S3.4

Single Cell Range

Technical manual

Delivering quality

ALCAD

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 Alcad pocket plate 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.

2 Benefits of the Alcad pocket plate nickel-cadmium battery

2.1 Complete reliability

The Alcad 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 Alcad 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 Alcad 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 Alcad 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 Alcad battery has an electrolyte which allows it to have a normal operating temperature of from – 20°C to + 50°C (– 4°F to + 122°F), and to accept extreme temperatures, ranging from as low as – 50°C to up to + 70°C (– 58°F to up to + 158°F) (see section 4.3 Electrolyte).

2.6 Fast recharge

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

2.7 Resistance to mechanical abuse

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

2.10 Extended storage

When stored in the empty and discharged state under the recommended conditions, the Alcad battery can be stored for many years (see section 10.2 Storage).

2.11 Well-proven pocket plate construction

Alcad 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 battery (see section 4 Construction features of the pocket plate battery).

2.12 Environmentally safe

Alcad operates a dedicated recycling centre to recover the nickel, cadmium, steel and plastic used (see section 12 Disposal and recycling).

2.13 Low life-cycle cost

When all the factors of lifetime, low maintenance requirements, simple installation and storage and resistance to abuse are taken into account, the Alcad 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 negative and positive plates is steel. This is unaffected by the electrolyte, and retains its strength 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 of a nickel-cadmium battery is as follows:

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.

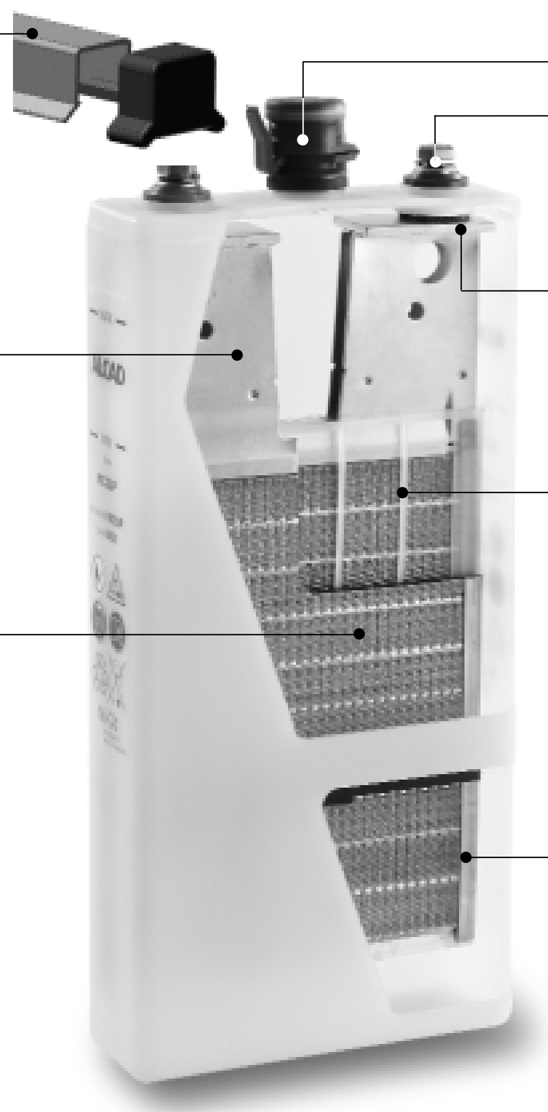
Unlike the lead acid battery, there is little change in the electrolyte density during charge and discharge. This allows large reserves of electrolyte to be used without inconvenience to the electrochemistry of the couple.

Thus, through its electrochemistry, the nickel-cadmium battery has a more stable behaviour 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 (V).

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

4 Construction features of the pocket plate battery



Alcad cells fulfil all requirements specified by IEC 60623

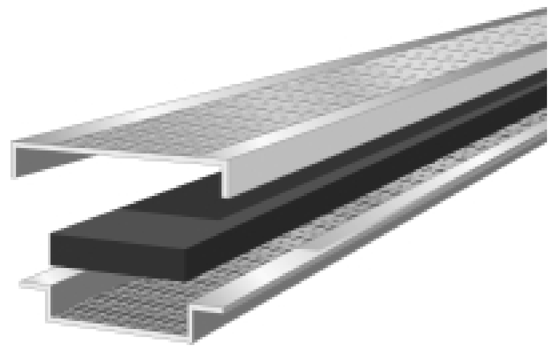
4.1 Plate assembly

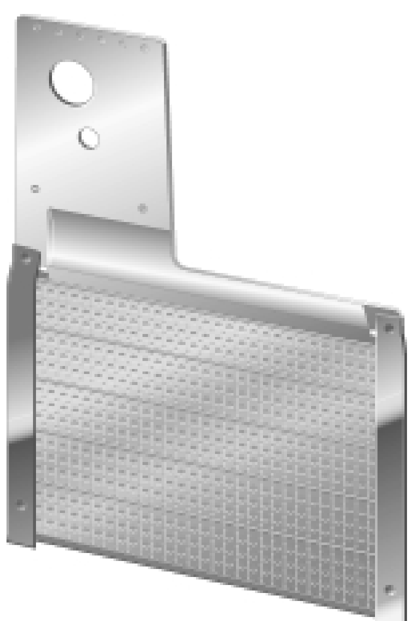
The nickel-cadmium cell consists of two groups of plates, the positive containing nickel hydroxide and the negative containing cadmium hydroxide.

