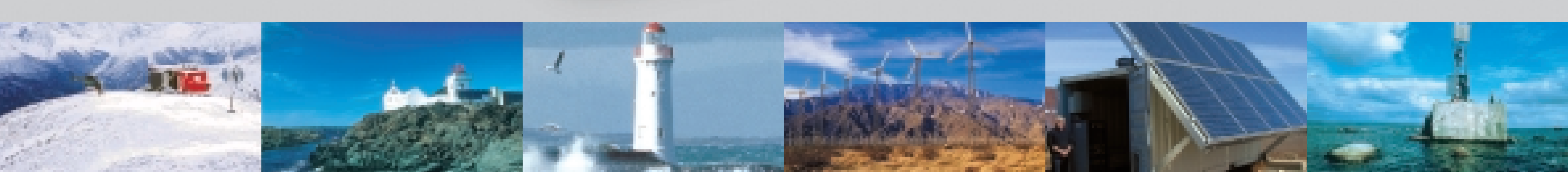
Sunica.plus
Technical manual



May 2007

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1. Introduction

The nickel-cadmium battery is the most reliable battery system available in the market today. Its unique features enable it to be used in applications and environments untenable for other widely available battery systems.

It is not surprising, therefore, that with the emergence of the photovoltaic (PV) market and its rigorous requirements, the nickel-cadmium battery has become an obvious first choice for users looking for a reliable, low maintenance, system.

This manual describes the introduction of an upgraded photovoltaic battery product with major improvements including:

- up to 4 years without topping-up at +20°C (+68°F)
- extended cycling at high temperature throughout seasonal variations of high and low temperature and state of charge.

Sunica.plus is built upon solid Saft expertise with more than 20 years field experience with Sunica, one of the most reliable batteries under the sun, and ultra-low maintenance Ultima batteries used in industrial stand-by applications.

This publication details the design and operating characteristics of the Saft Sunica.plus battery to enable a successful photovoltaic system to be achieved. A battery which, while retaining all the advantages arising from nearly 100 years of development of the pocket plate technology, can be so worry free that the only maintenance requirement is occasional topping-up with water.

2. The photovoltaic application

The typical requirements for photovoltaic (PV) applications are ruggedness, environmental flexibility, unattended operation, ease of installation, and reliability.

Photovoltaic applications can cover many applications including:

Navigational Aids: offshore, remote lighthouses, beacons

Telecommunications: emergency telephone posts, radio repeater stations, base stations

Rail Transport: crossing guards lighting, signalling, isolated telephone stations

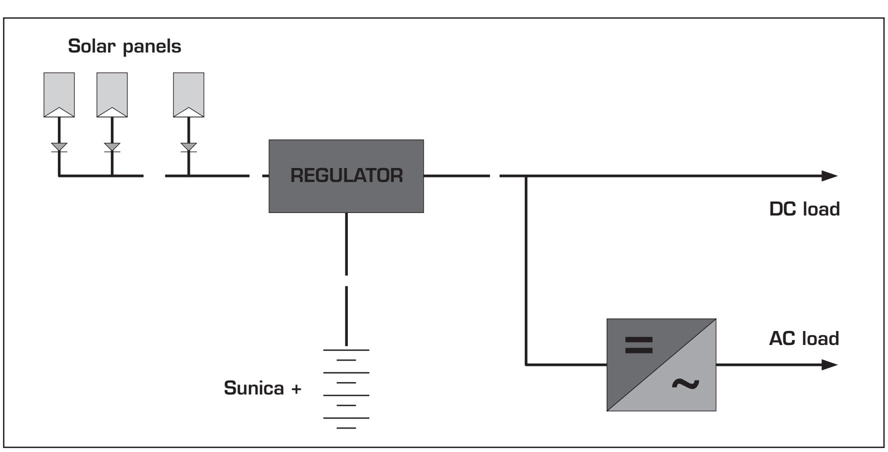
Oil and Gas: cathodic protection for pipelines, emergency lighting on offshore platforms

Utilities: electrification in remote areas

A photovoltaic system is made up of three distinct parts:

- The photovoltaic array which is built to give up to 20 years of service life
- Electronic components such as blocking diodes and logic circuits in power conditioners and as controllers or voltage regulators
- The battery must assure the autonomy required by the installation. Systems are often installed in remote areas, at sites accessible only by foot, helicopter or boat, in good weather conditions and with only limited skilled labour available.

Thus, the ideal photovoltaic power system is a reliable installation which requires only infrequent maintenance calls and, clearly, the battery plays a crucial part in this requirement as premature failure of the battery results in a total failure of the system.



The most important characteristics required in a battery for photovoltaic applications are:

- ability to withstand cycling, daily and seasonal
- ability to withstand high and low environmental temperatures
- ability to operate reliably, unattended and with minimal maintenance
- ruggedness for transportation to remote sites
- easily installed with limited handling equipment and unskilled labour
- reliability and availability during the 20 years service life of the photovoltaic modules
- resistance to withstand failure of electronic control systems
- no need for refreshing charges
- high charge efficiency during periods of low insolation (typically cold winter seasons)

3. Construction features of the Sunica.plus battery

Protective cover
Prevents external short-circuits.

Flame arresting vent
With transport seal protection.

Handles
Moulded polypropylene handles allow Sunica.plus batteries to be easily manoeuvred and installed.

Plate group bus
Connects the plate tabs with the terminal post. Plate tabs and terminal posts are projection welded to the plate group bus.

