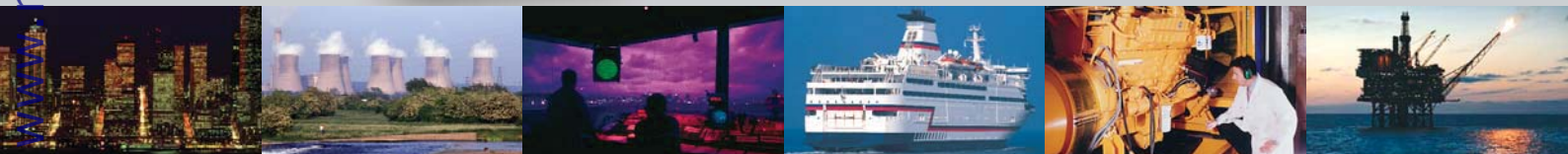


SPH Ni-Cd battery

Technical manual

norwatt@norwatt.es

norwatt.es



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1. Introduction

The Saft SPH Ni-Cd battery combines the best features of reliable battery power with the tangible benefit of exceptionally low maintenance.

Specified where a rapid discharge characteristic is vital for critical engine starting duties and UPS applications, SPH is fast becoming the battery of choice to safeguard today's high technology industries.

By reliably delivering high power within a low voltage window and needing only minimal maintenance even in harsh and remote locations, SPH meets the demands set by computer-controlled process systems, hospitals, telecommunications stations, on-shore, off-shore, and anywhere where a long life, low cycle cost is important.

The sintered/pbe plate construction and potassium hydroxide electrolyte at the heart of SPH allow to have a normal

operating temperature from -20°C to $+50^{\circ}\text{C}$ (-4°F to $+122^{\circ}\text{F}$), and accept extreme temperatures from -50°C to $+70^{\circ}\text{C}$ (-58°F to $+158^{\circ}\text{F}$), without risk of plate degradation and the catastrophe of sudden failure.

When used as recommended the SPH can operate for up to 20 years without the need for water replenishment. The battery's electrical characteristics enable it to tolerate ripple currents, overcharging, over-discharging and voltage reversal.

This manual provides a comprehensive guide to the construction, installation, and operation of your SPH battery. Saft are at the forefront of Ni-Cd battery technology development and always have available expert advice or practical help to ensure the smooth running of your installation.

2. Electrochemistry of nickel-cadmium batteries

The nickel-cadmium battery uses nickel hydroxide as the active material for the positive plate, cadmium hydroxide for the negative plate.

The electrolyte is an aqueous solution of potassium hydroxide containing small quantities of lithium hydroxide to improve cycle life and high temperature operation. The electrolyte is only used for ion transfer, it is not chemically changed or degraded during the charge/discharge cycle. In the case of the lead acid battery, the positive and negative active materials chemically react with the sulphuric acid electrolyte with a resulting ageing process.

The support structure of both plates is steel. This is unaffected by the electrochemistry and

retains its characteristics throughout the life of the cell. In the case of the lead acid battery, the basic structure of both plates are lead and lead oxide which play a part in the electrochemistry of the process and are naturally corroded during the life of the battery.

During discharge the trivalent nickel hydroxide is reduced to divalent nickel hydroxide and the cadmium at the negative plate forms cadmium hydroxide. On charge, the reverse reaction takes place until the cell potential rises to a level where hydrogen is evolved at the negative plate and oxygen at the positive plate which results in water loss.

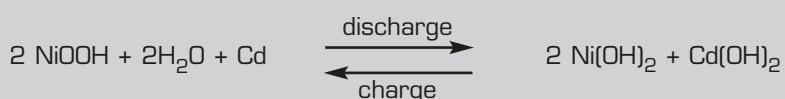
Unlike the lead acid battery, there is little change in the

electrolyte density during charge and discharge. This allows large reserves of electrolyte to be used without inconvenience to the electrochemistry of the couple.

Thus, through its electrochemistry, the nickel-cadmium battery has a more stable behavior than the lead acid battery so giving it a longer life, superior characteristics and a greater resistance against abusive conditions.

Nickel-cadmium cells have a nominal voltage of 1.2 volts (V).

The charge/discharge reaction is as follows :



3. Construction features of the SPH battery

3.1 Positive plate

The positive plate used in the cell is of the sintered type. This is obtained by chemical impregnation of nickel hydroxide into a porous nickel structure, which is obtained by sintering nickel powder onto a thin, perforated, nickel-plated strip.

3.2 Negative plate

The negative electrode is a plastic-bonded cadmium electrode, produced with a continuous process. This involves blending together the active material, binder and additives, continuously spreading this onto a perforated nickel-plated steel substrate, drying and, finally, passing the coated band through rollers for dimensioning.

3.3 Plate tab

The electrodes are seam welded to the plate tabs so producing a continuous interface between the two components. This ensures high current transfer and maximum strength. The plate tab material is nickel-plated steel and the plate tab thickness is chosen to ensure a satisfactory current carrying capability consistent with the application.

3.4 Separator

The separator consists of a sandwich of micro-porous polymer and non-woven felt which maintains an optimized distance between the electrodes. The separator system has been developed to give an optimum balance between performance, reliability and long life.

3.5 Terminal pillars

The material used for the terminal pillars (copper or steel) and the number of terminals per cell are chosen as a function of the intended application. The terminal pillars are nickel-plated.

3.6 Electrolyte

The electrolyte used in the sintered/pbe range, which is a solution of potassium hydroxide and lithium hydroxide, is optimized to give the best combination of performance, life, energy efficiency and a wide temperature range.

The concentration of the standard electrolyte is such as to allow the cell to be operated down to temperature extremes as low as -20°C (-4°F) and as high as $+50^{\circ}\text{C}$ ($+122^{\circ}\text{F}$). This allows the very high temperature fluctuation found in certain regions to be accommodated.