The active materials of the Alcad pocket plate 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 plate which is not only mechanically very strong but also retains its active material within a steel containment which promotes conductivity and minimises electrode swelling.

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





Nickel-cadmium batteries have an exceptionally good 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 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 Alcad battery, a solution of potassium hydroxide and lithium hydroxide, is optimised 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 to temperature extremes as low as – 20°C (– 4°F) and as high as + 50°C (+ 122°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.

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 either at the battery factory or during the battery commissioning 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.

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.

The standard electrolyte used for the first fill in 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 Alcad battery is fitted with a special flame-arresting flip-top vent to give an effective and safe venting system.

4.6 Cell container

The material in the cell containers is translucent polypropylene, a tough and well-proven plastic for battery use. The lid and container are welded together by heat sealing, creating a homogeneous joint.

5 Battery types and applications

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

5.1 Type L

The L type 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 back-up and bulk energy storage.

5.2 Type M

The M type 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 back-up applications.

5.3 Type H

The H type 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 back-up 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 1 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 section 7 Battery sizing.

5.5 Applications

Alcad batteries are providing standby back-up and emergency power for industry and commerce, government and defence departments, electricity supply and distribution installations, railway authorities, hospitals, airports, public buildings, bus and commercial vehicle companies, communications networks, oil and petrochemical industries, etc. The applications are all industrial applications such as emergency lighting, switchgear, UPS, process control, data and information systems, security and fire alarm systems, signalling, turbine and engine starting and electric train duties.

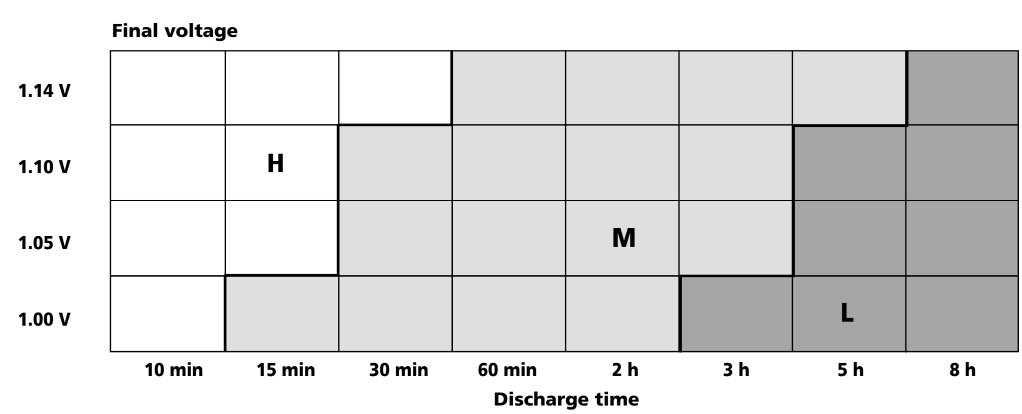


Table 1- General selection of cell range

6 Operating features

6.1 Capacity

The nickel-cadmium battery 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 for 7.5 hours at 0.2 C_5 A. This figure conforms to the IEC 60623 standard.

According to the IEC 60623 (Edition 4), 0.2 C_5 A is also expressed as 0.2 I_t A. The reference test current (I_t) is expressed as:

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

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.

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 V.

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 an Alcad pocket plate cell depends on the performance type and size. The normal values are given in the performance data brochures.

The normal values 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 (+32°F), the internal resistance is about 40% higher.

6.4 Effect of temperature on performance

Variations in ambient temperature affect the performance of the cell and this needs to be taken into account when sizing the battery.

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 – 20°C to + 50°C (-4°F to +122°F).

