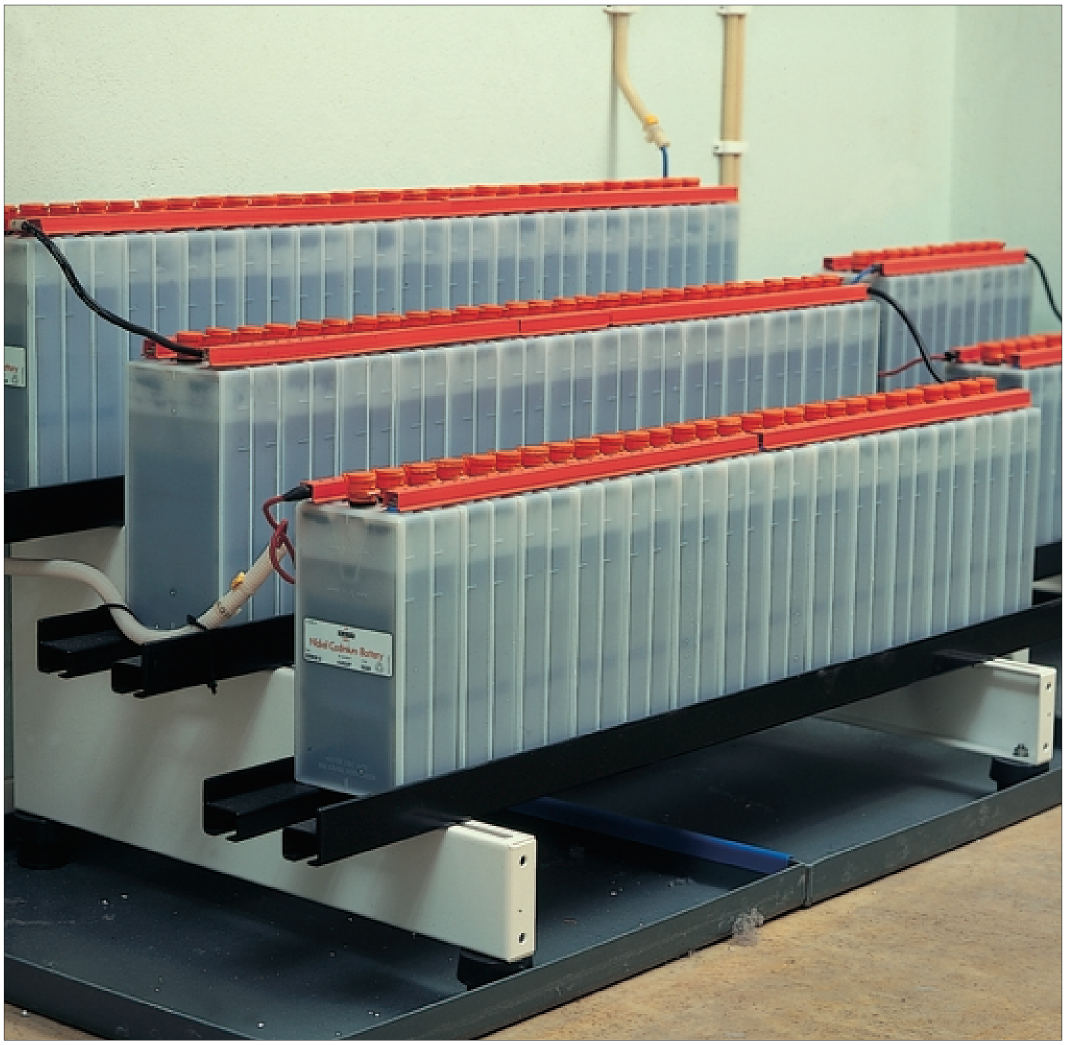
Nickel-cadmium block battery
Technical manual



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Contents

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 the nickel-cadmium battery has become an obvious first choice for users looking for a reliable, long life, low maintenance, system.

This manual details the design and operating characteristics of the Saft Nife pocket plate block battery to enable a successful battery 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 its only major maintenance requirement is topping up with water.

For the valve-regulated and photovoltaic pocket plate ranges, Ultima and Sunica, specific technical manuals are available which address the particular characteristics of these ranges.

2. Benefits of the block battery

2.1 Complete reliability

The block battery does not suffer from the sudden death failure associated with the lead acid battery (see section 4.1 Plate assembly).

2.2 Long cycle life

The block battery has a long cycle life even when the charge / discharge cycle involves 100 % depth of discharge (see section 6.7 Cycling).

2.3 Exceptionally long lifetime

A lifetime in excess of twenty years is achieved by the Saft Nife block battery in many applications, and at elevated temperatures it has a lifetime unthinkable for other widely available battery technologies (see section 6.8 Effect of temperature on lifetime).

2.4 Low maintenance

With its generous electrolyte reserve, the block battery reduces the need for topping up with water, and can be left in remote sites for long periods without any maintenance (see section 6.9 Water consumption and gas evolution).

2.5 Wide operating temperature range

The block battery has an electrolyte which allows it to have a normal operating temperature of from -20°C to +50°C, and accept extreme temperatures, ranging from as low as -50°C to up to +60°C (see section 4.3 Electrolyte).

2.6 Fast recharge

The block battery can be recharged at currents which allow very fast recharge times to be achieved (see 8.3 Charge acceptance).

2.7 Resistance to mechanical abuse

The block battery is designed to have the mechanical strength required to withstand all the harsh treatment associated with transportation over difficult terrain (see section 9.2 Mechanical abuse).

2.8 High resistance to electrical abuse

The block battery will survive abuse which would destroy a lead acid battery, for example overcharging, deep discharging, and high ripple currents (see section 9.1 Electrical abuse).

2.9 Simple installation

The block battery can be used with a wide range of stationary and mobile applications as it produces no corrosive vapors, uses corrosion-free polypropylene containers and has a simple bolted connector assembly system (see section 10 Installation and storage).

2.10 Extended storage

When stored in the empty and discharged state under the recommended conditions, the block battery can be stored for many years (see section 10 Installation and storage).