For very low temperatures a special high density electrolyte can be used.

It is an important consideration of the sintered/pbe range, and indeed all nickel-cadmium batteries, that the electrolyte concentration 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.

The electrode material is less reactive with the alkaline electrolyte (nickel-cadmium secondary batteries) than with acid electrolytes (lead acid secondary batteries). Furthermore, during charging and discharging in alkaline batteries the electrolyte works mainly as a carrier of oxygen or hydroxyl ions from one electrode to the other; hence the composition or the concentration of the electrolyte does not change noticeably.

In the charge/discharge reaction of the nickel-cadmium battery, the potassium hydroxide is not mentioned in the reaction

formula. A small amount of water is produced during the charging procedure (and consumed during the discharge). The amount is not enough to make it possible to detect if the battery is charged or discharged by measuring the density of the electrolyte.

Once the battery has been filled with the correct electrolyte at the battery factory there is no need to check the electrolyte

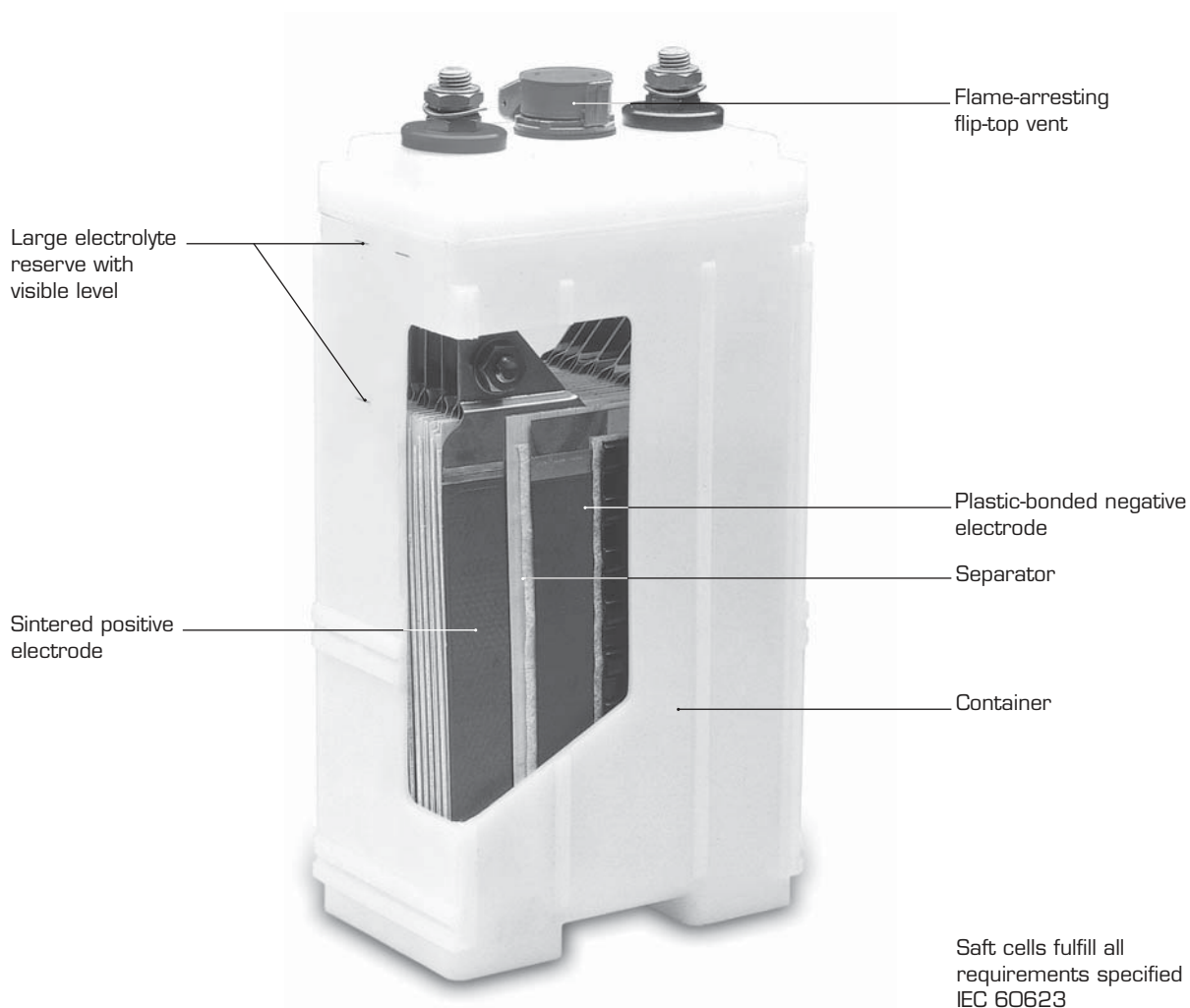
density periodically. The density of the electrolyte in the battery either increases or decreases as the electrolyte level drops because of water electrolysis or evaporation or rises at topping-up. Interpretation of density measurements is difficult and could be misleading.

3.7 Vent system

The SPH is fitted with a special flame-arresting flip-top vent to give an effective and safe venting system.

3.8 Cell container

The SPH range is available in polypropylene or in flame retardant polyamid (nylon).



Saft cells fulfill all requirements specified by IEC 60623

4. Operating features

4.1 Capacity

The SPH electrical capacity is rated in ampere-hours (Ah) and is the quantity of electricity at +20°C (+68°F) which it can supply for a 5 hour discharge to 1.0 V after being fully charged at 7.5 hours at 0.2 C₅ A. This figure is in agreement with the IEC 60623 standard.

According to the IEC 60623 (Edition 4), 0.2 C₅ A is also expressed as 0.2 I_t A. The reference test current (I_t) is expressed as:

$$I_t A = \frac{C_n \text{ Ah}}{1 \text{ h}}$$

where:

C_n is the rated capacity declared by the manufacturer in ampere-hours (Ah),
and
n is the time base in hours (h) for which the rated capacity is declared.