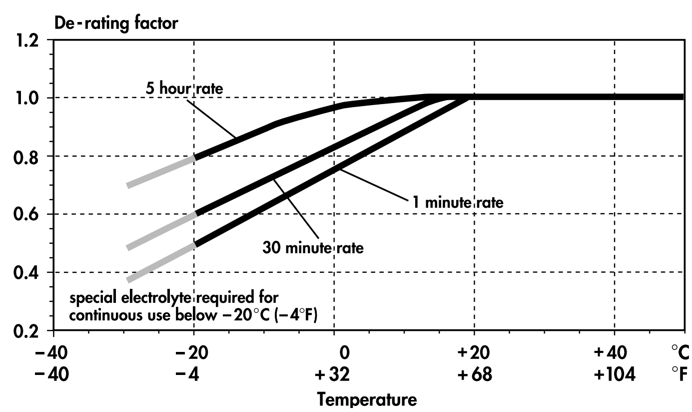


Figure 1 (a) – Temperature de-rating factors for H type cell

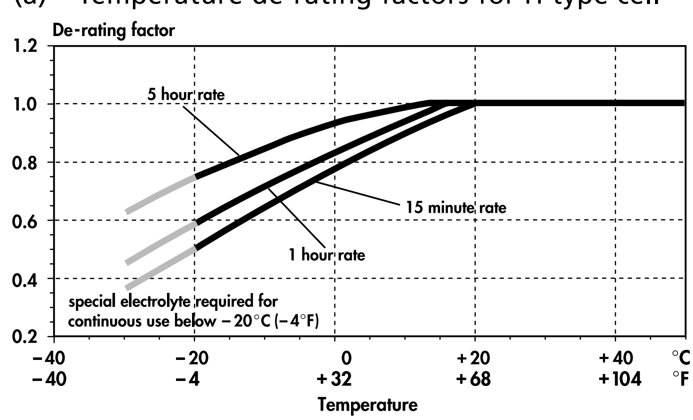


Figure 1 (b) – Temperature de-rating factors for M type cell

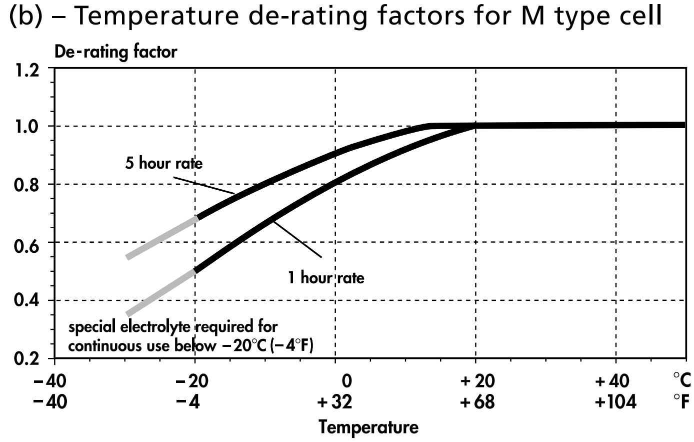


Figure 1 (c) – Temperature de-rating factors for L type cell

6.5 Short-circuit values

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

A 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 a 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 stabilises to about 2% per month at +20°C (+68°F).

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

The typical open circuit loss for a pocket plate battery for a range of temperatures which may be experienced in a stationary application is shown in Figure 2.

6.7 Cycling

The Alcad battery is designed to withstand the wide range of cycling behaviour 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.

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.

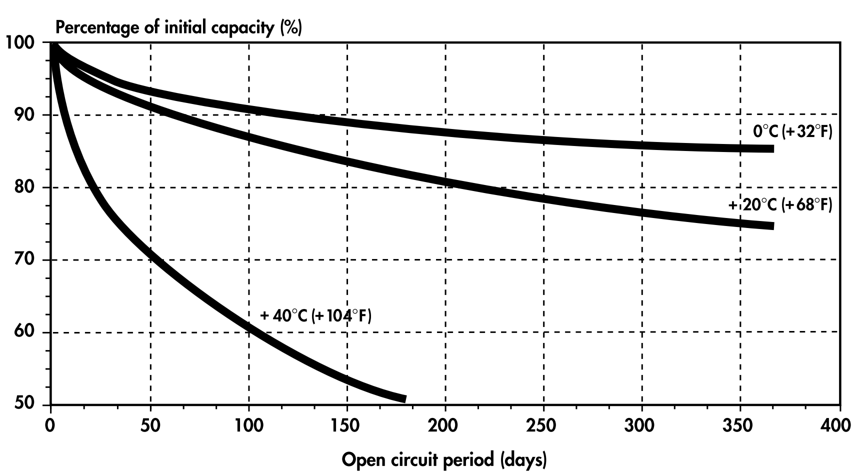


Figure 2 – Capacity loss on open circuit stand

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 Alcad 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 for 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 (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 (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 (+122°F).