2.11 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 block battery product (see section 4 Construction features of the block battery).

2.12 Environmentally safe

More than 99 % of the nickel-cadmium block battery can be recycled, and Saft operates a dedicated recycling center to recover the nickel, cadmium, steel and plastic used in the battery.

2.13 Low life-cycle cost

When all the factors of lifetime, low maintenance requirements, simple installation and storage and resistance to failure are taken into account, the Saft Nife block battery becomes the most cost effective solution for many professional applications.

3. Electrochemistry of nickel-cadmium batteries

The nickel-cadmium battery uses nickel hydroxide as the active material for the positive plate, and 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 resulting in an 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.

The charge/discharge reaction is as follows:

$$2\ NiOOH + 2H_2O + Cd \underset{\text{charge}}{\overset{\text{discharge}}{\rightleftarrows}} 2\ Ni(OH)_2 + Cd(OH)_2$$

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, 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.

4. Construction features of the block battery

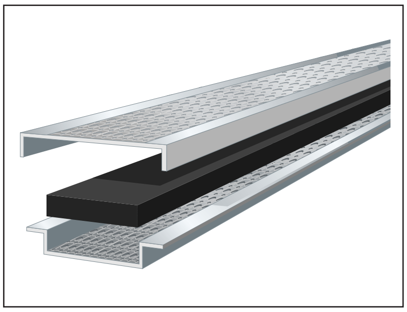
The cells are welded together to form rugged blocks of 1-10 cells depending on the cell size.

Saft Nife battery cells fulfill all requirements specified by IEC, publication 623.

4.1 Plate assembly

The nickel-cadmium cell consists of two groups of plates, the positive containing nickel hydroxide and the negative containing cadmium hydroxide.

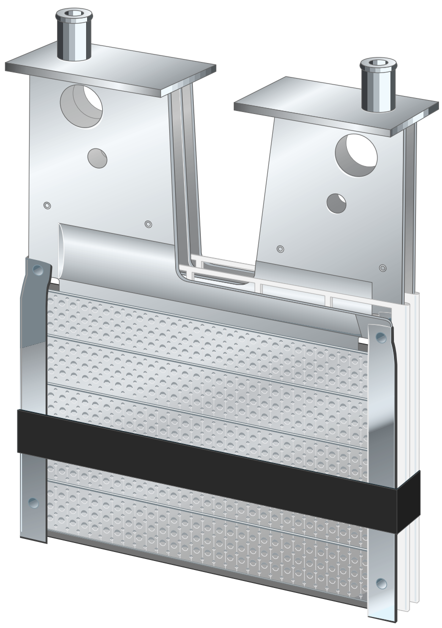
The active materials of the Saft Nife pocket plate block battery are retained in pockets formed from steel strips double perforated by a patented process.



These pockets are mechanically linked together, cut to the size corresponding to the plate width 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 containment which promotes conductivity and minimizes 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 lifetime and cycle life because their plates are not gradually weakened by corrosion, 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 block 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.



4.2 Separation

Separation between plates is provided by injection molded plastic separator grids, integrating both plate edge insulation and plate separation. By providing a large spacing between the positive and negative plates and a generous quantity of electrolyte between plates, good electrolyte circulation and gas dissipation are provided, and there is no stratification of the electrolyte as found with lead acid batteries.

4.3 Electrolyte

The electrolyte used in the block battery, 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 and as high as +60°C. 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 block battery, 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. However, under certain conditions, such as extended use in high temperature situations, the electrolyte can become carbonated. If this occurs the battery performance can be improved by replacing the electrolyte (see section 11.4).

The standard electrolyte used for the first fill in cells (see 10.5 Discharged and empty cells) is E22 and for replacement in service is E13.

4.4 Terminal pillars

Short terminal pillars are welded to the plate bus bars using a well established and proven method. These posts are manufactured from steel bar, internally threaded for bolting on connectors and nickel plated.

The sealing between the cover and the terminal 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.

4.5 Venting system

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

4.6 Cell container

The battery is built up using well-proven block battery construction. The tough polypropylene containers are welded together by heat sealing.

The block battery uses 4 plate sizes or plate modules. These are designated module type 1, 2, 3 and 4. They can be recognized from the block dimensions as follows:

Block width (mm)	Block height (mm)	Plate module
123	194	1
123	264	2
195	349	3
195	405	4

Table 1 - Correlation between block dimensions and plate module number

5. Battery types and applications

In order to provide an optimum solution for the wide range of battery applications which exist, the block battery is constructed in three performance ranges.

Saft Battery types		SBL	SBM	SBH
Autonomy	mini maxi	1 h 100 h	15 min 2 h	1 s 30 min
Capacity range	mini maxi	7.5 1540	11 1390	8.3 920
Use of battery		Power backup Bulk energy storage	Power backup	Starting, Power backup
Applications		Engine starting - Switchgear - UPS - Process control - Data and information systems - Emergency lighting - Security and fire alarm systems - Switching and transmission systems - Signalling		
Railways intercity and urban transport		▼	▼	▼
Stationary				
Utilities electricity, gas, water production and distribution		▼	▼	▼
Oil and gas offshore & onshore, petrochemical refineries		▼	▼	▼
Industry chemical, mining, steel metal works		▼	▼	▼
Buildings public, private		▼	▼	▼
Medical hospitals, X-ray equipment		▼	▼	▼
Telecom radio, satellite, cable, repeater stations, cellular base stations		▼	▼	
Railroad substations & signalling		▼	▼	▼
Airports		▼	▼	▼
Military all applications		▼	▼	▼

5.1 Type L

The SBL is designed for applications where the battery is required to provide a reliable source of energy over relatively long discharge periods. Normally, the current is relatively low in comparison with the total stored energy, and the discharges are generally infrequent. Typical uses are power backup and bulk energy storage.

5.2 Type M

The SBM is designed for applications where the batteries are usually required to sustain electrical loads for between 30 minutes to 3 hours or for “mixed” loads which involve a mixture of high and low discharge rates. The applications can have frequent or infrequent discharges. The range is typically used in power backup applications.

