



## Service Life Factors for VRLA Batteries

### INTRODUCTION

This technical paper from Constant Power Services provides information on battery service life and an understanding as to the differences between design and service life.

When discussing batteries with our customers, we find that car tyres are a good analogy; there are different types of tyres with different costs, suited to different applications. The tyre has a design life and a maximum number of miles that are expected of it. How the tyre is used affects its lifespan and occasionally you hit a nail and the tyre needs replacing prematurely.

### OVERVIEW

The design life of a battery is generally stated by the manufacturer as 5 or 10 years, but other durations also exist. The design life of a UPS battery is typically 5 years for small UPS devices of less than 10kVA, and 10 years for larger UPS. This is not always the case and some UPS manufacturers offer 5 year batteries as a cost saving option throughout the UPS size range. The design life does not mean that the battery will operate irrelevant of conditions; in fact there are a number of caveats that mean the battery is unlikely to reach this age, and certainly will not have the performance of a new battery.

## PERFORMANCE

If we consider first the performance of the battery with no premature failures, at optimum temperature for life (20°C), being float charged within the acceptable voltage limits (2.27Vpc) with a low AC ripple voltage (charger & load <1%), recharged fully soon after a discharge, battery cells not to be discharged below their minimum cut-off voltage, and within the battery manufacturer's recommended maximum amount of battery events, the battery will be at 80% of its performance at 10 years. This means that a battery of 100Ah day one would be 80Ah at 10 years. See graph below:

TYPICAL NOMINAL PERFORMANCE VERSUS NOMINAL LIFE - VRLA AGM BLOCK

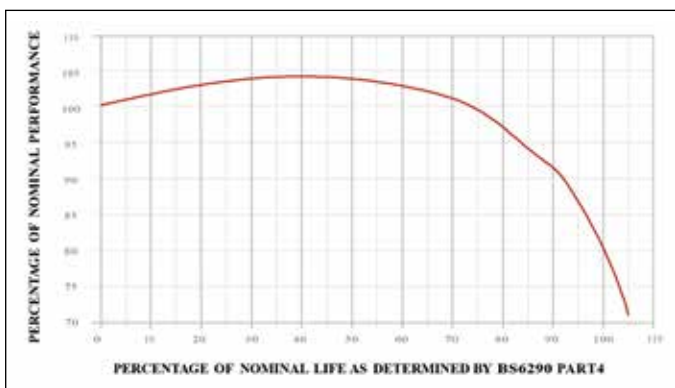


Figure 1: Source - FIAMM technical documentation.

If we consider the autonomy time given by a 100Ah battery against an 80Ah battery, the natural assumption would be that if a 100Ah battery gives 10 minutes then an 80Ah battery would give 8 minutes. In fact this is not correct as the 80Ah battery would give 7 minutes because the relationship between battery capacity and autonomy is not linear. In any case, the performance of a battery kept in optimal conditions would drop below 100% at 7.5 years.

In some cases customers will specify 'end of life' autonomy. In this case the battery provided in the example above would be 125Ah and at end of life the battery would therefore be effectively a 100Ah battery and give 10 minutes autonomy to suit. This, however, is expensive and depending on the service life, it may not give a significant benefit.

We could, therefore, say that from a customer perspective a battery with a 10 year design life that is kept in optimal conditions should be considered for replacement at or after 7.5 years. It is highly unlikely, however, that the battery will achieve a full life of 7.5 years plus due to service conditions.

## TEMPERATURE FACTORS

battery is stated at 20°C and battery manufacturers state the expected performance of the battery at 20°C and 25°C. The performance figures are higher with an increase in temperature, however the lifetime is reduced. The performance is reduced when the temperature is below 20°C.

The ambient temperature at which the battery is kept has a dramatic impact on the operational life. A battery manufacturer will state a particular operating range for their product but this does not mean that the life expectancy will not be affected. It is simply that the battery will operate within these conditions for a time, assuming other conditions such as charging voltage do not damage the battery.