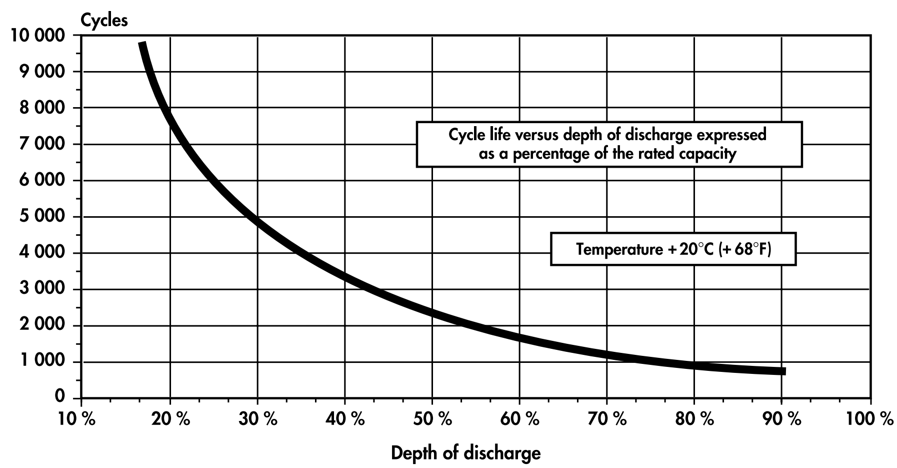


Figure 3 – Typical cycle life versus depth of discharge

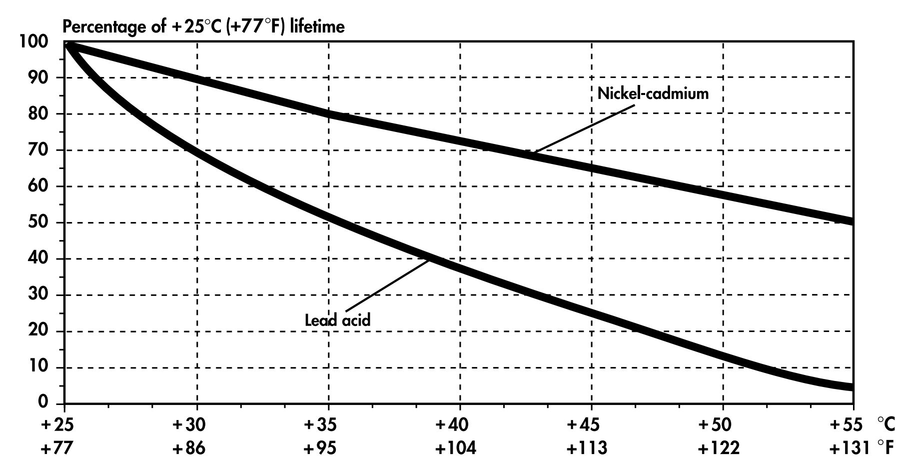


Figure 4 – Effect of temperature on lifetime

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 overcharge, breaks down the water content of the electrolyte into oxygen and hydrogen, and pure distilled or deionized 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 counteract 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 cell types.

Example: An LB 470 P is floating at 1.42 V/cell. The electrolyte reserve for this cell is 1300 cm^3. From Figure 5, an L type cell at 1.42 V/cell will use 0.16 cm^3/month for one Ah of capacity. Thus an LB 470 P will use 0.16 x 470 = 75.2 cm^3 per month and the electrolyte reserve will be used in

$$\frac{1300}{75.2} = 17.5 \text{ months.}$$

The gas evolution is a function of the amount of water electrolysed 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 1243 cm^3 of hydrogen.

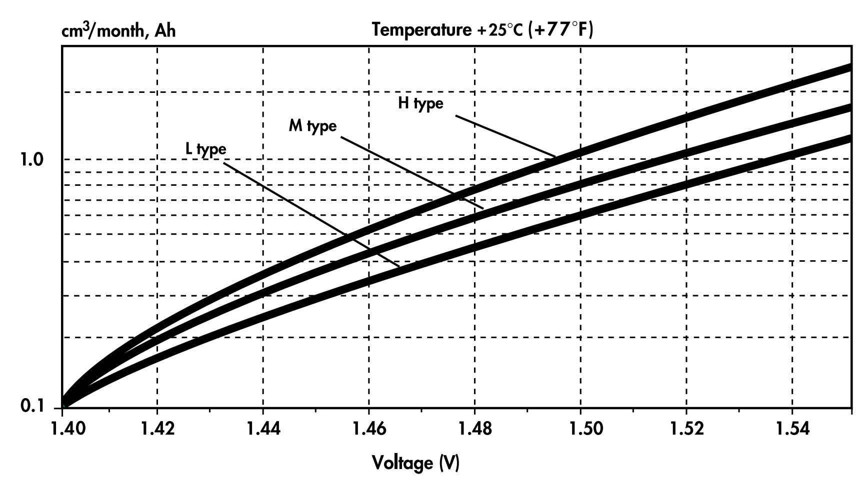


Figure 5 – Water consumption values for different voltages and cell types

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. The method employed by Alcad is the IEEE 1115 recommendation which is accepted internationally. The method takes into account multiple discharges, temperature de-rating, performance after floating and the voltage window available for the battery.

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 recalculated.

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 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.

7.6 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 cannot be eliminated by a boost charge.

It is therefore necessary to take this into account in any calculations concerning batteries in float applications.

As the effect of reducing the voltage level is to reduce the autonomy of the battery, the effect can be considered as reducing the performance of the battery and so performance down-rating factors are used. The factors which can be used for the Alcad battery are given in Table 2. Thus it is possible to use fully charged data and multiply by a de-rating factor, or to use data which has already been calculated for off-floating performance. It is this latter method which is used in the sizing program and the IEEE sizing method.