5.3 Type H

The SBH is designed for applications where there is a demand for a relatively high current over short periods, usually less than 30 minutes in duration. The applications can have frequent or infrequent discharges. The range is typically used in starting and power backup applications.

5.4 Choice of type

In performance terms the ranges cover the full time spectrum from rapid high current discharges of a second to very long low current discharges of many hours. Table 2 shows in general terms the split between the ranges for the different discharge types. The choice is related to the discharge time and the end of discharge voltage. There are, of course, many applications where there are multiple discharges, and so the optimum range type should be calculated. This is explained in the chapter “Battery Sizing”.

1.14 V								
1.10 V		H						
1.05 V					M			
1.00 V							L	
	10 min	15 min	30 min	60 min	2 h	3 h	5 h	8 h

Table 2 - General selection of cell range

6. Operating features

6.1 Capacity

The block battery capacity is rated in ampere hours (Ah) and is the quantity of electricity which it can supply for a 5 hour discharge to 1.0 volts after being fully charged for 7.5 hours at $0.2C_5$A. This figure conforms to the IEC 623 standard.

6.2 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.

6.3 Internal resistance

The internal resistance of a cell varies with the temperature 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 block battery cell depends on the performance type and at normal temperature has the values given in Table 3 in milliohms per Ah of capacity.

To obtain the internal resistance of a cell it is necessary to divide the value from the table by the rated capacity.

For example, the internal resistance of a SBH 118 (module type 3) is given by:

$$\frac{39}{118} = 0.33 \text{ m}\Omega$$

The figures of Table 3 are 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, the internal resistance is about 40% higher.

Cell type	Module plate size (see table 1)			
	1	2	3	4
SBL	84	105	123	142
SBM	55	62	78	86
SBH	N/A	30	39	43

Table 3 - Internal resistance in relation to rated capacity

6.4 Effect of temperature on performance

Variations in ambient temperature affect the performance of the cell, and this must be allowed for in 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 low 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(a), H type, Figure 1(b), M type and Figure 1(c) L type for operating temperatures from -30°C to +50°C.

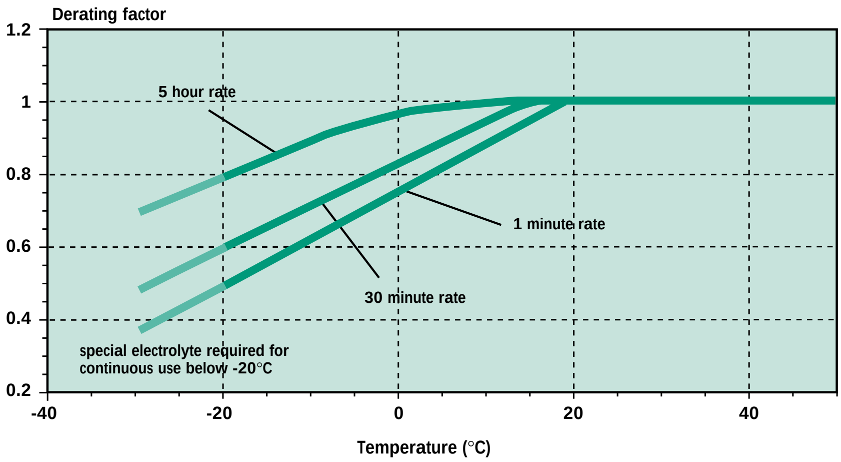


Figure 1(a) - Temperature derating factors for H type plate

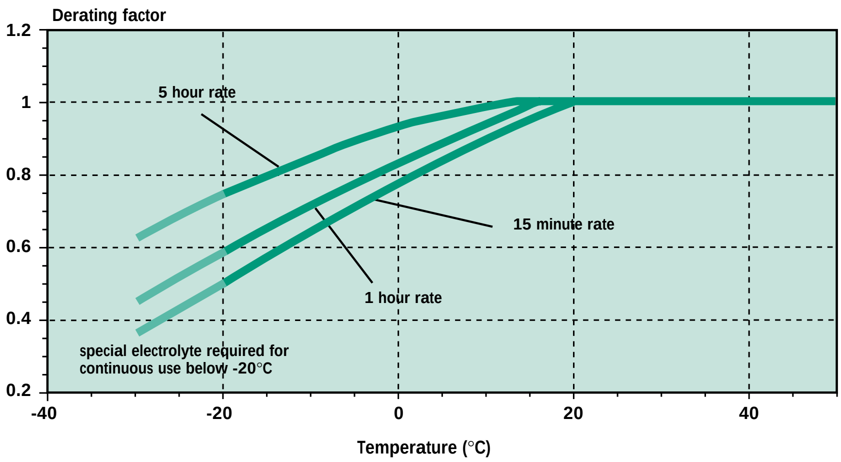


Figure 1(b) - Temperature derating factors for M type plate

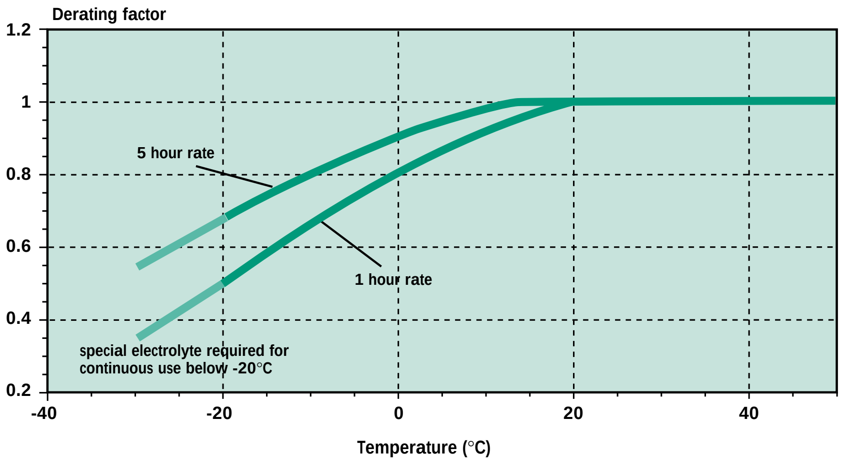


Figure 1(c) - Temperature derating factors for L type plate

6.5 Short-circuit values

The typical short-circuit value in amperes for a block battery cell is approximately 9 times the ampere-hour capacity for an L type block, 16 times the ampere-hour capacity for an M type block and 28 times the ampere-hour capacity for an H type block.

