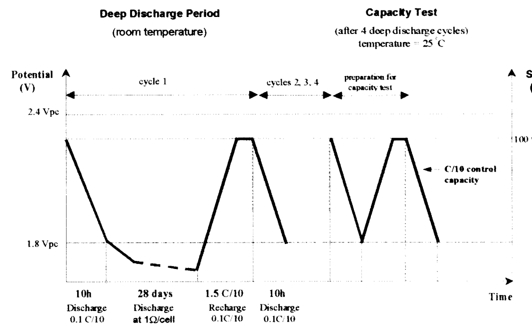


Figure 9 : Recovery from deep discharge procedure

③ The overcharge test is proposed to enhance the corrosion of the grid active mass interface. The batteries are charged at ambient temperature of 25°C. Then, they are maintained at a constant voltage chosen, equal to their corresponding floating voltage during 40 full days at 55°C or 12 full days at 71°C. The capacity is measured at I= 0.1 C/10 until U=1.8 Vpc at an ambient temperature of 25°C. The test procedure is repeated eight times.

After application on twelve batteries, five at 55°C (Figure 10) and seven at 71°C (Figure 11), it seems that this procedure is not yet discriminative enough and has to be strengthened.

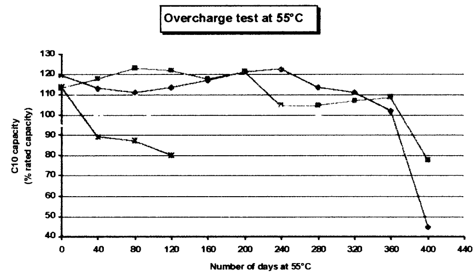


Figure 10 : Capacity (% rated capacity) recorded during overcharge test at 55 °C.

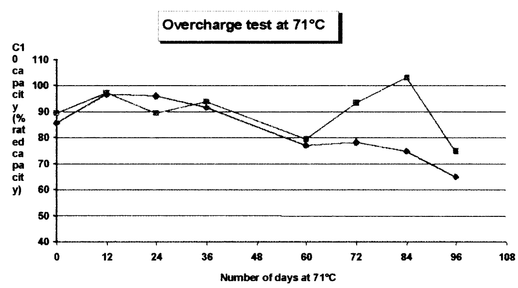


Figure 11 : Capacity (% rated capacity) recorded during overcharge test at 71 °C

④ The efficiency test (Figure 12) gives an additional information on the behaviour of the battery under specific PV conditions, namely cycling in low state of charge. Batteries are cycled 5 times between 0 % and 50 % of SOC. Two types of efficiency are then calculated, the faradic efficiency (Ah efficiency) and the energetic efficiency (Wh efficiency).

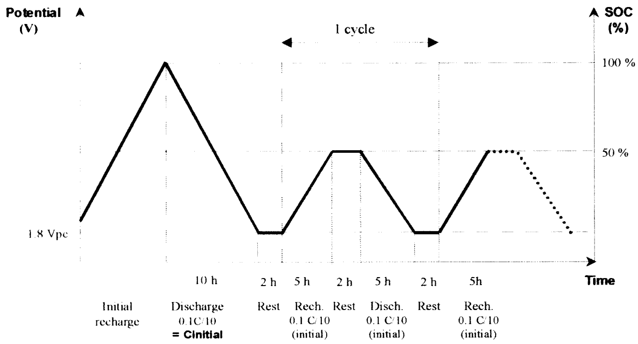
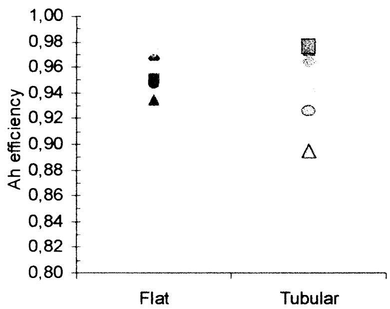
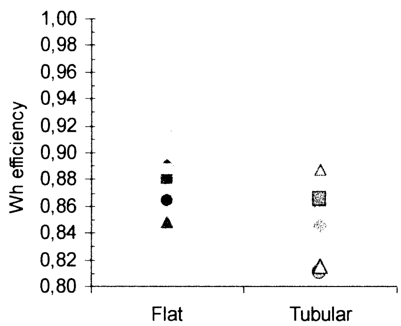


Figure 12 : Efficiency test procedure

Fiveteen batteries of different types were compared with this test procedure. An average value (between the 4th and the 5th cycle) has been calculated for each battery (Figure 13a and Figure 13b).



(a)



(b)

Figure 13 : Efficiency average values (between the 4th and 5th cycle) of flooded flat and tubular plates batteries
(a) : Faradic efficiency ; (b) : Energy efficiency.

Tubular plates batteries show higher Ah efficiency values dispersion (9 %) than flat plate batteries (5 %). The energy efficiency value dispersion is nearly equivalent around 8 % for both types of batteries.

Flat plates batteries and tubular plates batteries have similar faradic efficiency values. Energy efficiency values are higher for flat plates batteries (around 0.88) than for tubular plates batteries (around 0.85).

CONCLUSION

Results of this study will permit us to propose new test methods to choose the best suited battery for PV application with shorter time and less expensive test procedures than the existing ones.

The test procedure designed for quick cycling is above our expectations : three times quicker than the quickest one we have used so far. And the comparison made with another cycling procedure test validated the results obtained.

A result which was not expected is the one obtained with the deep discharge test procedure : six months at almost 0 V is not very damaging to some batteries, provided that the recharge is not limited, in order to recover from all the irreversible sulfation obtained. Therefore, this test is re-oriented from "resistance to deep discharge" to "recovery from deep discharge, with a limited recharge".

Regarding the further investigations carried out in order to obtain additional criteria to facilitate the battery selection process, the efficiency test seems to be interesting. A repeatable test procedure was developed, which makes interesting results achievable in four cycles (in less than two days) for most of the batteries. Discrepancies of more than 10 % are visible between different types of battery.

REFERENCE

[1] F. MATTERA, Ph. MALBRANCHE, D. DESMETTRE, J.L. MARTIN, "2nd World Conference and Exhibition on Photovoltaic Solar Energy Conversion", Wien (Austria) July 1998.