The life of a battery at 25°C is 71%, at 30°C it is 50% and at 40°C the life is only 25%. This means that if the battery is kept at 40°C the effective 'design life' would be 2.5 years and performance would drop below 100% before 2 years. This reduction of life with temperature is shown in the graph below:

EXPECTED SERVICE LIFE VERSUS TEMPERATURE

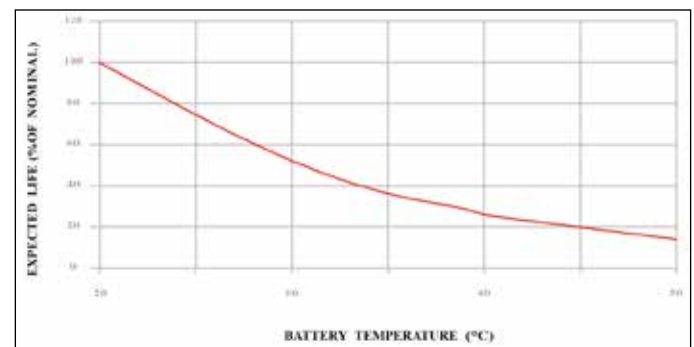


Figure 2: Source - FIAMM technical documentation.

It is therefore possible to plot the performance and life of the battery if the temperature is kept constant:

Temperature (°C)	Multiplier	Temperature (°C)	Multiplier
20	1	30	2.00
21	1.08	31	2.13
22	1.15	32	2.27
23	1.22	33	2.44
24	1.32	34	2.63
25	1.41	35	2.86
26	1.52	36	3.03
27	1.61	37	3.23
28	1.75	38	3.45
29	1.89	39	3.70
		40	4.00

Table 1: Battery aging factor multiplier for temperature.

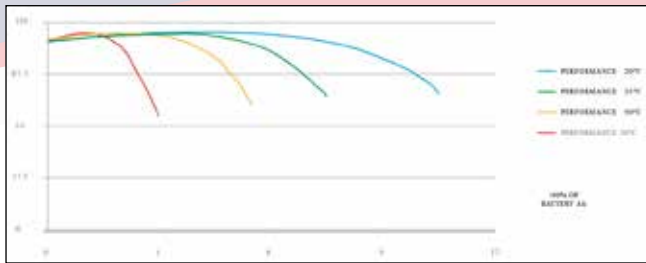


Figure 3: Graph plotted from temperature multiplier table showing battery performance at constant temperatures.

The actual calculation can be expanded so much that it is possible to calculate the life of a battery that is at different temperatures through its lifecycle.

Therefore, if a battery is kept at 25°C for 100 days and 30°C for 100 days, the effective aging is 341 days.

If the battery is in an unregulated temperature environment it is important that it is not under or overcharged. If the temperature of the battery is not permanently maintained at 20°C the floating voltage of the battery should be altered to compensate (see Figure 4 below). This can be problematic on commissioning where the room or cooling system is not complete. If the UPS is not at load (a common occurrence at commissioning) or the room temperature has not stabilised then a true ambient temperature will not yet have been achieved. In a similar way, during service visits the room temperature is only a snapshot based on the conditions of that day.

If the UPS is in the same room as the battery then this can heat the ambient temperature, particularly at higher load levels. Some sites such as data centres operate a continuous load level, others like manufacturing sites or hospitals, have a wider load variation. If service visits are carried out during audit days or when equipment is at low demand then temperature and battery issues may not be identified on that specific day.