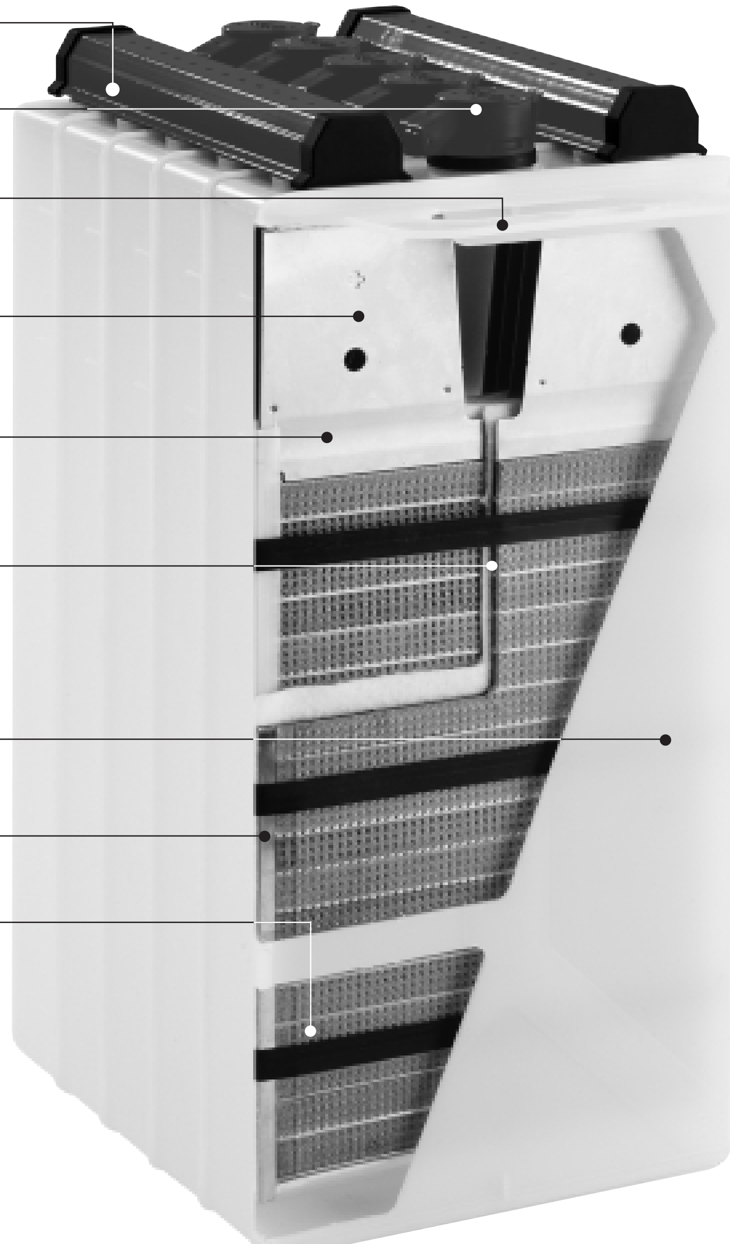
Plate tab
Spot welded to the plate side frames, to the upper edge of the pocket plate and to the plate group bus.

Separators
These separate the plates and insulate the plate frames from each other. This special type of separator improves the internal recombination.

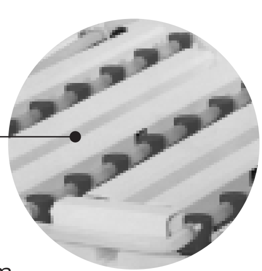
Cell container
Made of tough polypropylene.

Plate frame
Seals the plate pockets and serves as a current collector.

Plate
Horizontal pockets of double-perforated steel strips.



Automated integral water filling system



Saft’s automated integral water filling system is available as an option for Sunica.plus cell types from 185 Ah to 1110 Ah.

The construction of the Saft Sunica.plus cell is based upon the proven Saft pocket plate technology but with special features to enhance its use in the specialised photovoltaic application.

3.1. Plate assembly

The nickel-cadmium cell consists of two groups of plates, one containing nickel hydroxide (the positive plate) and the other containing cadmium hydroxide (the negative plate).

The active materials of the Saft Sunica.plus pocket plate have been specially developed and formulated to improve its cycling ability, a specific need for photovoltaic applications. These active materials are retained in pockets formed from nickel plated steel which is double perforated by a patented process. The pockets are mechanically linked together, cut to the size corresponding to the plate length and compressed to the final plate dimension. This process leads to a component which is not only mechanically very strong but also retains its active material within a steel boundary which promotes conductivity and minimises electrode swelling.

These plates are then welded to a current carrying bus bar assembly which further ensures the mechanical and electrical stability of the product.

Nickel-cadmium batteries have an exceptionally good cycle life because their plates are not gradually weakened by repeated cycling as the structural component of the plate is steel. The active material of the plate is not structural, only electrical. The alkaline electrolyte does not react with steel, which means that the supporting structure of the Sunica.plus battery stays intact and unchanged for the life of the battery. There is no corrosion and no risk of “sudden death”.

In contrast, the lead plate of a lead acid battery is both the structure and the active material and this leads to shedding of the positive plate material and eventual structural collapse.

3.2. Separation

The separator is a key feature of the Sunica.plus battery. It is a polypropylene fibrous material which has been used and proven by Saft in the Ultima ultra-low maintenance product over more than 20 years and has been further developed for this product to give the features required. Using this separator, the distance between the plates is carefully controlled to give the necessary gas retention to provide the level of recombination required.
By providing a large spacing between the positive and negative plates and a generous quantity of electrolyte between plates, the possibility of thermal runaway, a problem with VRLA cells, is eliminated.

3.3. Electrolyte

The electrolyte used in Sunica.plus, which is a solution of potassium hydroxide and lithium hydroxide, is optimised to give the best combination of performance, life, cycling ability, energy efficiency and wide operational temperature range. The concentration is such as to allow the cell to be operated to temperature extremes as low as – 20°C (– 4°F) and as high as +50°C (+122°F). This allows the very high temperature fluctuations found in certain remote regions to be accommodated. For continuous temperatures below – 20°C (– 4°F) a special high density electrolyte can be used.
It is an important consideration of Sunica.plus, and indeed all nickel-cadmium batteries, that the electrolyte does not change during charge and discharge. It retains its ability to transfer ions between the cell plates irrespective of the charge level. In most applications the electrolyte will retain its effectiveness for the life of the battery and will never need replacing.

3.4. Terminal pillars

Short terminal pillars are welded to the plate bus bars using the well established block battery construction. These posts are manufactured from steel bar, internally threaded for bolting on connectors and are nickel plated. The terminal pillar to cover seal is provided by a compressed visco-elastic sealing surface held in place by compression lock washers. This assembly is designed to provide satisfactory sealing throughout the life of the product.

3.5. Venting system

Sunica.plus is fitted with a flame arresting flip-top vent to simplify topping-up and is supplied with a transportation plug to ensure safe transportation. There is also an option of a water filling system which has been proven by Saft in railway applications over many years. This gives semi-automatic filling and an effective and safe venting system.

3.6. Cell container

Sunica.plus is built up using the well proven block battery construction. The tough polypropylene containers are welded together by heat sealing and the assembly of the blocks are completed by a clip-on terminal cover which gives protection to IP2 standard for the conductive parts.