4.2 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 V.

4.3 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 typical internal resistance of an SPH cell when measured at normal temperature is 40 mΩ per Ah capacity. For example, the internal resistance of SPH 150 is given by:

$$\frac{40}{150} = 0.27 \text{ m}\Omega$$

The above figure is for fully charged cells. For lower states of charge the values 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 15% higher.

4.4 Effect of temperature on performance

Variations in ambient temperature affect the performance of SPH and this is 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 at 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 in Figure 1 for an operating temperature range of -20°C to $+40^{\circ}\text{C}$ (-4°F to $+104^{\circ}\text{F}$). For use at temperatures outside this range, contact Saft for advice.

4.5 Short-circuit values

The minimum short-circuit value for the SPH cell is 30 times the ampere-hour capacity.

An approximate calculation of the short-circuit current for a given cell is $1.8 \times$ cell discharge current to 0.65 V for 1 s .

The SPH battery is designed to withstand a short-circuit current of this magnitude for many minutes without damage.

4.6 Open circuit loss

The state of charge of SPH 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 stabilizes to about 2% per month at $+20^{\circ}\text{C}$ ($+68^{\circ}\text{F}$).

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 the SPH cell for a range of temperatures is shown in Figure 2.

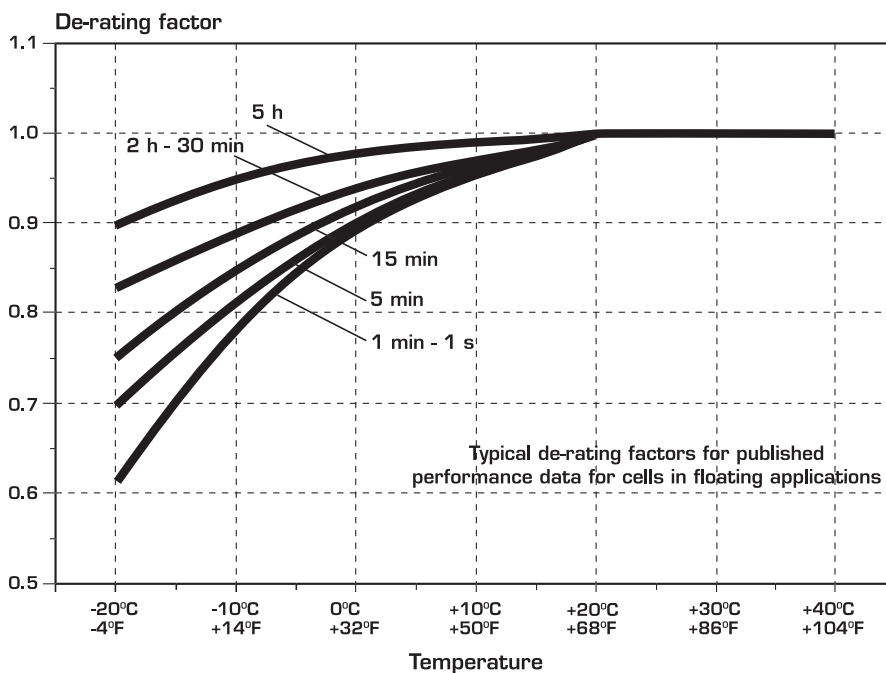


Figure 1 – Temperature de-rating factor for different rate discharge

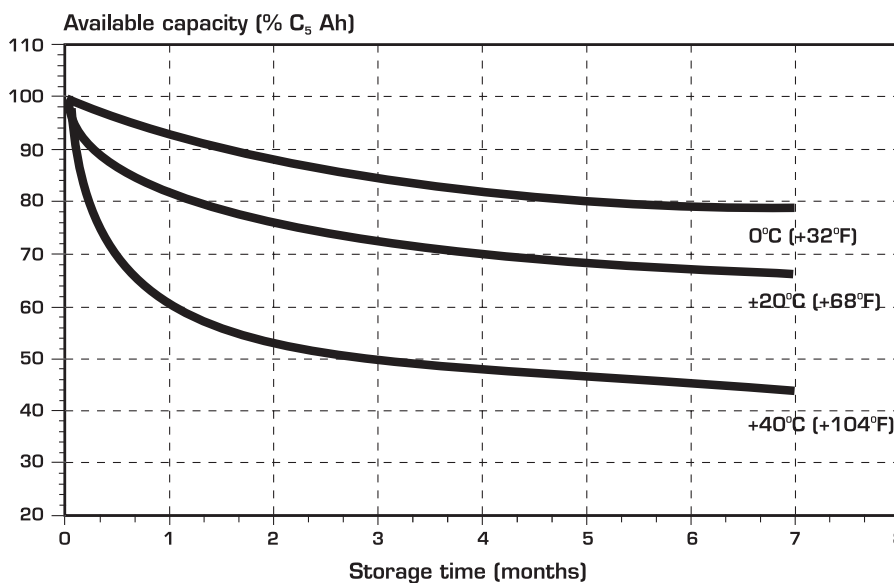


Figure 2 – Capacity loss on open circuit stand

4.7 Cycling

The SPH range is designed to withstand the wide range of cycling behavior encountered in stationary 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, the greater the number of cycles it is capable of performing before it is unable to achieve the minimum design limit. A shallow cycle will give many tens of thousands of operations, whereas a deep cycle will give fewer operations.

Figure 3 gives typical values for the effect of depth of discharge on the available cycle life, and it is clear that when sizing the battery for a cycling application, the number and depth of cycles have an important consequence on the predicted life of the system.

4.8 Effect of temperature on lifetime

The SPH range 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.

In comparison, a high quality lead acid battery is shown graphically in Figure 4. The values for the lead acid battery are as supplied by the industry and found in IEEE documentation.