The block battery with conventional bolted assembly connections will withstand a short circuit current of this magnitude for many minutes without damage.

6.6 Open circuit loss

The state of charge of the block cell on open circuit 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°C.
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 typical open circuit loss for the block battery for a range of temperatures which may be experienced in a stationary application is shown in Figure 2.

6.7 Cycling

The block battery 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 thousands of operations, whereas a deep cycle will give only hundreds of 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.

6.8 Effect of temperature on lifetime

The block battery 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 the nickel-cadmium battery, and for 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 Eurobat and IEEE documentation.

In general terms, for every 9°C increase in temperature over the normal operating temperature of 25°C, 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 VRLA battery, 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.

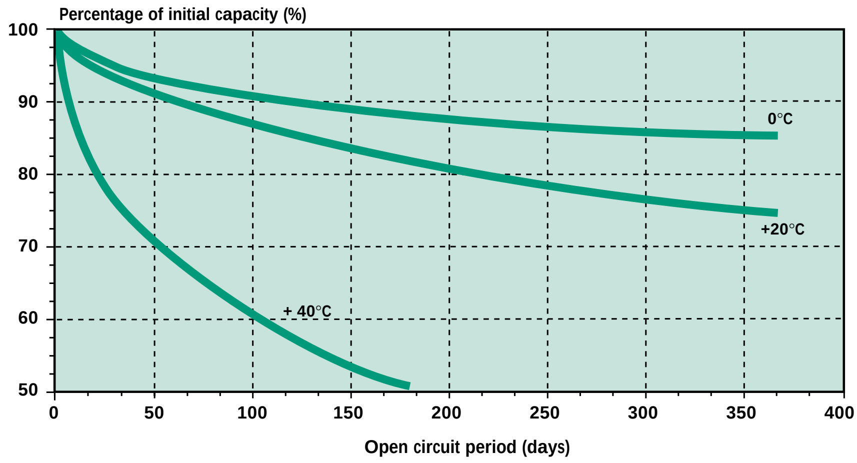


Figure 2 - Capacity loss on open circuit stand

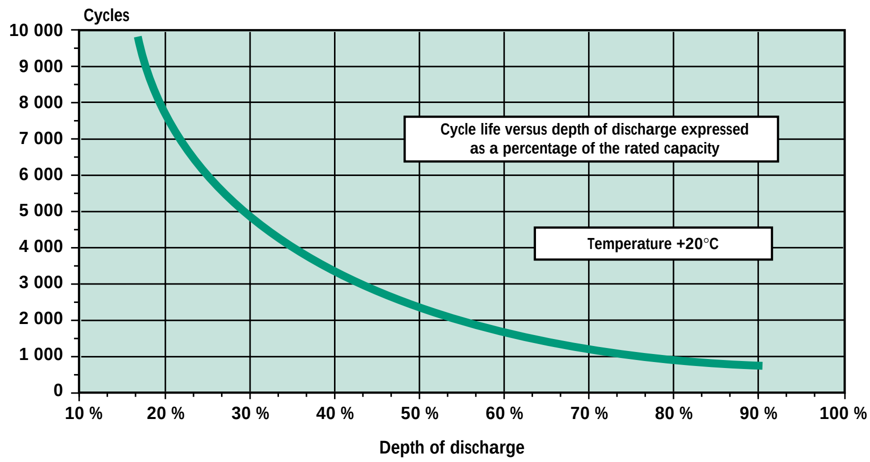


Figure 3 - Typical cycle life versus depth of discharge

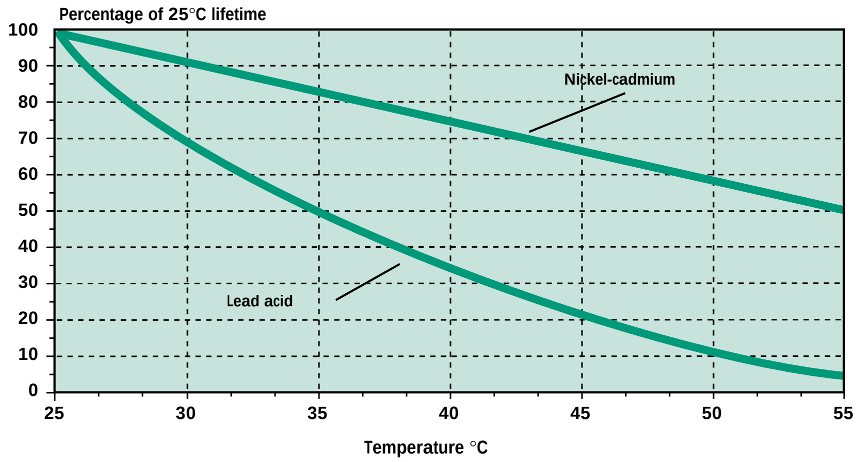


Figure 4 - Effect of temperature on lifetime

6.9 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 over-charge, 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 cm^3 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, so both have an influence on the consumption of water. Figure 5 gives typical water consumption values over a range of voltages for different plate types.