4. Benefits of the Sunica.plus battery

Complete reliability

Does not suffer from the sudden death failure associated with other battery technologies.

Long cycle life

Sunica.plus has a long cycle life even when the charge/discharge cycle involves full discharges and will give up to 8000 cycles at 15 % depth of discharge during a twenty year life.

Exceptional long life

Sunica.plus incorporates all the design features associated with the conventional Saft twenty year life products to ensure that, in many applications, it can achieve or exceed this lifetime.

Low maintenance

With its special recombination separator and generous electrolyte reserve, Sunica.plus reduces the need for topping-up with water. It can be left in remote sites for long periods and will, depending upon application demands, give up to 4 years without the need for topping-up.

Charge efficiency

Good charge efficiency at normal temperatures and excellent charge efficiency at low temperatures ensure that the battery is charged during the winter period.

Wide operating temperature range

Sunica.plus has a special optimised electrolyte which allows it to have a normal operating temperature of from – 20°C to + 50°C (– 4°F to + 122°F), and accept extreme temperatures, ranging from as low as – 50°C to up to + 70°C (– 58°F to up to + 158°F).

Resistance to mechanical abuse

Sunica.plus is designed to have the mechanical strength required to withstand all the harsh treatment associated with transportation over difficult terrain.

High resistance to electrical abuse

While the use of a voltage regulator is recommended to obtain maximum overall efficiency of the system, the failure of this component will not damage the battery. It will simply cause an overcharging of the battery and so use extra water. The Sunica.plus battery is resistant to overcharge and over-discharge conditions.

Low installation costs

Sunica.plus can be used with a wide range of photovoltaic systems as it produces no corrosive vapours, uses corrosion free polypropylene containers and has a simple bolted assembly system.

Well proven pocket plate construction

Saft has nearly 100 years of manufacturing and application experience with respect to the nickel-cadmium pocket plate product and this expertise has been built into the twenty plus years design life of the Sunica.plus product.

5. Operating features

5.1. Capacity

The Sunica.plus battery capacity is rated in ampere hours (Ah) and is the quantity of electricity it can supply for a 120 hour discharge to 1.0 volts after being fully charged. This figure was chosen as being the most useful for sizing photovoltaic applications.

5.2. Cell voltage

The cell voltage of nickel-cadmium cells results from the electrochemical potentials of the nickel and the cadmium active materials in the presence of the potassium hydroxide electrolyte. The nominal voltage for this electrochemical couple is 1.2 volts.

5.3. Internal resistance

The internal resistance of a cell varies with the type of service and the state of charge and is, therefore, difficult to define and measure accurately.

The most practical value for normal applications is the discharge voltage response to a change in discharge current.

The internal resistance of a Sunica.plus cell when measured at normal temperature is approximately 300 mΩ divided by the capacity (Ah). This value is for fully charged cells and for lower states of charge and temperature the value will increase. For cells 50 % discharged the internal resistance is about 20 % higher and when 90 % discharged it is about 80 % higher. The internal resistance of a fully discharged cell has very little meaning. Reducing the temperature also increases the internal resistance and, at 0°C (+ 32°F), the internal resistance is about 40 % higher. Table 1 shows typical values for a 100 Ah cell (values in mΩ).

Temperature	Fully charged	50 % discharged	90 % discharged
20°C (+ 68°F)	3.0	3.6	5.4
0°C (+ 32°F)	4.2	5.0	7.6

Table 1 - Internal resistance for a 100 Ah cell (in milliohms) for different conditions

5.4. Effect of temperature on performance

Variations in ambient temperature affect the performance of Sunica.plus and this must be allowed for in the battery engineering.

Low temperature operation has the effect of reducing the performance but the higher temperature characteristics are similar to those of normal temperatures. The effect of temperature is more marked at higher rates of discharge.

The factors which are required in sizing a battery to compensate for temperature variations are given in a graphical form for cells with standard electrolyte in Figure 1 for operating temperatures from – 20°C to + 40°C (– 4°F to + 104°F). These factors can be applied for daily depth of discharges (DOD) of up to 15 %.

When the special high density electrolyte is used, for operating temperatures from – 40°C (– 40°F) to room temperature, the factors which are required in sizing a battery to compensate for temperature variations are given in a graphical form in Figure 2.

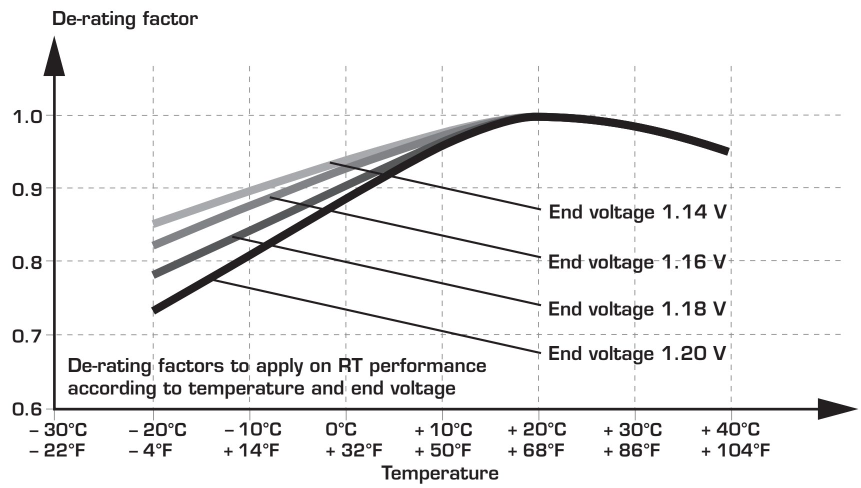


Figure 1 - Temperature de-rating: standard electrolyte for operating temperatures from – 20°C to + 40°C (– 4°F to + 104°F)