The reduction in lifetime for the nickel-cadmium battery, and for

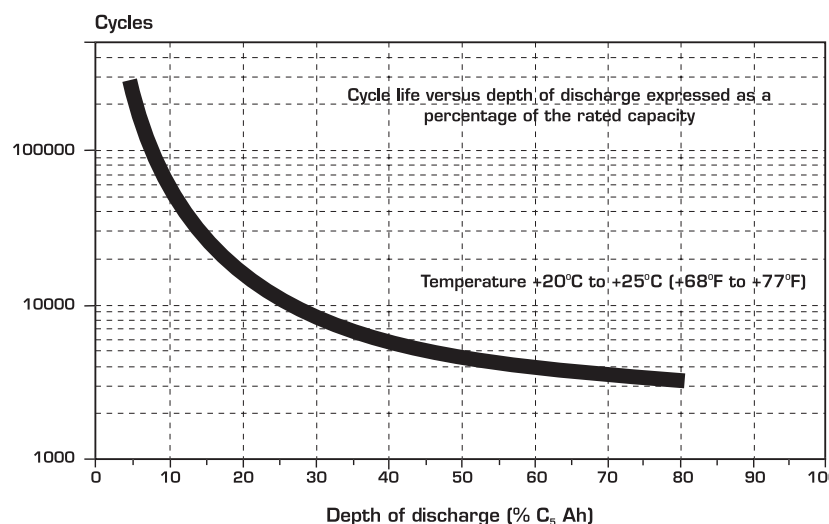


Figure 3: Typical cycle life versus depth of discharge

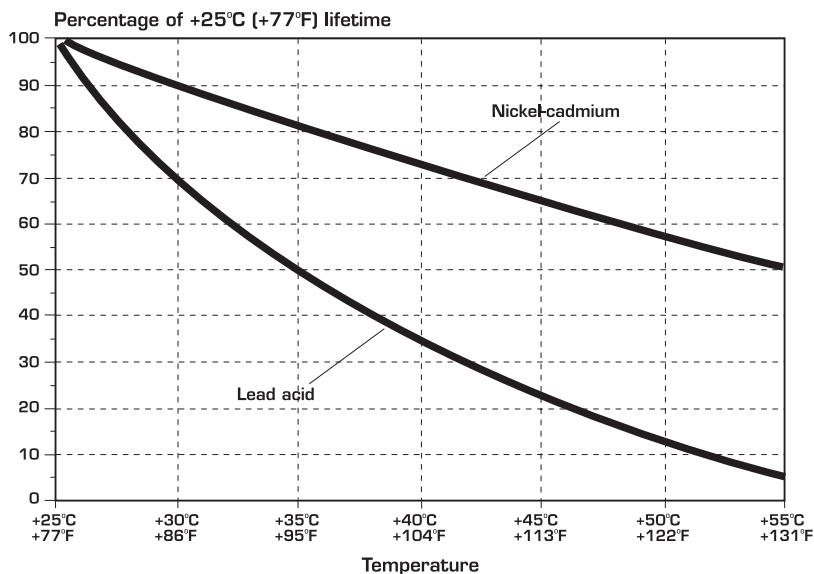


Figure 4: Effect of temperature on lifetime

In general terms, for every 9°C (16.2°F) increase in temperature over the normal operating temperature of +25°C (+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. The valve-regulated lead acid battery (VRLA), for example, which has a lifetime of about 7 years under good conditions, has this reduced to less than 1 year, if used at +50°C (+122°F).

4.9 Water consumption and gas evolution

During charging, more ampere-hours are 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 cm³ of water. However, in practice, the water usage will be less than this as the overcharge current is also needed to support self-discharge of the electrodes.

The overcharge current is a function of both voltage and

temperature and so both have an influence on the consumption of water.

Figure 5 gives typical water consumption values over a range of temperature at floating voltage of 1.41 V/cell.

The gas evolution is a function of the amount of water electrolyzed into hydrogen and oxygen and is predominantly given off at the end of the charging period. The battery gives off no gas during a normal discharge.

The electrolysis of 1 cm³ of water produces 1865 cm³ of gas mixture and this gas mixture is in the proportion of 2/3 hydrogen and 1/3 oxygen. Thus the electrolysis of 1 cm³ of water produces about 1243 cm³ of hydrogen.

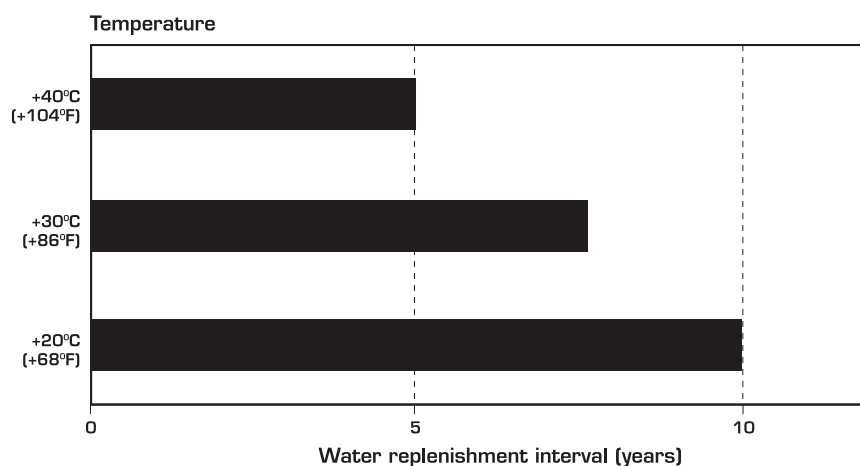


Figure 5: Water replenishment intervals at 1.41 V/cell

5. Battery sizing principles in standby applications

There are a number of methods which are used to size nickel-cadmium batteries for standby floating applications. These include the IEEE 1115 method of the Institute of Electrical and Electronics Engineers. This method is approved and recommended by Saft for the sizing of nickel-cadmium batteries. Sizing methods must take into account multiple discharges, temperature de-rating, performance after floating and the voltage window available for the battery. All methods have to use methods of approximation and some do this more successfully than others.