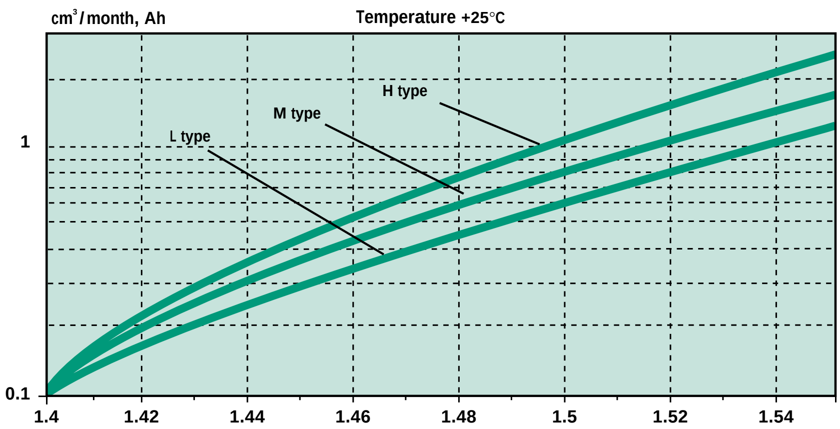


Figure 5 - Water consumption values for different voltages and plate types

Example: An SBM 161 is floating at 1.43 volts per cell. The electrolyte reserve for this cell is 500 cm^3.
From Figure 5, an M type cell at 1.43 volts per cell will use 0.27 cm^3/month for one Ah of capacity. Thus an SBM 161 will use 0.27 x 161 = 43.5 cm^3 per month and the electrolyte reserve will be used in $\frac{500}{43.5}$ = 11.5 months.

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

The electrolysis of 1 cm^3 of water produces 1865 cm^3 of gas mixture and this gas mixture is in the proportion of 2/3 hydrogen and 1/3 oxygen. Thus the electrolysis of 1 cm^3 of water produces about 1240 cm^3 of hydrogen.

7. Battery sizing principles in stationary standby applications

There are a number of methods which are used to size nickel-cadmium batteries for standby floating applications. These include the “Hoxie” sizing method, the IEEE 1115 .
All these 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 certain methods of approximation and each does this more or less successfully.

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:

7.1 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.

7.2 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.

7.3 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 re-calculated.

7.4 State of charge or recharge time

Some applications may require that the battery shall give a full-duty cycle after a certain time after 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.

7.5 Aging

Some customers require a value to be added to allow for the aging 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.

7.6 Floating effect

When a nickel-cadmium cell is maintained at a fixed floating voltageover 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 sizing program, the IEEE sizing method and the published data.

8. Battery charging

8.1 Charging generalities

The block battery can be charged by all normal methods. Generally, batteries in parallel operation with charger and load are charged with constant voltage. In operations where the battery is charged separately from the load, charging with constant current or declining current is possible. High-rate charging or overcharging will not damage the battery, but excessive charging will increase water consumption to some degree.

8.2 Constant voltage charging methods

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

The values used for the block battery ranges for single and two-rate charge systems are as shown in Table 5 below.

	single level (V)		two level (V)		
	min	max	min	max	floating
SBH	1.43	1.50	1.45	1.70	1.40
SBM	1.43	1.50	1.45	1.70	1.40
SBL	1.43	1.50	1.47	1.70	1.42

Table 5 - Charge and float voltages for the block battery ranges

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 (see Battery sizing chapter 7).

The values given as maximum are those which are acceptable to the battery, but would not normally be used in practice, particularly for the single level, because of high water usage.

8.3 Charge acceptance

A discharged cell will take a certain time to achieve a full state of charge. Figures 6(a), (b) and (c) give the capacity available for typical charging voltages recommended for the block battery range during the first 30 hours of charge from a fully discharged state.

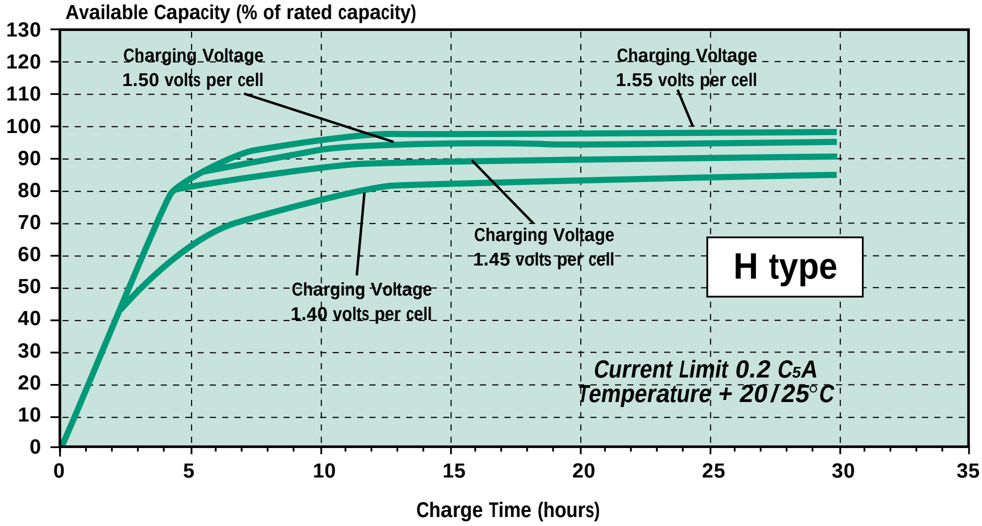


Figure 6(a) - Typical recharge times from a fully discharged state for the H block

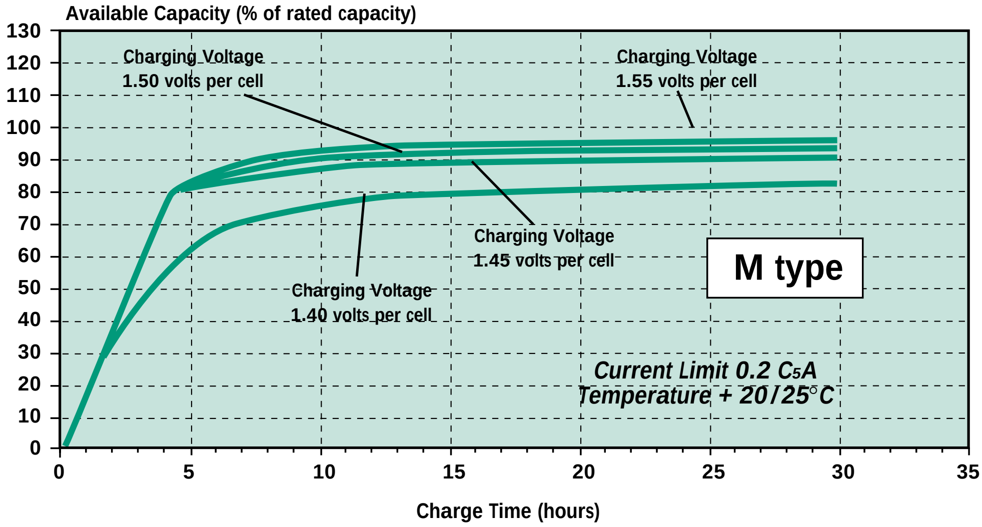


Figure 6(b) - Typical recharge times from a fully discharged state for the M block