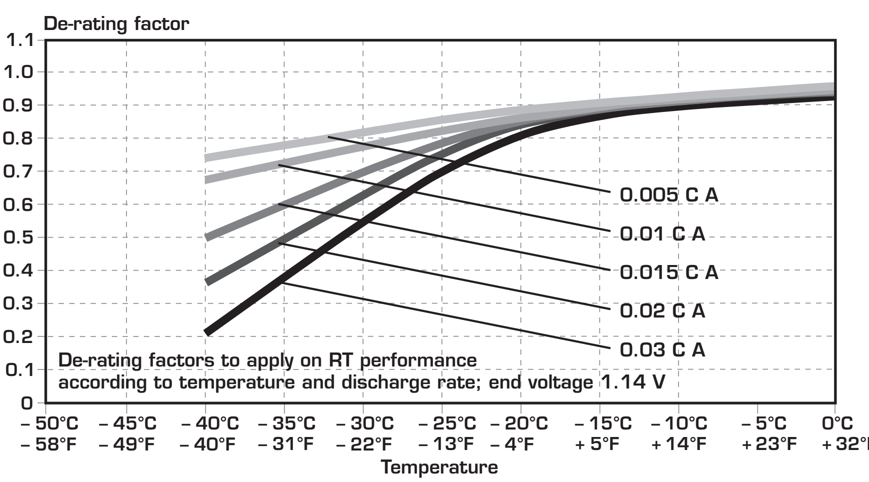


Figure 2 - Temperature de-rating: special electrolyte for operating temperatures down to – 40°C (– 40°F)

5.5. Short circuit values

The typical short circuit value in amperes for a Sunica.plus cell is approximately 9 times the ampere-hour capacity, e.g. for a 100 Ah cell the short circuit value would be 900 amperes. The Sunica.plus battery with conventional bolted assembly connections will withstand a short circuit current of this magnitude for many minutes without damage.

5.6. Open circuit loss

The state of charge of the Sunica.plus cell on open circuit stand slowly decreases with time due to self discharge. In practice this decrease is relatively rapid during the first two weeks but then stabilises to about 2 %–3 % per month at + 20°C (+ 68°F).

The self discharge characteristics of a nickel-cadmium cell are affected by the temperature. At low temperatures the charge retention is better than at normal temperature and so the open circuit loss is reduced. However, the self discharge is significantly increased at higher temperatures.

The open circuit loss for Sunica.plus for normal temperature and the higher temperature which may be experienced in a photovoltaic application is shown in Figure 3.

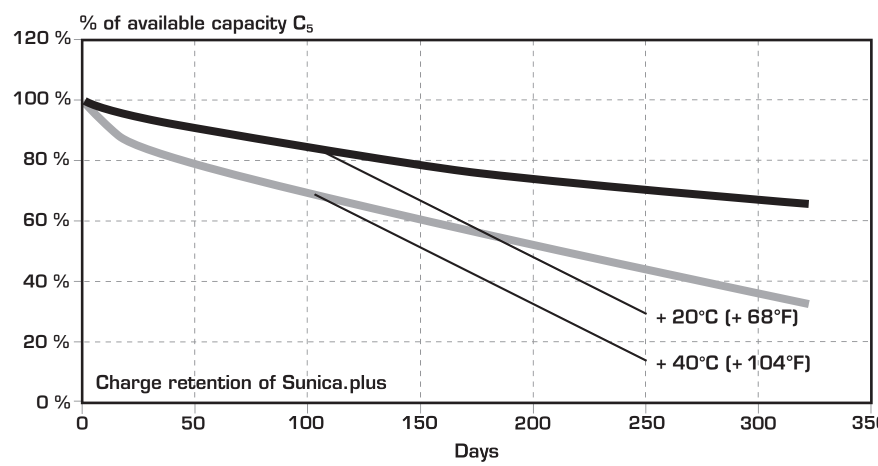


Figure 3 - Open circuit loss at + 20°C and + 40°C (+ 68°F and + 104°F)

5.7. Cycling

Sunica.plus is designed to withstand the wide range of cycling behaviour encountered in photovoltaic applications. This can vary from low depth of discharges to discharges of up to 100 % and the number of cycles that the product will be able to provide will depend on the depth of discharge required.

The less deeply a battery is cycled then the greater the number of cycles it is capable of performing before it is unable to achieve the minimum design limit. A shallow cycle (say 10 %) will give more than 10000 operations, whereas a deep cycle (say 80 %) will give about 1000 operations.

Figure 4 gives the effect of depth of discharge on the available cycle life and, it is clear, that when sizing the battery for an application, the number and depth of cycles have an important consequence on the predicted life of the system.

In practice, in photovoltaic applications, the battery is exposed to a large number of relatively shallow cycles operating at different states of charge and, often, this will be at high temperatures. In order to simulate this, the IEC Standard 61427 incorporates an accelerated cycling test procedure which replicates a photovoltaic energy system operating in very severe conditions. The test consists of a period with a high state of charge, to simulate the effect of overcharge on the lifetime of the battery, and a period with a low state of charge, to simulate the effect of a poor state of charge on a battery. This mix of high and low state of charge cycling is difficult for a battery and allows evaluating the ability of the battery to meet the requirements of the photovoltaic application.

In testing to this standard, Sunica.plus has demonstrated that it can achieve more than 12 periods each of 150 cycles, i.e. more than 1800 charge/discharge cycles, without reaching the requirements of the end of test criteria (see Figure 5).