A significant advantage of the nickel-cadmium battery compared to a lead acid battery is that it can be fully discharged without any inconvenience in terms of life or recharge. Thus, to obtain the smallest and least costly battery, it is an advantage to discharge the battery to the lowest practical value in order to obtain the maximum energy from the battery.

The principle sizing parameters which are of interest are:

5.1 The voltage window

This is the maximum voltage and the minimum voltage at the battery terminals acceptable for the system. In battery terms, the maximum voltage gives the voltage which is available to charge the battery, and the minimum voltage gives the lowest voltage acceptable to the system to which the battery can be discharged. In discharging the nickel-cadmium battery, the cell voltage should be taken as low as possible in order to find the most economic and efficient battery.

5.2 Discharge profile

This is the electrical performance required from the battery for the application. It may be expressed in terms of amperes for a certain duration, or it may be expressed in terms of power, in watts or kW, for a certain duration. The requirement may be simply one discharge or many discharges of a complex nature.

5.3 Temperature

The maximum and minimum temperatures and the normal ambient temperature will have an influence on the sizing of the battery. The performance of a battery decreases with decreasing temperature and sizing at a low temperature increases the battery size. Temperature de-rating curves are produced for all cell types to allow the performance to be recalculated.

5.4 State of charge or recharge time

Some applications may require that the battery shall give a full duty cycle after a certain time following the previous discharge. The factors used for this will depend on the depth of discharge, the rate of discharge, and the charge voltage and current. A requirement for a high state of charge does not justify a high charge voltage if the result is a high end of discharge voltage.

5.5 Ageing

Some customers require a value to be added to allow for the ageing of the battery over its lifetime. This may be a value required by the customer, for example 10%, or it may be a requirement from the customer that a value is used which will ensure the service of the battery during its lifetime. The value to be used will depend on the discharge rate of the battery and the conditions under which the discharge is carried out.

5.6 Floating effect

When a nickel-cadmium cell is maintained at a fixed floating voltage over a period of time, there is a decrease in the voltage level of the discharge curve. This effect begins after one week and reaches its maximum in about 3 months. It can only be eliminated by a full discharge/charge cycle, and it cannot be eliminated by a boost charge. It is therefore necessary to take this into account in any calculations concerning batteries in float applications.

This is used in the IEEE sizing method and the published data for SPH.

5.7 Number of cells in a battery

As mentioned earlier, due to the voltage window available, the charge voltage and the end of discharge voltage have to be chosen to give the best compromise between charging time and final end of discharge voltage.

If the difference in published performance for a cell for the same time of discharge but to different end voltages is examined, it is clear that there is a significant improvement in performance as the end of discharge voltage is reduced.

As the charge voltage and the end of discharge voltage are linked by the voltage window, it is an advantage to use the lowest charge voltage possible in order to obtain the lowest end of discharge voltage.

The number of cells in the battery is determined by the maximum voltage available in the voltage window, i.e. the charge voltage.

6. Battery charging

6.1 Constant voltage charging methods

Batteries in stationary applications are normally charged by a constant voltage float system and this can be two types: the two-rate type where there is an initial constant voltage charge followed by a lower floating voltage; or a single rate floating voltage.

The single voltage charger is necessarily a compromise between a voltage high enough to give an acceptable charge time and low enough to give a low water usage. However, it does give a simpler charging system and accepts a smaller voltage window than the two-rate charger.

The two-rate charger has an initial high voltage stage to charge the battery followed by a lower voltage maintenance charge. This allows the battery to be charged quickly, and yet, have a low water consumption due to the low voltage maintenance level.

For float applications the values used for SPH range for single and two-rate charge systems are:

- Single rate charge:
1.41 ± 0.01 V/cell at +20°C (+68°F)
- Dual rate charge:
High rate:
1.45 ± 0.01 V/cell at +20°C (+68°F)
Float charge:
1.40 ± 0.01 V/cell at +20°C (+68°F)

In case of frequent cycling, the recommended charge voltages are:

- Single rate charge:
1.45 - 1.55 V/cell at +20°C (+68°F)
- Dual rate charge:
High rate:
1.45 - 1.60 V/cell at +20°C (+68°F)
Float charge:
1.40 ± 0.01 V/cell at +20°C (+68°F)

To minimize the water usage, it is important to use a low charge voltage, and so the minimum voltage for the single level and the two level charge voltage is the normally recommended value. This also helps within a voltage window to obtain the lowest, and most effective, end of discharge voltage.

6.2 Charge acceptance

A discharged cell will take a certain time to achieve a full state of charge. Figure 6 gives the capacity available for typical charging voltages recommended for the SPH range during the first 24 hours of charge from a fully discharged state.

This graph gives the recharge time for a current limit of 0.2 C₅ A. Clearly, if a lower value for the current is used, e.g. 0.1 C₅ A, then the battery will take longer to charge.

If a higher current is used then it will charge more rapidly. This is not in general a pro rata relationship due to the limited charging voltage.

If the application has a particular recharge time requirement then this must be taken into account when calculating the battery.