Type H

EOD*	**Time**														
V/cell	**Hours**						**Minutes**						**Seconds**		
	8 h	5 h	3 h	2 h	1.5 h	1 h	30 min	20 min	15 min	10 min	5 min	1 min	30 s	5 s	1 s
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.93	0.88	0.84	0.84	0.84	0.84
1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.92	0.88	0.83	0.81	0.81	0.81	0.81
1.10	1.00	1.00	1.00	1.00	1.00	0.99	0.92	0.87	0.85	0.81	0.77	0.76	0.76	0.76	0.76
1.14	1.00	1.00	1.00	1.00	1.00	0.94	0.85	0.81	0.79	0.75	0.72	0.71	0.71	0.71	0.71

Table 2(a) - Typical floating de-rating factors from fully charged data for H type cells

* End of Discharge

Type M

EOD*	**Time**														
V/cell	**Hours**						**Minutes**						**Seconds**		
	8 h	5 h	3 h	2 h	1.5 h	1 h	30 min	20 min	15 min	10 min	5 min	1 min	30 s	5 s	1 s
1.00	1.00	1.00	1.00	1.00	0.93	0.87	0.82	0.82	0.81	0.80	0.80	0.80	0.80	0.80	0.80
1.05	1.00	1.00	1.00	0.90	0.85	0.82	0.78	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.75
1.10	1.00	1.00	0.93	0.84	0.80	0.77	0.74	0.73	0.72	0.71	0.71	0.71	0.71	0.71	0.71
1.14	1.00	1.00	0.85	0.77	0.75	0.72	0.69	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.67

Table 2(b) - Typical floating de-rating factors from fully charged data for M type cells

* End of Discharge

Type L

EOD*	**Time**															
V/cell	**Hours**							**Minutes**						**Seconds**		
	10 h	8 h	5 h	3 h	2 h	1.5 h	1 h	30 min	20 min	15 min	10 min	5 min	1 min	30 s	5 s	1 s
1.00	1.00	1.00	1.00	1.00	0.95	0.90	0.87	0.83	0.82	0.81	0.80	0.80	0.79	0.79	0.79	0.79
1.05	1.00	1.00	1.00	0.91	0.86	0.84	0.81	0.78	0.77	0.76	0.76	0.75	0.74	0.74	0.74	0.74
1.10	1.00	0.97	0.90	0.83	0.80	0.78	0.76	0.73	0.73	0.72	0.71	0.70	0.70	0.70	0.70	0.70
1.14	1.00	0.95	0.81	0.76	0.74	0.73	0.71	0.68	0.68	0.67	0.66	0.65	0.65	0.65	0.65	0.65

Table 2(c) - Typical floating de-rating factors from fully charged data for L type cells

* End of Discharge

8 Battery charging

8.1 Charging generalities

The Alcad 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 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 maintenance charge or float voltage level.

The values used for the Alcad pocket plate battery ranges for single and two-rate charge systems are as shown in Table 3 below.

To minimise the water usage, it is important to use a low charge voltage per cell, 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 per cell (see section 7 Battery sizing).

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

Cell type	Single level: (V/cell)		Two level: (V/cell)		
	min	max	min	max	floating
H	1.43	1.50	1.45	1.70	1.40 ± 0.01
M	1.43	1.50	1.45	1.70	1.40 ± 0.01
L	1.43	1.50	1.47	1.70	1.42 ± 0.01

Table 3 – Charge and float voltages for the Alcad pocket plate battery ranges

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 pocket plate battery range during the first 30 hours of charge from a fully discharged state.

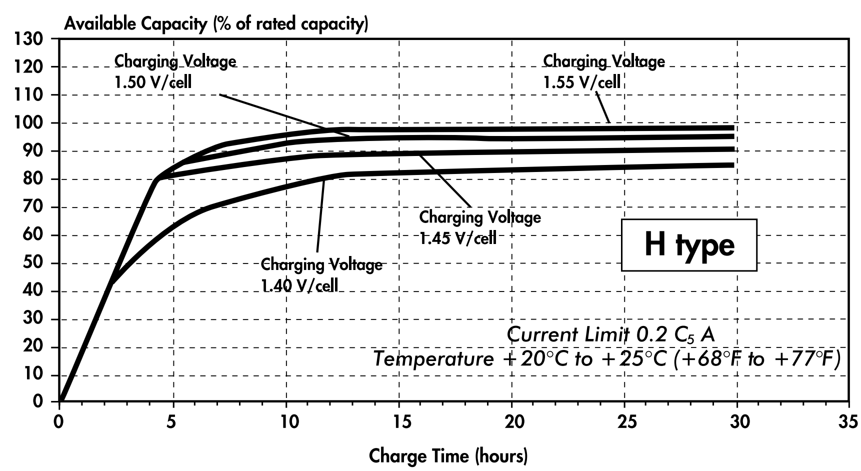


Figure 6(a) – Typical recharge times from a fully discharged state for the H type cell