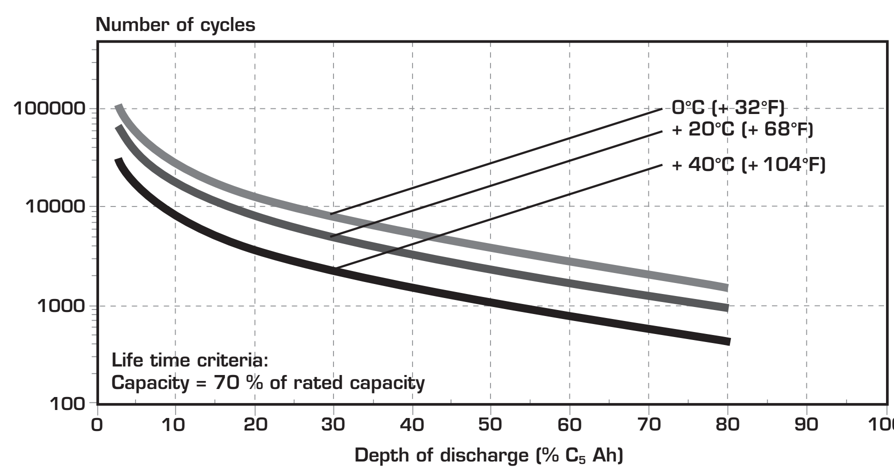


Figure 4 - Typical cycle life values at different temperatures

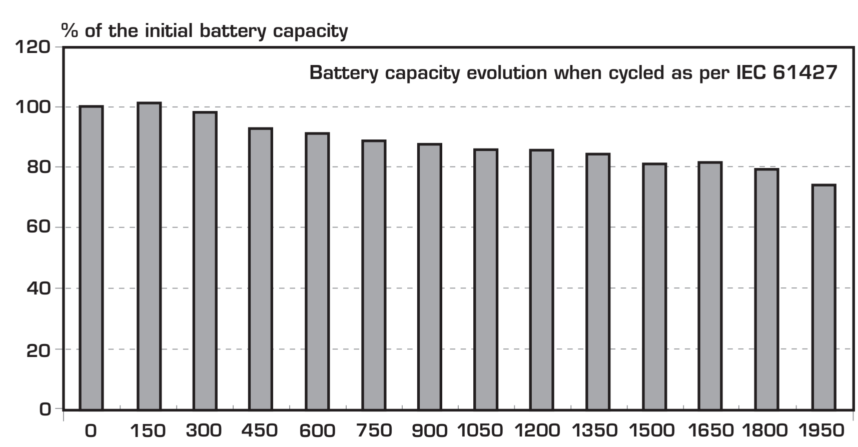


Figure 5 - Sunica.plus cycling to IEC Standard 61427

5.8. Effect of temperature on lifetime

Sunica.plus is designed as a twenty year life product but, as with every battery system, increasing temperature reduces the expected life. However, the reduction in lifetime with increasing temperature is very much lower for the nickel-cadmium battery than the lead acid battery.

The reduction in lifetime for both the nickel-cadmium battery and, for comparison, a lead acid battery is shown graphically in Figure 6.

In general terms for every + 10°C (+ 18°F) increase in temperature over the normal operating temperature of + 20°C to + 25°C (+ 68°F to + 77°F), the reduction in service life for a nickel-cadmium battery will be 20 % and for a lead acid battery will be 50 %. In high temperature situations, therefore, special consideration must be given to dimensioning the nickel-cadmium battery. Under the same conditions, the lead acid battery is not a practical proposition due to its very short lifetime.

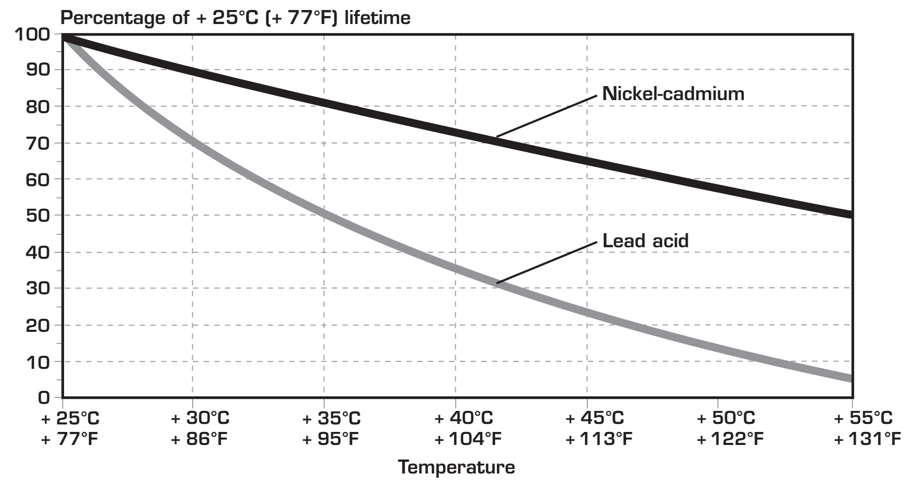


Figure 6 - Lifetime reduction with temperature

5.9. Water consumption

During charging, more ampere hours is supplied to the battery than the capacity available for discharge. These additional ampere-hours must be provided to return the battery to the fully charged state and, since they are not all retained by the cell and do not all contribute directly to the chemical changes to the active materials in the plates, they must be dissipated in some way.

This surplus charge, or overcharge, breaks down the water content of the electrolyte into oxygen and hydrogen, and pure distilled water has to be added to replace this loss.

Water loss is associated with the current used for overcharging. A battery which is constantly cycled i.e. is charged and discharged on a regular basis, will consume more water than a battery on standby operation.

In theory, the quantity of water used can be found by the Faradic equation that each ampere hour of overcharge breaks down 0.366 cc of water. However, due to the recombination separator used in the Sunica.plus battery, the water usage will be considerably less than this.

The consumption of water used by the battery varies according to the voltage, temperature and the level of cycling which occurs in the application.

Table 2 gives typical water consumption values over a range of voltages corresponding to daily depth of discharges at two typical photovoltaic temperatures.

Charge voltage	**1.5 V**	**1.55 V**	**1.6 V**
Daily DOD	5 % to 10 %	10 % to 15 %	15 % to 25 %
Topping-up interval at + 20°C (+ 68°F)	4 year	3 year	2 year
Topping-up interval at + 40°C (+ 104°F)	2 year	1.5 year	1 year

Table 2 - Typical water consumption values at different voltages

6. Battery charging

6.1. Charging generalities

The photovoltaic array converts solar irradiance into dc electrical power at a predetermined range of voltages whenever sufficient solar radiation is available.

Unlike a mains connected system, the output from a photovoltaic array is variable and, to obtain the best efficiency from the system, it is quite normal to have some form of charge control.

In general the solar panels are sized in such a way that they can provide the requested energy to the load during the season of low solar radiation and the extra energy obtained during the season where the solar radiation is at its highest is then available for recovering full battery capacity.

Depending on the season, the battery in solar application cycles is either at high state of charge or at low state of charge and, as a consequence, the charge parameters are never well defined in solar applications.

In practice, as the charging current depends on the sun irradiance and the charging time on the light duration, the charge voltage is left as the main parameter which can be used to optimise the battery state of charge for a given solar application.

The optimised charge voltage is linked to the daily depth of discharge (which is in relationship with the battery autonomy) and the target is to maintain a high state of charge cycle after cycle with low water consumption.

6.1.1 The Daily Depth of Discharge (DOD)

In order to define the optimised charge voltage, it is necessary to define the Daily DOD. This is obtained from the fact that the battery is cycling every day; it is charging during the day and is discharging during the night.
In general the daily discharge is going to fall between 5 to 20 % DOD.