These graphs gives the recharge time for a current limit of $0.2C_5$ amperes. Clearly, if a lower value for the current is used, e.g. $0.1C_5$ amperes, then the battery will take longer to charge.
If a higher current is used then it will charge more rapidly but, does so less efficiently, and so this is not a pro-rata relationship.

The charge time for an M type plate at different charge regimes for a fixed voltage is given in Figure 6(d).

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

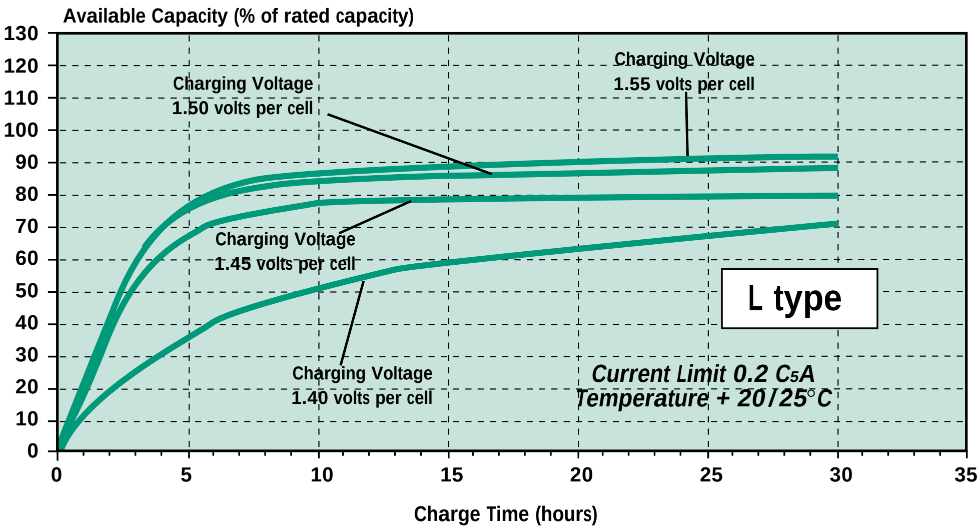


Figure 6(c) - Typical recharge times from a fully discharged state for the L block

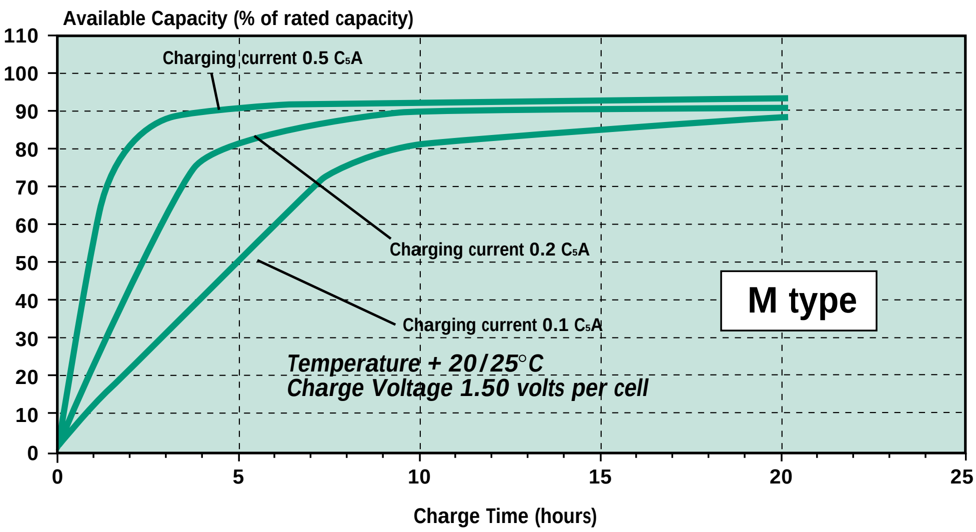


Figure 6(d) - Typical recharge times for different charge rates for the M block

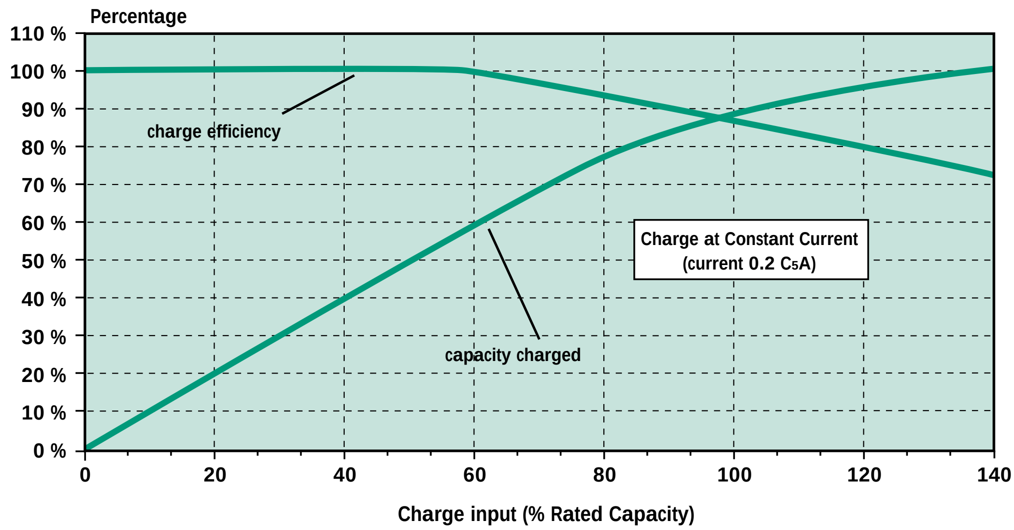


Figure 7 - Charge efficiency as a function of state of charge

8.4 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.