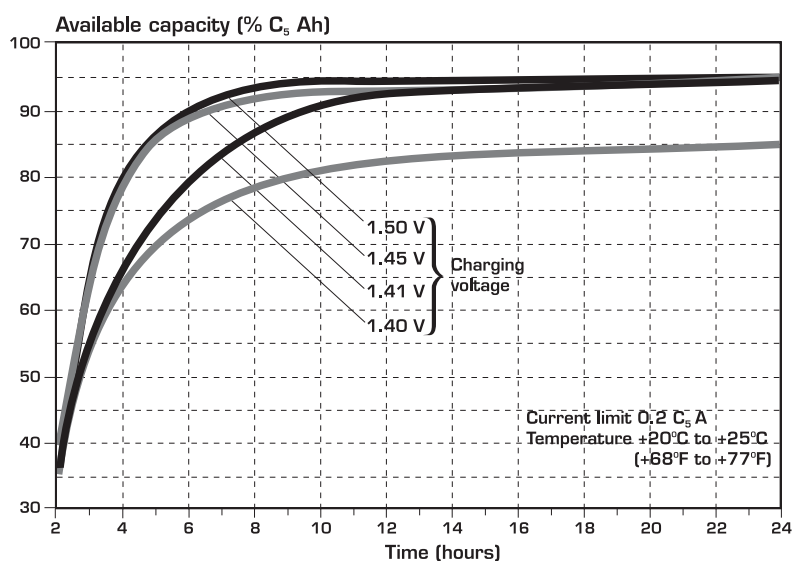


Figure 6: Available capacity for typical charging voltages

6.3 Charge efficiency

The charge efficiency of the battery 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 general, at states of charge less than 80% the charge efficiency remains high, but as the battery approaches a fully charged condition, the charging efficiency falls off. This is illustrated graphically in Figure 7.

6.4 Temperature effects

As the temperature increases, the electrochemical behavior becomes more active, and so for the same floating voltage, the current increases. As the temperature is reduced then the reverse occurs. Increasing the current increases the water loss, and reducing the current creates the risk that the cell will not be sufficiently charged. For standby application, it is normally not required to compensate the charging voltage with the temperature. However if water consumption is of main concern, temperature compensation

should be used if the battery is operating at high temperature such as +35°C (+95°F). At low temperature (< 0°C/+32°F), there is a risk of poor charging and it is recommended to adjust the charging voltage or to compensate the charging voltage with the temperature.

Value of the temperature compensation: -2 mV/°C/cell (-1.1 mV/°F/cell) starting from an ambient temperature of +20°C to +25°C (+68°F to +77°F).

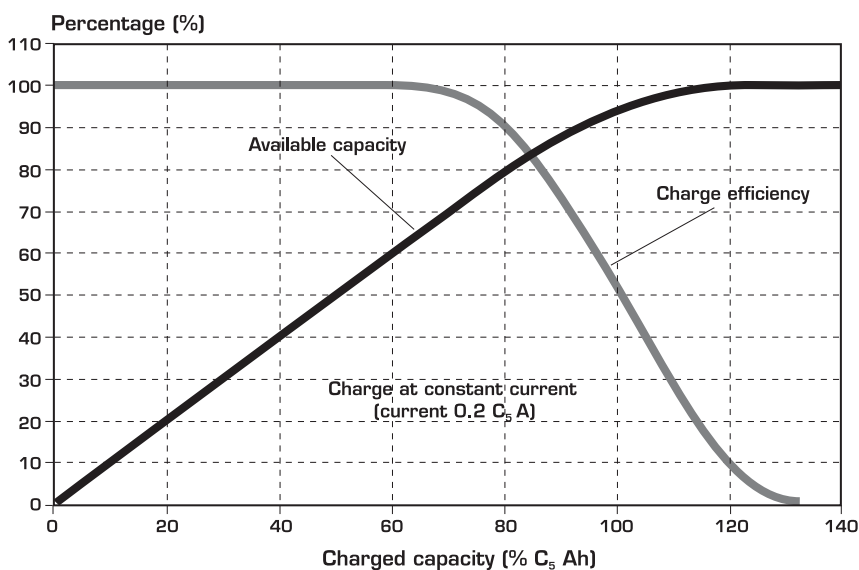


Figure 7: Charge efficiency as a function of state of charge

7. Special operating factors

7.1 Electrical abuse

Ripple effects

The nickel-cadmium battery is tolerant to high ripple and will accept ripple currents of up to $0.2 C_5 A I_{eff}$. In fact, the only effect of a high ripple current is that of increased water usage. Thus, in general, any commercially available charger or generator can be used for commissioning or maintenance charging of the SPH. This contrasts with the VRLA battery where relatively small ripple currents can cause battery overheating, and will reduce life and performance.

Over-discharge

If more than the designed capacity is taken out of a battery then it becomes deep-discharged and reversed. 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 SPH battery is designed to make recovery from this situation possible.

Overcharge

In the case of an SPH battery with its generous electrolyte reserve, a small degree of overcharge over a short period 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

Shock load

The SPH battery concept has been tested to IEC 68-2-29 (bump tests at 5 g, 10 g and 25 g) and IEC 77 (shock test 3 g), where g = acceleration.

Vibration resistance

The SPH battery concept has been tested to IEC 77 for 2 hours at 1 g, where g = acceleration.

External corrosion

All external metal components are nickel-plated or stainless steel, protected by a neutral vaseline and a rigid plastic cover.

8. Installation and operating instructions

Important recommendations

- Never allow an exposed flame or spark near the battery, particularly while charging.
- Never smoke while performing any operation on the battery.
- For protection, wear rubber gloves, long sleeves, and appropriate splash goggles or face shield.
- The electrolyte is harmful to skin and eyes. In the event of contact with skin or eyes, wash immediately with plenty of water. If eyes are affected, flush with water, and obtain immediate medical attention.
- Remove all rings, watches and other items with metal parts before working on the battery.
- Use insulated tools.
- Avoid static electricity and take measures for protection against electric shocks.
- Discharge any possible static electricity from clothing and/or tools by touching an earth-connected part "ground" before working on the battery.

8.1 Receiving the shipment

Unpack the battery immediately upon arrival. Do not overturn the package. Transport seals are located under the cover of the vent plug.

The battery is normally shipped filled, discharged and ready for installation.

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

8.2 Storage

Store the battery indoors in a dry, clean and cool location (0°C to +30°C/+32°F to +86°F).