The following example gives an illustration.

The battery has to be defined to give 5 days back up time with a load of 50 W. Thus the battery requirement is
5 x 24 x 50 W = 6000 Wh

The daily discharge of the battery during the night is 50 W for about 12 h. So, each day the battery has to supply
50 W x 12 h = 600 Wh.

From this it can be seen that the daily DOD is
600 Wh / 6000 Wh i.e. 10 %

6.1.2 Optimum charge voltage

It is now necessary to define the optimum charge voltage when the battery is cycling at high state of charge.

This can be carried out by checking the values of the stabilised state of charge in cycling according to different daily DOD, charge voltage and temperature and the values are summarised in Figure 7.

When cycling with the recommended charge voltage corresponding to the daily DOD, it is expected that a stabilised state of charge of 90 % will be achieved providing the solar panels are correctly sized for the load and the site conditions.

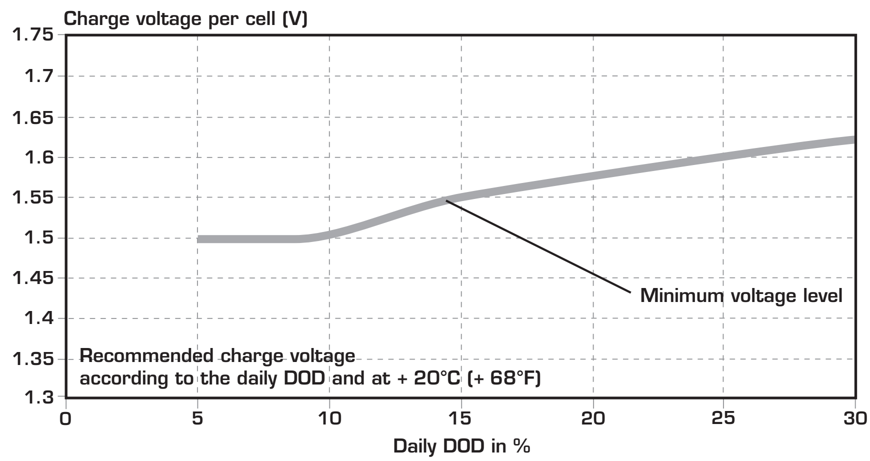


Figure 7 - Charge voltage required for high state of charge

6.2. Charge efficiency

The charge efficiency of Sunica.plus is dependent on the state of charge of the battery and the temperature. For much of its charge profile it is recharged at a high level of efficiency. In cycling at 20°C (+68°F), with the advised charge voltage corresponding to the daily DOD, the Ah efficiency is close to 100 % at a 50 % state of charge, and it is better than 90 % at a 90 % state of charge. At higher temperatures the Ah efficiency is reduced and at +40°C (+104F°) the values are respectively 96 % and 82 %. When the charge voltage is less than or more than the recommended value the stabilised state of charge and the Ah efficiency will be modified.

The relationship between the charge efficiency and the daily depth of discharge, autonomy and charge voltage for +20°C (+68°F) is shown in Table 3.

It is important to note that the charging efficiency of Sunica.plus is not reduced with time and so this does not have to be taken into account in battery sizing.

In practice, a photovoltaic system's battery normally has a state of charge between 20 % and 80 % and so the charging efficiency of Sunica.plus remains high.

6.3. Temperature effects

As the temperature increases, then the electrochemical behaviour becomes more active and so, for the same charge voltage, the current at the end of charge increases. This end of charge increase in the current helps to compensate for the variation in charge efficiency at high temperatures and allows a high state of charge to be achieved. For this reason it is not recommended that temperature compensation of the charge voltage is used for ambient temperatures above 0°C (+32°F). In terms of water loss, this is not increased significantly at these higher temperatures due to the effectiveness of the partial gas recombination features of Sunica.plus.

Daily DOD	Typical autonomy	Charge voltage per cell	Expected SOC	Ah efficiency at H SOC	Ah efficiency at 50% SOC
5 to 10 %	5 days or +	1.5 V	90 % min	>90 %	≈100 %
10 to 15 %	3 to 5 days	1.55 V	90 % min	>90 %	≈100 %
15 to 25 %	2 to 5 days	1.6 V	90 % min	>90 %	≈100 %

Table 3 - Typical Ah efficiencies under different application conditions

As the temperature is reduced, then the reverse occurs and it is recommended that, for applications where the ambient temperature during the critical period of the year falls below 0°C (+32°F), temperature compensation of the charge voltage should be used to maintain the end of charge current at a constant value.

The change in voltage required per cell, or "temperature compensation", should be between –2 mV and –3.5 mV per °C. The recommended value is –2.5 mV per °C and per cell.

6.4 Regulators

6.4.1 A pulse width modulator (PWM) type regulator

For a PWM type regulator the advised charge voltage should be based on the daily depth of discharge according to the values in Table 4.

6.4.2 A battery regulator based on the switching principle

For this type of regulator it is useful to define the boost threshold (not mandatory), the float threshold and the charge reconnect threshold.

Typical threshold values for a battery system with Sunica.plus defined for 5 days or more autonomy is shown in Table 5.

6.4.3 Recommendation for choosing the voltage regulators.

The charge voltages shall be adjustable due to the wide charge voltage range of Sunica.plus. The low voltage disconnect shall be adjustable or inhibit due to the deep discharge possible of the Sunica. plus. Regulators with voltage regulation using PWM systems are recommended due to the need of maintaining the charge voltage on the battery during the daily charge process.
Examples of voltage regulators
- The TriStar from Morningstar
- The Enerstat from Total energie
- The Trace C40
- etc

Voltage system	**12 V**	**24 V**	**48 V**
Typical number of Ni-Cd cells	9	18	36

Daily DOD	**Typical autonomy**	**Charge voltage per cell**
5 to 10 %	5 days or +	1.5 V
10 to 15 %	3 to 4 days	1.55 V
15 to 25 %	2 to 3 days	1.6 V

Table 4 - PWM regulator recommended charge voltages for different conditions

Voltage system	**12 V**	**24 V**	**48 V**
Typical number of Ni-Cd cells	9	18	36
Boost threshold (not mandatory or 1.65 V per cell)	14.7 V	29.4 V	58.8 V
Float threshold (by 1.55 V per cell)	14.1 V	28.2 V	56.4 V
Battery reconnect threshold (by 1.45 V per cell)	13 V	26 V	52 V
End of discharge threshold (not mandatory or 1 V per cell)	9 V	18 V	36 V

Table 5 - Typical threshold values for switching type regulator

7. Special operating factors

7.1. Electrical abuse

7.1.1. Ripple effects

The nickel-cadmium battery is tolerant to high ripple and the only effect is that of increased water usage. In general, any commercially available charger or generator can be used for commissioning or maintenance charging of Sunica.plus.