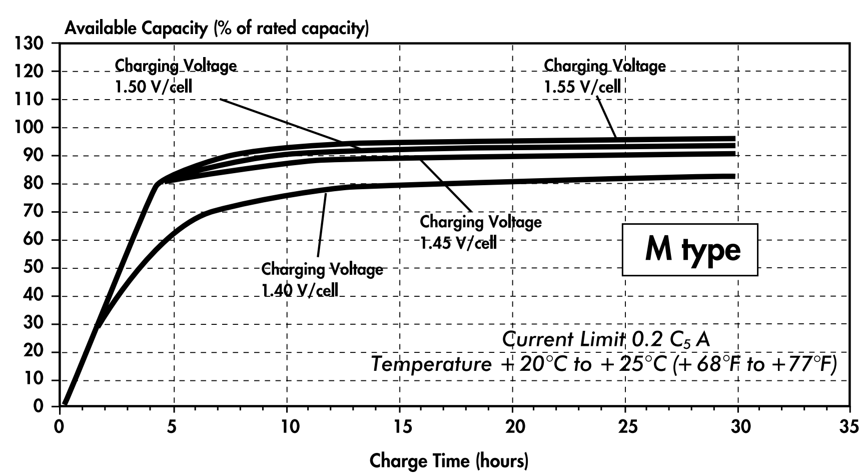


Figure 6(b) – Typical recharge times from a fully discharged state for the M type cell

These graphs give the recharge time for a current limit of 0.2 C_5 amperes. Clearly, if a lower value for the current is used, e.g. 0.1 C_5 amperes, 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.

The charge time for an M type cell 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.

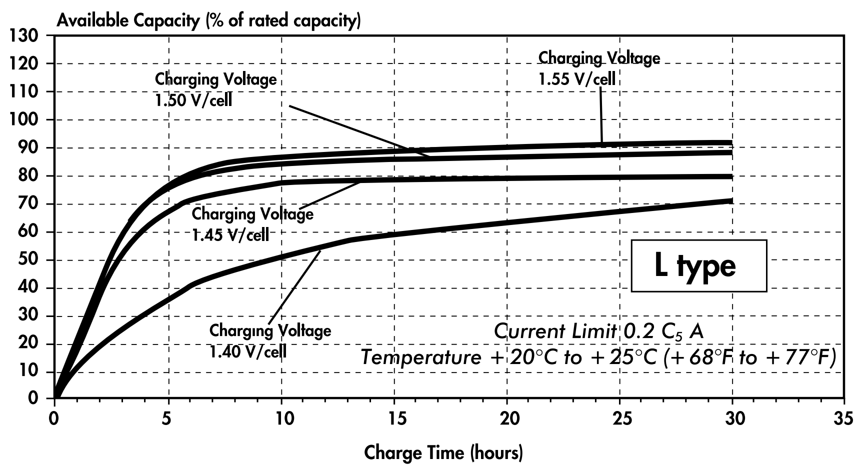


Figure 6(c) – Typical recharge times from a fully discharged state for the L type cell

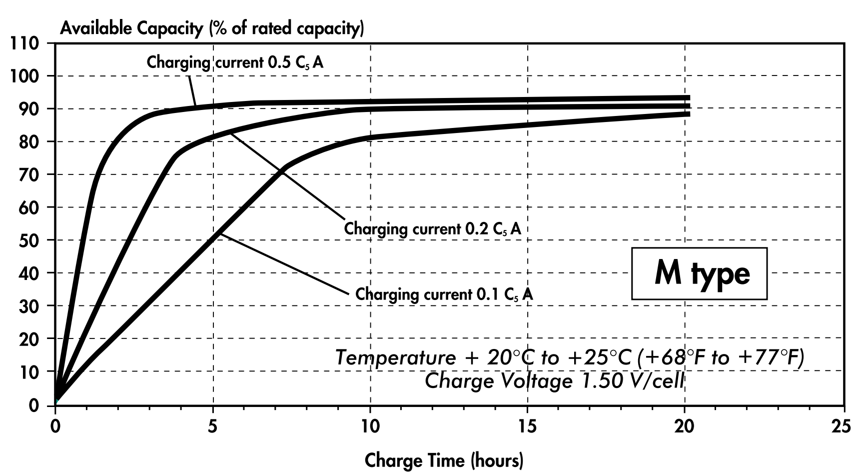


Figure 6(d) – Typical recharge times for different charge rates for the M type cell

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.

8.5 Temperature effects

As the temperature increases, the electrochemical behaviour 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 either to adjust the charging voltage or to compensate the charging voltage with the temperature (value: –3 mV/°C / – 1.7mV/°F), starting from an ambient temperature of +20°C to +25°C (+68°F to +77°F).

8.6 Commissioning*

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 200% of the rated capacity of the cell. Thus, a 250 Ah cell will require 500 ampere-hours input, e.g. 50 amperes for 10 hours.

*Please refer to the operating instructions in section 10.

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 0.2 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 Alcad 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.

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 Alcad battery will not be damaged by over-discharge but must be recharged to compensate for the over-discharge.

Overcharge

In the case of the Alcad 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 Alcad 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 Alcad battery concept has been tested to IEC 77 for 2 hours at 1 g, where *g* = acceleration.