- Do not store in unopened packing crates. The lid and the packing material on top of the cells must be removed.
- Make sure that the transport seals remain in place during storage.
- Do not store in direct sunlight or exposed to excessive heat.
- A battery delivered discharged and filled may be stored for many years before it is installed.
- A battery delivered exceptionally 80% charged (for starting application) **must not be stored for more than 3 months (including transport)**.

8.3 Installation

8.3.1 Location

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

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

The batteries can be fitted on to stands, floor-mounted or fitted into cabinets.

Local standards or codes normally define the mounting arrangements of batteries, and these must be followed if applicable. However, if this is not the case, the following comments should be used as a guide.

When mounting the battery, it is desirable to maintain an easy access to all cells; they should be situated in a readily available position.

Distances between stands, and between stands and walls, should be sufficient to give good access to the battery.

The overall weight of the battery must be considered and the load bearing on the floor taken into account in the selection of the battery accommodation.

If the battery is enclosed in a cabinet or other such enclosed space, it is important to provide sufficient space to disperse the gases given off during charging, and also to minimize condensation.

It is recommended that at least 200 mm be allowed above cell tops, to ensure easy access during inspection and water replenishment, and that enough space is allowed between cabinet walls and the battery to avoid any risk of short-circuits. Flip-top vents may be turned through 180° to achieve the most convenient position for water replenishment.

8.3.2 Ventilation

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

When the battery is housed in a cubicle or enclosed compartment, it is necessary to provide adequate ventilation.

During the last part of high-rate charging, the battery is emitting gases (oxygen and hydrogen mixture).

If it is required to establish that the ventilation of the battery room is adequate, then it is necessary to calculate the rate of evolution of hydrogen to ensure that the concentration of hydrogen gas in the room is kept within safe limits.

The theoretical safe limit for hydrogen concentration is 4%. However, some standards call for more severe levels than this, and levels as low as 1% are sometimes required.

To calculate the ventilation requirements of a battery room, the following method can be used:

1 Ah of overcharge breaks down 0.366 cm³ of water, and 1 cm³ of water produces 1.865 liters of gas in the proportion 2/3 hydrogen and 1/3 oxygen. Thus 1 Ah of overcharge produces 0.42 liters of hydrogen.

Therefore, the volume of hydrogen evolved from a battery per hour = number of cells x charge current x 0.42 liters or = number of cells x charge current x 0.00042 m³

The volume of hydrogen found by

this calculation can be expressed as a percentage of the total volume of the battery room, and from this, the number of air changes required to keep the concentration of hydrogen below a certain level can be calculated.

Example:

A battery of 98 cells, type SPH 70 on a two step, two tier stand, is placed in a room of dimensions 2 m x 2 m x 3 m. The charging system is capable of charging at 0.1 C₅ and so the charging current is 7 A. The volume of hydrogen evolved per hour in this, the worst, case is:

$$98 \times 7 \times 0.00042 \text{ m}^3 = 0.29 \text{ m}^3$$

The total volume of the room is 2 x 2 x 3 = 12 m³

Approximate volume of battery and stand does not exceed 1m³, and so, the volume of free air in the room is 11 m³. Therefore, the concentration of hydrogen gas after charging for 1 hour at full gassing potential at 0.1 C₅ will be:

$$\frac{0.29}{11} = 2.6\%$$

Thus, to maintain a maximum concentration of 3% (for example), the air in the room will need changing

$$\frac{2.6}{3} = \text{around 1 time per hour.}$$

In practice, a typical figure for natural room ventilation is about 2.5 air changes per hour, and so, in this case, it would not be necessary to introduce any forced ventilation.

In a floating situation, the current flowing is very much lower than when the cell is being charged, and the gas evolution is minimal;

it may be calculated in the same way using typical floating currents.

8.3.3 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 connecting nuts are:

- M 10 = 10 ± 2 N.m
- M 12 = 15 ± 2 N.m

The connectors and terminal nuts should be corrosion-protected by coating with a film of neutral vaseline.

Remove the transport seals and close the vents.

8.3.4 Electrolyte

The electrolyte to be used is: E4.

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 separator of each cell. The level should be at least 15 mm above the minimum mark and there is normally no need to adjust it.

When the cells are charged, the electrolyte level can be above the high level mark.

8.4 Commissioning

Verify that the ventilation is adequate during this operation.

- For filled and discharged cells stored up to 1 year, a commissioning charge is normally not required and the cells are ready for immediate use. If full performances are necessary immediately, a commissioning charge as

mentioned in the section below is recommended.

- For cells stored more than 1 year, a commissioning charge is necessary:
 - constant current charge is preferable: 8 h at 0.2 C₅ A. When the charger maximum voltage setting is too low to supply constant current charging, divide the battery into two parts to be charged individually.
 - constant potential charge: 1.50 V/cell minimum.

Charging time: 24 h if the charging current is limited to 0.2 C₅ A, 48 h if the charging current is limited to 0.1 C₅ A.

Please note: if cells have been stored in charged conditions for more than 3 months (including transport), or if cells have been stored for a few years or show difficulties in recovering performance, constant current charging becomes necessary and the following values are recommended:

- a) 15 h charge at 0.2 C₅ A
- b) discharge at 0.2 C₅ A down to 1.0 V/cell
- c) 8 h charge at 0.2 C₅ A
- d) the battery is ready for use.

8.5 Charging in service

At continuous parallel operation, the battery is on continuous charge and has only occasional discharges.

Recommended charging voltage (+20°C to +25°C/+68°F to +77°F):

- **for dual charge level:**
 - Float level: 1.40 ± 0.01 V/cell
 - High level: 1.45 ± 0.01 V/cell
- **for single charge level:** 1.41 ± 0.01 V/cell

In case of frequent deep discharges (cycling), the charging voltage values should be increased. See section 6.1.