8.5 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. Thus, as it is clearly advantageous to maintain the same current through the cell, it is necessary to modify the floating voltage as the temperature changes. The recommended change in voltage required, or "temperature compensation", is -3 mV/ °C, starting from an ambient temperature of + 20°C to + 25°C.

8.6 Commissioning charge

It is recommended that a good first charge should be given to the battery. This is a once, only operation, and is essential to prepare the battery for its long service life. It is also important for discharged and empty cells which have been filled, as they will be in a totally discharged state.

A constant current first charge is preferable and this should be such as to supply 300% of the rated capacity of the cell. Thus, a 250 Ah cell will require 750 ampere hours input, e.g. 50 amperes for 15 hours.

Cells which have been stored for less than one year should be charged for 15 hours at the recommended charge current* before being placed in service.

Cells that have been stored for more than one year, or have been supplied empty and have been filled, should be charged for 15 hours at the recommended charge current * discharged to 1.0 volts per cell and then charged for 10 hours at the recommended charge current*.

In cases where it is not possible to provide constant current charging, it is possible to achieve this with a constant voltage by using a high voltage level, e.g. 1.65 voltage limit may be used for 20 to 30 hours, if the current limit is approximately equivalent to the 5 hour charge current*. If the current rating is lower, then the charge time should be increased accordingly.

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 a high voltage.

The battery can now be put into service.

**Please refer to the installation and operation instruction sheet.*

9. Special operating factors

9.1 Electrical abuse

Ripple effects

The nickel-cadmium battery is tolerant to high ripple and will accept ripple currents of up to $0.5C_5$ peak to peak. 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 block battery.
This contrasts with the valve regulated lead-acid battery (VRLA) where relatively small ripple currents can cause battery overheating, and will reduce life and performance.
Thus, for VRLA, the charger voltage must fall within ± 2.5% of the recommended float voltage.

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 block battery is designed to make recovery from this situation possible.

Overcharge

In the case of the block 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.

9.2 Mechanical abuse

Shock loads

The 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).

Vibration resistance

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

External corrosion

The block battery is manufactured in durable polypropylene. All external metal components are nickel-plated or stainless steel, protected by a neutral grease, and then protected by a rigid plastic cover.

10. Installation and storage

10.1 Batteries on arrival

On receiving the battery, open the cases and check for any indication of damage in transit.

Remove the cells and any accessories from the packaging, and check that the contents are in order and inspect for any damage in transit.

Damage must be reported immediately to the carrier, and the company or its agent.

If batteries are not put into service immediately they should be stored in a clean, dry, cool and well ventilated storage space on open shelves. Plastic cells should not be exposed to direct sunlight.

Before storage, ensure that:

a) Cells are kept clean with adequate protective finish, such as neutral grease on posts and connectors.

b) Electrolyte in cells is filled to the correct level.

c) Vents are correctly seated and vent plugs firmly in position.Keep the transit sealing tape in position.

Note that if excessive loss of electrolyte in transit is found in cells supplied filled, ensure that the cells are correctly filled before storage.

Filled cells

Filled cells can be stored for up to a maximum of one year. The cells should be sealed with the plastic transport seal supplied with the cells. Check the transport seals upon receipt.
If for unavoidable reasons filled cells have been stored for more than one year, then they must be given a maintenance cycle as follows:

a) Remove transport seals from the cells.

b) Discharge at the charging current* to 1.0 volts per cell.

c) Charge for 10 hours at the charging current* or equivalent.

d) Wait 24 hours for all gassing to stop.

e) Replace plastic transport seals and return to store.

For batteries stored more than 12 months, at least one discharge/charge cycle as above should be carried out before the commissioning charge is begun.

Discharged and empty cells

Cells discharged and empty can be stored for many years if kept under the correct conditions. They should be stored in a clean, dry, cool (+10°C to +30°C) and well ventilated storage space on open shelves. It is important that they are sealed with the transport seals firmly in place. These should be checked at least yearly, and if necessary replaced or refitted. Failure of the seal will result in an ingress of carbon dioxide from the atmosphere, which will result in carbonation of the plates. This can affect the capacity of the battery.

Storage of the battery at temperatures above +30°C can result in loss of capacity. This can be as much as 5% per 10°C above +30°C per year. Discharged and empty cells should be filled with electrolyte, then the procedure for filled cells stored more than 1 year must be followed.

Cells after storage

All cells after storage must be prepared for service and fully commissioned as described in section 8.6.

10.2 Cell oil

On top of the electrolyte of filled cells floats a layer of cell oil to reduce self discharge and water loss due to evaporation. This layer is approximately 5 mm thick and, when the cells are delivered empty, must be added to the cells after they have been filled with electrolyte.

**Please refer to the installation and operation instruction sheet.*

10.3 Emplacement

The battery should be installed in a dry and clean location away from direct sunlight, strong daylight and heat.

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

The battery will give the best performance and maximum service life when the ambient temperature is between + 10°C and + 35°C.

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 blocks, 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. In case of doubt, please contact your Saft Nife representative for advice.

When mounting the battery, ensure that the cells are correctly interconnected with the appropriate polarity. The battery connection to load should be with nickel-plated cable lugs.

Recommended torque for connecting screws are:

- M 5 = 7.5 ± 0.8 N.m
- M 6 = 11 ± 1.1 N.m
- M 8 = 20 ± 2 N.m
- M10 = 30 ± 3 N.m

To avoid accelerated aging of the plastic due to UV-light, batteries with plastic cell containers should not be exposed to direct sunlight or strong daylight for a prolonged period.