External corrosion

The Alcad battery is manufactured in durable polypropylene. All external metal components are nickel-plated or stainless steel, protected by an anti-corrosion oil, and then protected by a rigid plastic cover.

10 Installation and operating instructions

Important recommendations

- **Never allow an exposed flame or spark near the batteries, 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.**

10.1 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 discharged and empty.** Do not remove the plastic transport seals until ready to fill the battery.
- **If the battery is shipped filled and charged,** the battery is ready for installation. Remove the plastic transport seals only before use.

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

10.2 Storage

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

Do not store in direct sunlight or expose to excessive heat.

Cells empty and discharged

- Alcad recommends to store cells empty and discharged. This ensures compliance with IEC 60623 section 4.9 (storage).
- Cells can be stored like this for many years.

Cells filled and charged

- If cells are stored filled, they must be fully charged prior to storage.
- Cells may be stored filled and charged for a period not exceeding 12 months from date of dispatch.

Storage of a filled battery at temperatures above +30°C (+86°F) can result in loss of capacity. This can be as much as 5% per 10°C (18°F) above +30°C (+86°F) per year.

- When deliveries are made in cardboard boxes, store without opening the boxes.
- **When deliveries are made in plywood boxes, open the boxes before storage. The lid and the packing material on top of the cells must be removed.**

10.3 Installation

10.3.1 Location

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

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

Alcad 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 minimise 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.

10.3.2 Ventilation

Special regulations for ventilation may be valid in your area depending on the applications.

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 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 cm^3 of water, and 1 cm^3 of water produces 1.865 litres of gas in the proportion 2/3 hydrogen and 1/3 oxygen. Thus 1 Ah of overcharge produces 0.42 litres of hydrogen.

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

= number of cells x charge current x 0.42 litres

or

= number of cells x charge current x 0.00042 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 96 cells, type HB 28O P on a three step, two tier stand, is placed in a room of dimensions 3m x 5m x 3m.

The charging system is capable of charging at 0.1 C_5 and so the charging current is 28 amperes.

The volume of hydrogen evolved per hour in this, the worst, case is: = 96 x 28 x 0.00042 m^3 = 1.13 m^3.

The total volume of the room is 3 x 5 x 3 = 45m^3

Approximate volume of battery and stand does not exceed 2 m^3, and so, the volume of free air in the room is 43 m^3.

Therefore, the concentration of hydrogen gas after charging for 1 hour at full gassing potential at 0.1 C_5 will be: $= \frac{1.13}{43} = 2.7\%$

Thus, to maintain a maximum concentration of 2% (for example), the air in the room will need changing

$$\frac{2.7}{2} = 1.4 \text{ times per hour.}$$

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.

10.3.3 Mounting

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

Recommended torques for terminal bolts are:

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

The connectors and terminal should be corrosion-protected by coating with a thin layer of anti-corrosion oil.

Remove the transport seals and close the vent plug.

10.3.4 Electrolyte/cell oil

- **Cells delivered filled and charged:**

  Check the level of electrolyte. It should not be more than 20 mm below the upper level mark. If this is not the case, adjust the level with distilled or deionized water. Cells delivered filled have already the cell oil in place.

- **Cells delivered empty and discharged:**

  If the electrolyte is supplied dry, prepare it according to its separate instructions sheet. The electrolyte to be used is E22. Remove the transport seals just before filling.

  Fill the cells about 20 mm above the lower level mark with electrolyte.

  Wait 4 to 24 hours and adjust if necessary before commissioning.

  It is recommended to add the cell oil after the commissioning charge, with the syringe, according to the quantity indicated in the Installation and Operating Instructions sheet.

10.4 Commissioning

Verify that the ventilation is adequate during this operation.

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

When the charger maximum voltage setting is too low to supply constant current charging, divide the battery into two parts to be charged individually.
If the current limit is lower than indicated in the table of the Installation and Operating Instructions sheet, charge proportionally for a longer time.

For cells filled on location or for filled cells which have been stored more than 6 months:

- charge 10 h at 0.2 C_5 A (recommended)
- or charge for 30 h at 1.65 V/cell, current limited to 0.2 C_5 A
- discharge at 0.2 C_5 A to 1.0 V/cell
- charge according to section below.

For cells filled and charged by the factory and stored less than 6 months:

- charge 10 h at 0.2 C_5 A (recommended)
- or charge 24 h at 1.65 V/cell, current limited to 0.2 C_5 A
- or charge 48 h at 1.55 V/cell, current limited to 0.2 C_5 A.

Cell oil and electrolyte after commissioning:

Wait for 4 hours after commissioning. Cells delivered filled by the factory have already the cell oil in place.

For cells filled on location, add the cell oil with the syringe.

Check the electrolyte level and adjust it to the upper level mark by adding:

- distilled or deionized water for cells filled by the factory
- electrolyte for cells filled on location.

The battery is ready for use.

10.5 Charging in service

Continuous parallel operation, with occasional battery discharge.