For use at temperature outside +10°C to +30°C (+50°F to +86°F), the correcting factor for charge voltage is -2 mV/°C/cell (-1.1 mV/°F/cell).

8.6 Topping-up

No electrolyte level measurement is necessary if you use a Saft filling-pistol, which allows the correct level to be obtained by a simple nozzle setting. See nozzle lengths in Operating and Instruction sheet.

If a filling-pistol is not available, the electrolyte level can be checked by transparence or measured in the case of flame retardant containers. Insert a transparent glass or plastic tube (alkali resistant, 5 to 6 mm in diameter) vertically into the cell vent until it touches the top of the plates. Close the top end of the tube by putting a finger on it and remove the tube from the cell.

The height of the liquid in the tube indicates the electrolyte level above the plates.

	Level (mm)	
	high	low
SPH 16 B to SPH 47 B	25	5
SPH 11	25	5
SPH/F 16 to SPH/F 52	55	5
SPH/F 60 to SPH/F 80	70	5
SPH/F 90 to SPH/F 190	65	5
SPH/F 220 to SPH/F 320	55	5

8.7 Periodic maintenance

- Keep the battery clean using only water. Do not use a wire brush or solvents of any kind. Vent caps can be rinsed in clean water if necessary.
- Check visually the electrolyte level. Never let the level fall below the minimum level mark. Use only distilled or deionized water to top-up. Experience will tell the time interval between topping-up.

Note:
Once the battery has been filled with the correct electrolyte at the battery factory, there is no need to check the electrolyte density periodically. Interpretation of density measurements is difficult and could be misleading.
- Check every two years that all connectors are tight. The connectors and terminal nuts should be corrosion-protected by coating with neutral vaseline.

- It is important that the recommended charging voltage remains unchanged. The charger should be checked at least once a year. High water consumption of the battery is usually caused by improper voltage setting of the charger.

8.8 Changing electrolyte

Due to the sintered electrode plastic-bonded technology, it is not necessary to change the electrolyte during the lifetime of the cell.

9. Maintenance of the SPH in service

In a correctly designed standby application, SPH requires the minimum of attention. However, it is good practice with any system to carry out an inspection at least once per year, or at the recommended water replenishment interval, to ensure that the charger, the battery and the auxiliary electronics are all functioning correctly.

When this inspection has been done, it is recommended that certain procedures should be carried out to ensure that the battery is maintained in a good state.

9.1 Cleanliness/mechanical

Cells must be kept clean and dry at all times, as dust and damp cause current leakage. Terminals and connectors should be kept clean, and any spillage during maintenance should be wiped off with a clean cloth. The battery can be cleaned, using water. Do not use a wire brush or a solvent of any kind. Vent caps can be rinsed in clean water, if necessary.

Check that the flame-arresting vents are tightly fitted and that there are no deposits on the vent cap.

Terminals should be checked for tightness, and the terminals and connectors should be corrosion-

protected by coating with a thin layer of neutral grease or anti-corrosion oil.

9.2 Water replenishment

Check the electrolyte level. Never let the level fall below the lower MIN mark. Use only approved distilled or deionized water to replenish. Do not overfill the cells.

Excessive consumption of water indicates operation at too high a voltage or too high a temperature. Negligible consumption of water, with batteries on continuous low current or float charge, could indicate under-charging.

A reasonable consumption of water is the best indication that a battery is being operated under the correct conditions. Any marked change in the rate of water consumption should be investigated immediately. The water replenishment interval can be calculated as described in section 4.9. However, it is recommended that, initially, electrolyte levels should be monitored monthly to determine the frequency of topping-up required for a particular installation.

Saft has a full range of water topping-up equipment available to aid this operation.

9.3 Capacity check

Electrical battery testing is not part of normal routine maintenance, as the battery is required to give the back-up function and cannot be easily taken out of service.

However, if a capacity test of the battery is needed, the following procedure should be followed:

- a) Charge of 7.5 h at 0.2 C₅ A
- b) Discharge the battery at the rate of 0.2 C₅ A to a final average voltage of 1.0 V/cell (i.e. 92 V for a 92 cell battery)
- c) Charge of 7.5 h at the same rate used in a)
- d) Discharge at the same rate used in a), measuring and recording current, voltage and time every quarter hour. This should be continued until a final average voltage of 1.0 V/cell is reached. The overall state of the battery can then be seen, and if individual cell measurements are taken, the state of each cell can be observed.

9.4 Recommended maintenance procedure

In order to obtain the best from your battery, the following maintenance procedure is recommended.

Yearly
check charge voltage settings
check cell voltages
check float current of the battery
Every 2 years
clean cell lids and battery area
check torque values
protect terminal nuts and terminals with neutral vaseline
Every 5 years or as required
capacity check
As required
replenish with water according to defined period (depend on float voltage, cycles and temperature)

It is also recommended that a maintenance record be kept which should include a record of the temperature of the battery room.

10. Disposal and recycling

In a world where autonomous sources of electric power are ever more in demand, Saft batteries provide an environmentally responsible answer to these needs. Environmental management lies at the core of Saft's business and we take care to control every stage of a battery's life-cycle in terms of potential impact. Environmental protection is our top priority, from design and production through end-of-life collection, disposal and recycling.

Our respect for the environment is complemented by an equal respect for our customers. We aim to generate confidence in our products, not only from a functional standpoint, but also in terms of the environmental safeguards that are built into their life-cycle. The simple and unique nature of the battery components make them readily recyclable and this process safeguards valuable natural resources for future generations.

In partnership with collection agencies worldwide, Saft organizes retrieval from pre-collection points and the recycling of spent Saft batteries. Information about Saft's collection network can be found on our web site :

www.saftbatteries.com

Ni-Cd batteries must not be discarded as harmless waste and should be treated carefully in accordance with local and national regulations. Your Saft representative can assist with further information on these regulations and with the overall recycling procedure.