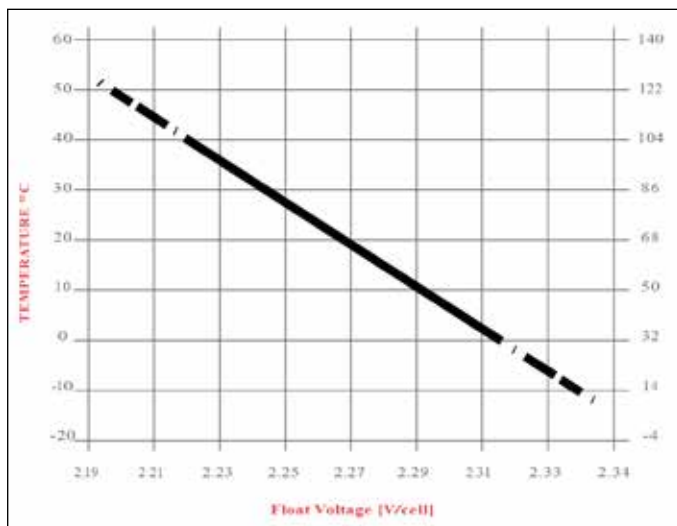


Figure 4: Recommended cell charging voltage against temperature.

## TEMPERATURE COMPENSATION

In some larger UPS systems it is possible to add a temperature compensated charger. This consists of a temperature probe being fitted within the battery enclosure this then feeds back a signal to adjust the battery charger voltage. It should be noted that the only effect of this is to reduce the chance of under or overcharging batteries. This does not increase battery service life when operating at higher temperatures.

An increase or variable temperature without charger compensation can lead to a dramatically shortened service life through 'undercharging' or 'overcharging'.

Constant Power Services recommends temperature compensation wherever possible. Even when a battery room is temperature controlled, the control system may fail or be switched off. However, this is an additional cost and it is not always possible to retro-fit.

## OVERCHARGING

Overcharging can be caused by charging the battery at an excessively high current or voltage. This can result in excess gassing, high temperatures and corrosion of the positive plates. Overcharging can also occur due to cells within the battery failing short-circuit. This effectively raises the charge voltages on the remaining cells slightly. If multiple cells fail short-circuit then this may be significant enough to cause a cascading failure where all of the batteries are damaged. This generally only occurs either at the end of service life or where multiple issues are present.

## UNDERCHARGING

Undercharging can occur if the battery is not connected to the UPS for an extended period or if a battery cell fails open circuit and this goes undetected and results in sulphation of the remaining cells. This occurs when sulphate crystals form on the negative plates which reduces the charging rate, battery capacity and life.

## BATTERY CHARGERS & AC RIPPLE VOLTAGE

Battery manufacturers recommend that the battery is float charged at all times when not being discharged. The type of battery charger can vary and with it other factors such as AC ripple.

AC ripple is an oscillating voltage on top of the DC charger voltage normally associated with rectified mains voltage. AC ripple on the battery causes increased water loss, raised temperature and increases corrosion – all of which are factors that can reduce battery life. The AC ripple, and resultant damage, is primarily caused by the battery charger but also by the load during discharge. A single phase output UPS will generally have a reduced battery life compared to a balanced three phase output UPS. Similarly, there can be a reduction in battery life

if a three phase UPS load is not balanced or if the load has a high crest factor (high peak current drawn) such as switch-mode power supplies.

Generally, there are two types of battery charger designs: the first is part of the UPS rectifier and the second is a dedicated circuit that charges the battery.

In older UPS technology, a thyristor based rectifier is used to charge the battery and feed the inverter, which in turn supplies the load. The output of this type of rectifier is directly at the battery charging voltage or a reduced voltage in order to limit the charging current into the battery. This can be set in order to supply a battery much larger than typically expected to be connected to the size of UPS, if the maximum load of the inverter is reduced to suit. The drawback of this type of rectifier with regards to battery charging is that the DC output contains an AC ripple caused by the rectification process.