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

for two level charge:

- float level
  = 1.42 ± 0.01 V/cell for L cells
  = 1.40 ± 0.01 V/cell for M and H cells
- high level
  = 1.47 - 1.70 V/cell for L cells
  = 1.45 - 1.70 V/cell for M and H cells

A high voltage will increase the speed and efficiency of the recharging.

for single level charge: 1.43 - 1.50 V/cell.

Buffer operation, where the load exceeds the charger rating.

Recommended charging voltage
(+20°C to +25°C/+68°F to +77°F): 1.50 - 1.60 V/cell.

10.6 Periodic maintenance

- Keep the battery clean using only water. Do not use a wire brush or solvents of any kind. Vent plugs can be rinsed in clean water if necessary.
- Check the electrolyte level. Never let the level fall below the lower 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 either at the battery factory or during the battery commissioning, 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 bolts should be corrosion-protected by coating with a thin layer of anti-corrosion oil.
- Check the charging voltage. It is important that the recommended charging voltage remains unchanged. The charging voltage should be checked at least once yearly. High water consumption of the battery is usually caused by improper voltage setting of the charger.

10.7 Changing electrolyte

In most stationary battery applications, the electrolyte will retain its effectiveness for the life of the battery. However, under special battery operating conditions, if the electrolyte is found to be carbonated, the battery performance can be restored by replacing the electrolyte.

The electrolyte type to be used for replacement in these cells is: E13.

Refer to "Electrolyte Instructions".

11 Maintenance of batteries in service

In a correctly designed standby application, the Alcad 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 auxiliary 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 caps.

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 deionized 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.

Alcad 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 0.1 C_5 to 0.2 C_5 amperes (10 to 20 amperes for a 100 Ah battery) to a final average voltage of 1.0 V/cell (i.e. 92 volts for a 92 cell battery).

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

11.4 Recommended maintenance procedure

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

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

Yearly
• check charge voltage settings
• check cell voltages (30 mV deviation from average is acceptable)
• check float current of the battery
• check electrolyte level
• high voltage charge if agreed for application
Every 2 years
• clean cell lids and battery areas • 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).

12 Disposal and recycling

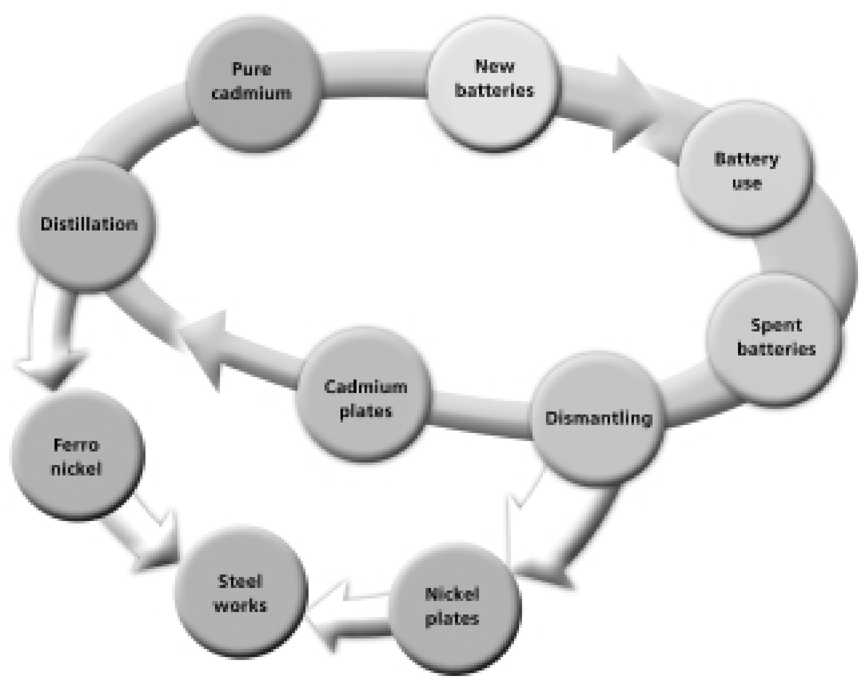
In a world where autonomous sources of electric power are ever more in demand, Alcad batteries provide an environmentally responsible answer to these needs. Environmental management lies at the core of Alcad's business and we take care to control every stage of a battery's life-cycle in terms of potential 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, Alcad organises retrieval from pre-collection points and the recycling of spent Alcad batteries. Information about Alcad's collection network can be found on our web site:

www.alcad.com

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



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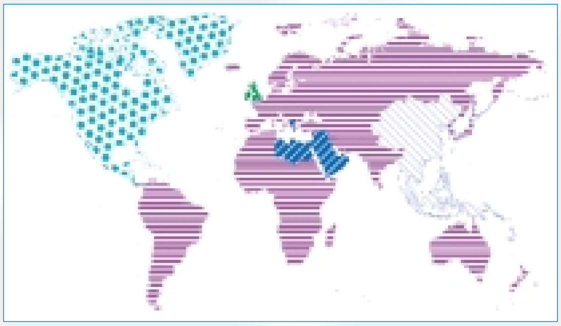

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