7.1.2. Over-discharge

If more than the designed capacity is taken out of a battery then it becomes over-discharged. This is considered to be an abuse situation for a battery and should be avoided.

In the case of lead acid batteries this will lead to failure of the battery and is unacceptable.

The Sunica.plus battery is designed to make recovery from this situation possible.

7.1.3. Overcharge

Overcharge is the effect of forcing current through a battery when it is fully charged. This can be damaging for a lead acid battery and, due to its starved electrolyte technology, seriously reduce the life of a VRLA battery. In the case of Sunica.plus, with its generous electrolyte reserve, a small degree of overcharge will not significantly alter the maintenance period. In the case of excessive overcharge, water replenishment is required but there will be no significant effect on the life of the battery.

7.2. Mechanical abuse

7.2.1. Shock loads

The Sunica.plus block battery concept has been tested to both IEC 68-2-29 (bump tests at 5 g, 10 g and 25 g) and IEC 77 (shock test 3 g).

7.2.2. Vibration resistance

The Sunica.plus block battery concept has been tested to IEC 77 for 2 hours at 1 g.

7.2.3. External corrosion

Sunica.plus nickel-cadmium cells are manufactured in durable polypropylene, all external metal components are nickel plated and these components are protected by a rigid plastic cover.

8. Battery sizing principles

8.1 Introduction

The type of use of the PV system and the required reliability is of paramount importance in sizing the system.

Professional applications (emergency systems, sea-lights, radio beacons etc.) have to be oversized according to their importance and it is necessary to take into account the working conditions of the system.

It is not the purpose of this manual to give sizing methods for complete photovoltaic systems. However, this is an application with specific performance requirements and it is useful to discuss the different factors which can affect the design of the system and the battery sizing. The array and battery size are related since the photovoltaic system must have array and battery sizes which are sufficient for the load to operate at all the required times throughout the year. The system could have a small array and a large battery or vice versa. However, there are limits to these sizes as, while the minimum array size is that which can deliver the annual daily load in the average daily insolation, the minimum battery size is that which can supply the overnight load.

8.2 The basic principles

The basic rules controlling the calculation of the correct battery for an application require the calculation of the following parameters:

Unadjusted capacity

This is the average daily load (in Ah per day) multiplied by the number of days of battery reserve. This capacity has to be adjusted according to the battery characteristics and operating conditions.

Discharge adjustment

This is the capacity adjusted for life. It is obtained by dividing the unadjusted capacity by the required capacity at the end of life (expressed as a percentage of the rated capacity). Figure 4 shows the number of cycles before reaching a capacity of 70 %.

Charge adjustment

It is recommended to use a charge voltage optimised for the daily DOD and temperature. With an optimised charge voltage we get a good state of charge with the lowest water consumption. As a guideline, an optimised charge voltage will allow to keep a state of charge by 90 to 95 % when the battery is cycling at high state of charge.

Temperature adjustment

Cell capacity ratings are defined at +20°C to +25°C (+68°F to +77°F). For temperatures outside this range, it is necessary to use the temperature correction factor (see Figures 1 and 2).

Design margin adjustment

It is a common practice to provide a design margin to allow for uncertainties in the load determination. This is usually in the region of 10 to 25 %.

Load current calculation

The purpose of the equivalent load current calculation is to be able to use the performance table data at +20°C to +25°C (+68°F to +77°F).

From this information it is possible to correctly calculate a battery capacity value from the unadjusted capacity, to apply the derating factors from the capacity adjustment, to calculate the equivalent average current in dividing the capacity calculated by the discharge time (number of days x 24 h) and, using the current value calculated, the end voltage, and the autonomy, to select the right battery Sunica.plus from the performance table.

8.3 Battery sizing example

In this case we consider a telecom application, but this is typical of many applications.

Requirements

The average load current = 3A / 8 days or 192 h of autonomy.

There is no information concerning the performance requirement at the battery end of life but we will assume that full autonomy is required. The average temperature is considered to be +40°C (+104°F) and the voltage window: 41.8 V to 54.4 V.

The expected load growth which has to be allowed for in the design is 10 %.

Unadjusted capacity

Calculating a simple unadjusted capacity we have 3 A x 192 = 576 Ah.

Discharge adjustment

As we anticipate achieving the full 8 days autonomy at the end of life, then, as described in 8.2 above, we will use a factor of 0.7 (70 % of initial capacity).

Charge adjustment

If the charge voltage is in accordance with the recommended value corresponding to the daily depth of discharge, then the charge adjustment used is 0.9.

Temperature adjustment

The temperature adjustment value = 0.95 (Figure 1: +40°C/+104°F)

Design margin

The design margin adjustment value is 0.9 as allowance for a load growth of 10 % is required.

Load current calculation

From this data, the calculated battery capacity is 576 Ah / (0.7 x 0.9 x 0.95 x 0.9) = 1058 Ah.

And the equivalent load current is 1058 Ah / 192 h = 5.5 A.

End voltage is 41.8 V / 36 cells = 1.16 V.

Battery selection in the performance table becomes 5.5 A / 192 h / 1.16 V = SUN⊕ 1110.

Charge voltage calculation

The daily depth of discharge is calculated according to the methodology given in paragraph 6.1.1.

If we assume that the daily night duration during the critical month is 18 hours, then the daily DOD is 3 A x 18 h x 100/1058 Ah = 5.1 %. Thus the charge voltage to be used is 1.5 V per cell (see the table in paragraph 6.4.1) and the voltage at the battery terminals is 1.5 V x 36 = 54 V which is compatible with the load voltage window.

9. Installation and storage

9.1 Receiving the shipment

Unpack the battery immediately upon arrival. Do not overturn the package. Check the packages and cells for transport damage.

The battery is shipped filled and charged, and is ready for immediate use. Transport seals are located under the lid of each vent; they must be removed prior to mounting.

The battery must never be charged with the plastic transport seals in place as this is dangerous and can cause permanent damage.