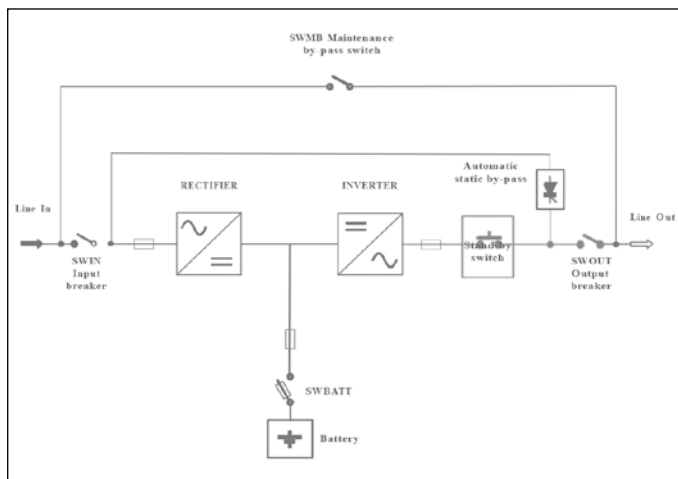


Figure 5: Diagram of UPS with combined rectifier and battery charger.

A separate battery charger will have a smaller charging capability. If a long runtime is required then a larger/ additional charger may be needed in order to prevent sulphation. It is likely that this type of charger has a lower AC ripple voltage.

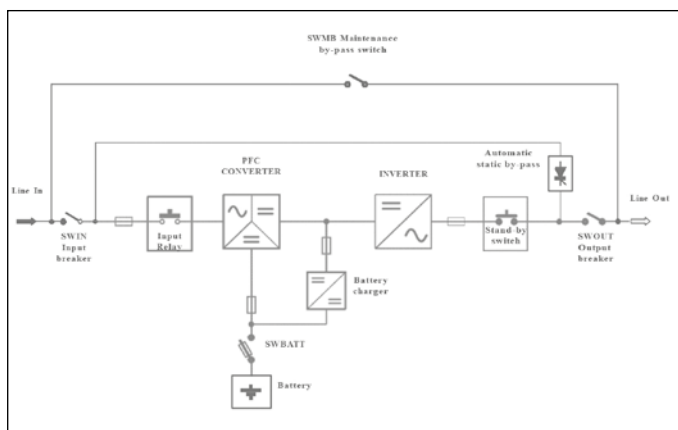


Figure 6: Diagram of UPS with separate battery charger.

## CYCLIC CHARGING

In some UPS there is the possibility to cyclically charge the battery. The battery is charged/ re-charged normally and when it reaches a fully charged state, the charger switches off and automatically disconnects the battery. The voltage is monitored and when it drops below a pre-set limit the battery is recharged. When a charger has high ripple voltage this reduces the damage caused by charging. It also means the system is more efficient and with thyristor based rectifiers, the DC voltage can increase, reducing input currents by increasing the rectifier power factor.

Battery manufacturers do not recommend cyclic charging of batteries due to the risk of sulphation and any benefit of reduced AC ripple should be evaluated against this.

## FLOAT CHARGING

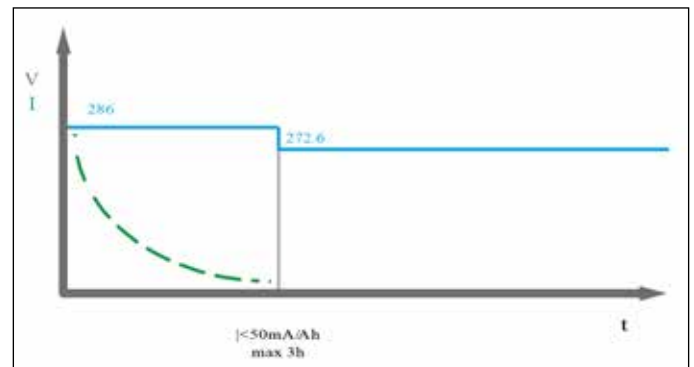


Figure 7: Two level charging voltage plot.