If the battery is enclosed in a cabinet or other such enclosed space, it is important to provide sufficient space to disperse the gasses 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 topping up, 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 topping-up.

10.4 Ventilation

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-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 normally accepted safe limit for hydrogen 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 cm^3 of water, and 1 cm^3 of water produces 1.865 liters of gas in the proportion 2/3 hydrogen and 1/3 oxygen. Thus, 1 Ah of overcharge produces 0.45 liters of hydrogen.

Therefore, the volume of hydrogen evolved from a battery per hour

= number of cells x charge current x 0.45 liters
or = number of cells x charge current x 0.00045 m^3

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 SBH 77 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 $0.1C_5$ and so the charging current is 7.7 amperes.

The volume of hydrogen evolved per hour in this, the worst, case is:
= 98 x 7.7 x 0.00045 m^3= 0.34m^3

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

Approximate volume of battery and stand does not exceed 1 m^3 , and so, the volume of free air in the room is 11 m^3 .

Therefore, the concentration of hydrogen gas after charging for 1 hour at full gassing potential at $0.1C_5$ will be:
$= \frac{0.34}{11} = 3\%$

Thus, to maintain a maximum concentration of 2 % (for example), the air in the room will need changing 3/2 = 1.5 times 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.

10.5 Preparation for service

Filled cells

Check that cells are externally clean with adequate protective finish on posts and connectors.

Carefully remove the plastic transport seal, and visually check that the electrolyte levels in the opened cells are at the MAX level.

If necessary, adjust by careful addition of approved distilled or demineralised water.

Wipe away any small spillage on cells using a clean cloth and close the flip-top vents to complete preparation for service.

The cells can now be commissioned as described in section 8.6.

Discharged and empty cells

Check that cells are externally clean with adequate protective finish on posts and connectors.

Identify and calculate the electrolyte type and quantity required to fill the cells*. Do not remove the plastic transport seals at this stage.

Prepare new electrolyte to requirement from solid electrolyte or liquid electrolyte, as supplied. When filling the cells, refer to the ìElectrolyte Instructionsî data sheet supplied with the electrolyte. Ensure that only demineralised or pure distilled water is used.

Carefully remove the plastic transport seal and leave the flip-top vents open.

Carefully fill the cells using a plastic jug and funnel to a level 5-10 mm below the MAX level. Allow the cells to stand for 24 hours. For large installations, a pump system is recommended.

Add cell oil as described in the electrolyte leaflet.

After 24 hours stand, carefully complete filling the cell to the maximum level.

Wipe away any small spillage on cells using a clean cloth and close the flip-top vents to complete preparation for service.

The cells can now be commissioned as described in section 8.6.

**Please refer to the installation and operation instruction sheet.*

11. Maintenance of block batteries in service

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

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

11.1 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.

11.2 Topping-up

Check the electrolyte level. Never let the level fall below the lower MIN mark. Use only approved distilled or deionised water to top-up. 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 topping-up interval can be calculated as described in section 6.9. 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 topping-up equipment available to aid this operation.

11.3 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) Discharge the battery at the rate of $0.1C_5$ to $0.2C_5$ amperes (10 to 20 amperes for a 100 Ah battery) to a final average voltage of 1.0 volts per cell (i.e. 92 volts for a 92 cell battery)

b) Charge 200% (i.e. 200 Ah for a 100 Ah battery at the same rate used in a)

c) Discharge at the same rate used in a), measuring and recording current, voltage and time every hour, and more frequently towards the end of the discharge. This should be continued until a final average voltage of 1.0 volts per 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.

11.4 Changing electrolyte

In most stationary battery operations, the electrolyte will retain its effectiveness for the life of the battery. Thus, normally it is not necessary to change the electrolyte.

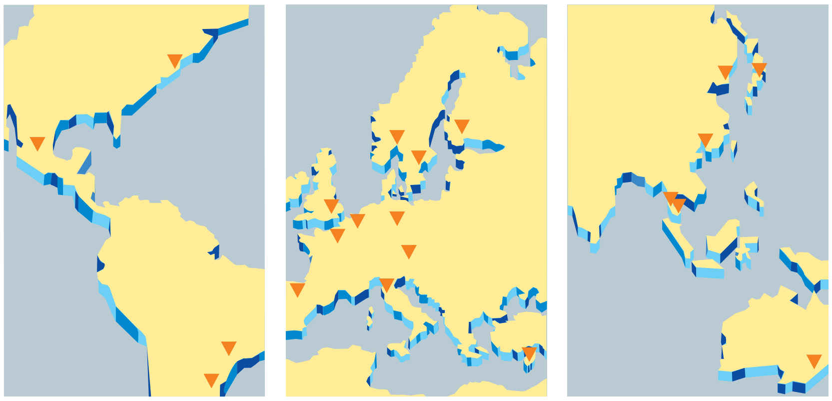
However, under certain battery operating conditions involving high temperature and cycling, the electrolyte can become excessively carbonated. Under these circumstances the battery performance can be improved by replacing the electrolyte. Please consult your Saft representative under these conditions.

11.5 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 (30mV deviation from average is acceptable)
check float current of the battery
check electrolyte level
equalizing charge if agreed for application
clean cell lids and battery area check torque values grease terminals and connectors
every 5 years or as required
capacity check
as required
top-up 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.



Saft, the brand name of the battery activity within Alcatel's Cables and Components Sector, hold a leading position in the worldwide marketplace of self-contained energy solutions. Saft's product range includes portable power sources, industrial and advanced technology and power systems.
As one of Saft's three product groups, the Advanced and Industrial Battery Group spans an extremely broad range of industrial applications : aircraft, railways, electric vehicles, space, defense and other industries.
Its plants, located in Bordeaux, Poitiers, France, Oskarshamn, Sweden and Valdosta, Georgia, U.S.A., are operated through a quality management system that extends to R&D and production automation. All sites are ISO 9001 certified.
Nickel-cadmium batteries are 99.9% recyclable and Saft operates its own dedicated recycling center.

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