9.2. Storage

Store the battery indoors in a dry, clean, cool location (0°C to +30°C /+32°F to +86°F) and well ventilated space on open shelves. Storage of a filled battery at temperatures above +30°C (+86°F) can result in loss of capacity. This can be as much as 5 % per 10°C (18°F) above +30°C (+86°F) per year. Do not store in direct sunlight or expose to excessive heat. Sunica.plus batteries are supplied filled with electrolyte and charged, they can be stored in this condition for a maximum of 12 months. The electrolyte should never be drained from the cells.

When deliveries are made in cardboard boxes, store without opening the boxes.

When deliveries are made in plywood boxes, open the boxes before the storage. The lid and the packing material on top of the cells must be removed.

9.3. Installation

9.3.1. Location

Install the battery in a dry and clean room. Avoid direct sunlight and heat.

The battery will give the best performance and maximum service life when the ambient temperature is between +10°C to +30°C / +50°F to +86°F.

9.3.2. Ventilation

During the last part of charging, the battery is emitting gases (oxygen and hydrogen mixture). At normal float charge, the gas evolution is very small but some ventilation is necessary.

Note that special regulations for ventilation may be valid in your area depending on the application.

9.3.3. Mounting

Verify that cells are correctly interconnected with the appropriate polarity. The battery connection to load should be with nickel plated cable lugs.

Recommended torques for terminal bolts are:

- M 6 = 11 ± 1.1 N.m
- M 8 = 20 ± 2 N.m
- M 10 = 30 ± 3 N.m

The connectors and terminals should be corrosion-protected by coating with a thin layer of anti-corrosion oil. Remove the transport seals and close the vent caps.

If a central water filling system is used as an option, refer to the corresponding installation and operating instructions sheet.

9.3.4. Electrolyte

When checking the electrolyte levels, a fluctuation in level between cells is not abnormal and is due to the different amounts of gas held in the separators of each cell. The level should be at least 15 mm above the minimum level mark and there is normally no need to adjust it.

Do not top-up prior to initial charge.

9.4. Commissioning

A good commissioning charge is important. Charge at constant current is preferable.

9.4.1. Cells stored up to 6 months:

A commissioning charge is normally not required and the cells are ready for immediate use. If full performance is necessary immediately, a commissioning charge as mentioned in section 9.4.2. is recommended.

9.4.2. Cells stored more than 6 months and up to 1 year:

For cells stored more than 6 months a commissioning charge is necessary. It is important to verify that the ventilation is adequate during this operation.

The preferred method is to charge at constant current for 16 h with the current in Table 6. With this charge method the individual cell voltage may rise to 1.85 V/cell at the end of the charge period.

If constant current charging is not available, then it is possible to achieve an equivalent level of charge with constant voltage by using a high voltage level. This should be a minimum 1.65 V/cell for 30 hours with the same current limit as in Table 6.

When the charger maximum voltage setting is too low to supply constant current charging, divide the battery into two parts to be charged individually at constant current.

In the case of remote areas, where the only charger available is the photovoltaic array, the battery should be connected to the system with no connected load and no voltage limit.

The battery should then be charged in good sunshine conditions. During this operation, the Ah charged shall be in the magnitude of 1.6 times the rated capacity, and, in order to limit the risk of electrolyte overflow, it is recommended not to exceed the charge current value specified in Table 6.

Cell type	Rated capacity 5 h - 1.00 V C_5 Ah	Nominal capacity 120 h - 1.00 V C_{120} Ah Ah	Charging current 0.1 C_5 A A	Max. quantity of water to be added cc	Cell terminal
SUN ⊕ 45	43	45	4.3	190	M 6
SUN ⊕ 90	85	90	8.5	280	M 8
SUN ⊕ 105	100	105	10	380	M 10
SUN ⊕ 140	128	140	13	380	M 10
SUN ⊕ 185	171	185	17	500	M 10
SUN ⊕ 230	213	230	21	590	M 10
SUN ⊕ 275	256	275	26	700	M 10
SUN ⊕ 320	300	320	30	860	2 X M10
SUN ⊕ 370	341	370	34	1000	2 X M10
SUN ⊕ 415	384	415	38	1100	2 X M10
SUN ⊕ 460	427	460	43	1200	2 X M10
SUN ⊕ 505	469	505	47	1300	2 X M10
SUN ⊕ 555	512	555	51	1400	2 X M10
SUN ⊕ 645	597	645	60	1700	3 X M10
SUN ⊕ 735	682	735	68	1900	3 X M10
SUN ⊕ 830	768	830	77	2100	3 X M10
SUN ⊕ 920	853	920	85	2400	4 X M10
SUN ⊕ 1110	1024	1110	102	2800	4 X M10

Table 6

10. Maintenance of Sunica.plus batteries in service

In a correctly designed standby application, Sunica.plus requires the minimum of attention.

However, it is good practice with any system to carry out an inspection of the system once per year or at the recommended topping-up interval period to ensure that the charging system, the battery and the ancillary electronics are all functioning correctly.

When this system service is carried out, it is recommended that the following actions should be taken:

- Cell electrolyte levels should be checked visually to ensure that the level is above the minimum and if necessary the cells should be topped-up. Use only distilled or deionized water (see Table 6 for the quantity of water per cell).

- The batteries should also be checked for external cleanliness, and if necessary cleaned with a damp brush using water. Do not use a wire brush or solvents of any kind. Vent plugs can be rinsed in clean water if necessary.

- All the connectors must be tight. The connectors and terminal bolts should be corrosion-protected by coating with a thin layer of anti-corrosion oil.

Saft is committed to the highest standards of environmental stewardship.

Implementing this commitment to minimise the impact of its products and operations on the environment means that Saft gives priority to recycled over unrecycled raw materials, reduces its plant releases into the environment year after year, minimizes water usage, and ensures that its customers have recycling solutions for their batteries at the end of their lives.

Regarding industrial Ni-Cd batteries, Saft has had partnerships for many years with collection companies in most EU countries as well as in North America. This collection network receives and dispatches our customers' batteries at the end of their lives to fully approved recycling facilities, in compliance with the Laws governing transboundary waste shipments. Saft offers these services free of charge to its customers.

Please find a list of our collection points on our web site.

In other countries, Saft assists its customers in finding environmentally sound recycling solutions. Please contact your sales representative for further information.

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