## CYCLIC CHARGING

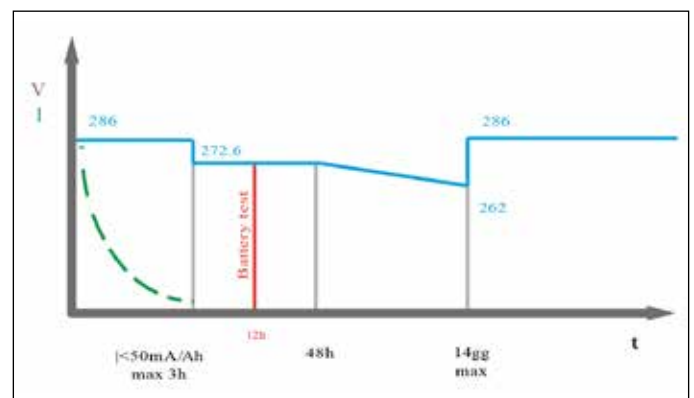


Figure 8: Cyclic charging voltage plot.

## BATTERY CUT-OFF VOLTAGE

In order not to permanently damage a battery through discharge there is a minimum cut-off voltage which the battery should not be discharged beyond. This voltage is typically never below 1.6Vpc, the voltage should be higher for longer duration discharges. If a battery



is discharged too low then it is possible that it will be damaged permanently and not be able to take or hold a charge.

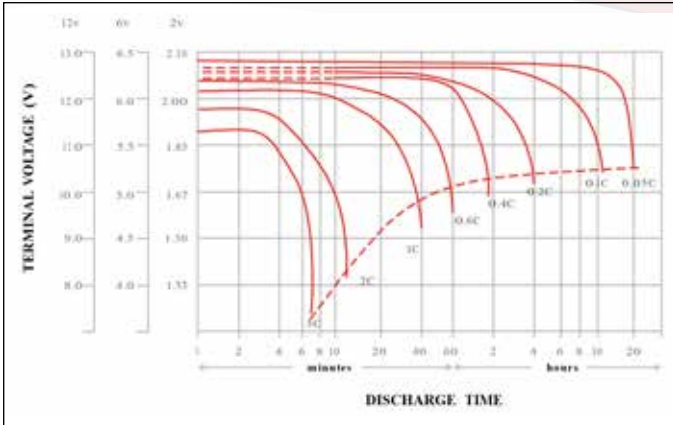


Figure 9: Battery voltage discharge curve at varying discharge rates.

## LOCATION / ENCLOSURE

Batteries, and indeed UPS, are often not considered within the space planning of a project. The result is that often they are located into wholly unsuitable locations such as plant rooms, switch rooms, electrical cupboards and roof spaces.

If batteries are not located in a dedicated room then it is likely that some form of cladding will be required. Cladding of battery enclosures will inhibit cooling of the battery but may well be a safety requirement of the area. It is important to ensure adequate cooling / airflow through the battery enclosure. It is common for UPS to be positioned in comms rooms with under-floor cooling, forced cooled air should therefore be pushed directly into the bottom of the battery enclosure to promote airflow through the cabinet. It is important not to restrict service access and reduce enclosure sizes as such action may also reduce cabinet airflow and result in reduced life.

## PRE/POST COMMISSIONING

Where a UPS install is part of a large project, it may be that the delivery of the battery has to happen months prior to commissioning or that the commissioning date gets delayed. The result in both cases is that batteries are left on site for many months, during which time they self-discharge and a recharge is required in order not to prevent damage. This recharge is dependent upon ambient temperature and measured open-circuit values. Typically a battery kept at 20°C should be recharged every 6 months for 48 hours. Specific charging regimes are given by the battery manufacturer.

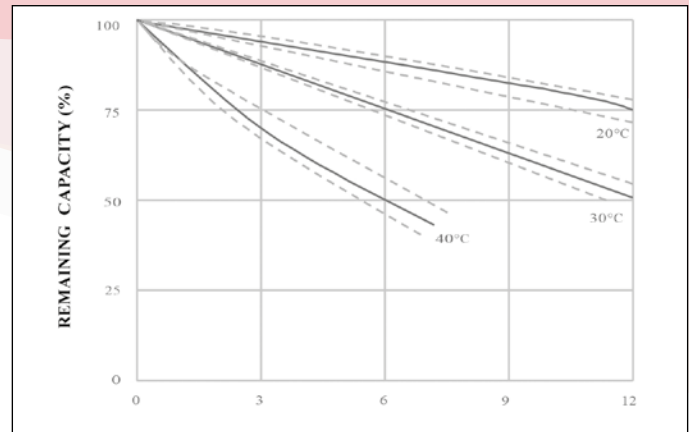


Figure 10: Battery self discharge at varying temperatures.

Following commissioning, the battery must be given appropriate time to recharge fully, particularly if a load test is required. We generally recommend one week between commissioning and load test. This is partly due to the charge state of the battery prior to commissioning and partly due to tests done during the commissioning visit.

If there is a long period between commissioning and project handover/completion, the UPS must remain switched on while the battery is charging. It is also important that the supply is relatively stable and ideally not on a temporary generator. During building commissioning it is common for isolation of supply to occur many times during testing. It is also important that cooling is not switched off in error or intentionally in order to save costs (assuming that it has already been fitted and commissioned). The primary cause of premature battery failures is overcharge resulting from high ambient temperatures and no maintenance visit to detect initial cell failures.

## CUSTOMER & SERVICE CHECKS

It is important for customers to run daily checks on the UPS and battery room. Constant Power Services advises customers to monitor temperatures and check for alarms. Any smells of sulphur (rotten eggs) or increase in temperature will indicate a battery failure and it may be recommended that the battery is promptly isolated to prevent further issues.

Normally a UPS will have a form of battery test that will detect open cells or if the battery voltage is low during a test, that will indicate low cells. Whether a battery test is able to detect faulty cells will be related to the load connected during discharge and the size of the battery. A preventative maintenance visit is more likely to detect faulty cells but it is only a snapshot in time – similar to a car MOT – and offers no fixed guarantee that the battery or UPS will perform correctly in the future.

Recommendations are normally given based on

issues at that point in time or history and experience of similar sites and products. There are two types of recommendation.

Recommendation based on actual information, for example:

- Some battery blocks have been found low during discharge and require replacement.
- The battery has been damaged and has been isolated for safety.
- There is no battery back-up and the condition of the battery blocks means they must be replaced.
- The battery room temperature is too high and this will affect the battery life.
- There is corrosion on the battery terminals / links or indication of venting of gas / electrolytes.

Recommendation based on similar site conditions, for example:

- No controlled cooling, this may lead to battery problems in the future should the temperature increase.
- The battery is at an age where we suggest that budget should be set aside for a battery replacement in the near future.
- There are signs of aging on the battery that indicate it may require replacing in the near future.
- Recommendations based on the amount of previously replaced battery blocks.

Due to the high cost of battery replacements, Constant

Power Services tries in all cases try to give advanced indication of the costs involved. We also see an increase of battery failures from 5 years and therefore we will typically quote for the replacement of a 10 year battery at 5 years taking into account budgets and the varying importance of this cost versus the cost of a potential power loss to the load due to battery failure.

Based on our experience, Constant Power Services can give general advice as to typical battery service life. It must be noted that due to the critical nature of UPS loads this is far more conservative than that given by battery manufacturers. One factor at play here is that due to the high battery voltage and high power there are normally no or few redundant battery strings. This lack of redundancy means that the open-circuit failure of any one cell could immediately shutdown the UPS system upon mains failure. As the frequency of individual battery cell failures increases with age, this risk goes up through the battery's life.

Typically, if a UPS battery is kept in a temperature controlled environment for its life we would expect the battery to require replacement at 6-8 years for a 10 year design life block. If a UPS battery is kept in an uncontrolled environment, we would expect the battery to require replacement at 3-6 years with temperature compensation and dramatically less without it.