

# Nickel Cadmium



## Technical Hand Book

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## NOTICE TO READERS

The information in this technical handbook is generally descriptive only, and is not intended to make or imply any guarantee or warranty with respect to any cells and batteries. Cell and battery designs are subject to modification without prior notice. Performance of a battery should be based on its corresponding data sheet and product specification.

# 1 Introduction

## 1.1 Overview

Nickel Cadmium (NiCd) is one of the most established amongst the various commercially available rechargeable battery systems. The energy density of NiCd batteries are lower than the newer battery systems, such as Nickel Metal Hydride and Lithium-Ion. However, the robust NiCd batteries are very durable, reliable, easy-to-use and economical. They remain a popular choice for many electrical and electronic applications that emphasize lower cost while maintaining good performance.

SESNiCd rechargeable batteries had long been established as a well-known choice that offer performance, reliability and value. We have expanded our NiCd product range into various series to custom fit various application requirements.

-- the ever popular **standard series** is designed for a wide variety of general applications, including toys, personal audio equipment, cameras and cordless phones.

-- the **high-temperature series** is designed for applications whereby the battery may encounter elevated temperature during operation. Special designs ensure that the battery performance is stable and reliable under adverse environmental conditions. Emergency lighting is one of such applications best served by the high-temperature series.

-- the **high-drain series** is expertly customized for powerful delivery of electrical energy on demand. Power tools and electric bicycles are among some of the applications that excel with our high-drain series as power sources.

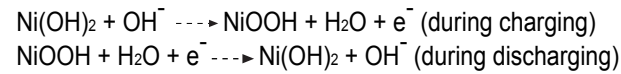
## 1.2 NiCd Chemistry

### 1.2.1 Principle

As with any other rechargeable battery systems, NiCd batteries operate on the principle that electrochemical reactions at each of the electrodes are reversible; this enables energy to be stored during charging and released during discharging.

### 1.2.2 Positive electrode chemistry

The reaction that occurs at the positive electrode of a NiCd battery is the same as that for its NiMH counterpart:

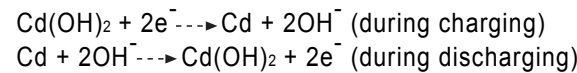


Ni(OH)<sub>2</sub> and NiOOH are viewed as a reversible couple, able to transform from one to the other, depending on whether charging or discharging is in effect.

During the charging operation, electrical energy provided from an external power source is stored as chemical energy in the cell, when the lower energy Ni(OH)<sub>2</sub> is converted to the higher energy NiOOH. During a discharge reaction, the NiOOH is converted back to Ni(OH)<sub>2</sub>, releasing the stored chemical energy as electrical energy.

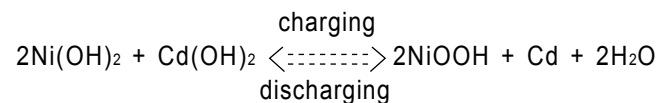
### 1.2.3 Negative electrode chemistry

The following reactions occur during the charge and discharge operations:



### 1.2.4 Overall reaction

Combining the equations in 1.2.2 and 1.2.3 reveals the overall cell equation.

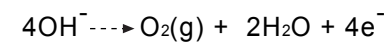


The overall reaction schematically depicts a simple transfer of OH-ion between Ni(OH)<sub>2</sub> and Cd, depending on whether the cell is being charged or discharged.

### 1.2.5 Cell pressure management - charge reserve

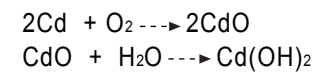
Up till now, only those reactions involving the main charging and discharging process have been shown. However, when a NiCd cell is close to being fully charged, gas-generating side reactions start to develop. For hermetically sealed batteries, if the side reactions are not prevented, the internal pressure may become excessively high.

In sealed NiCd batteries, the internal pressure is designed to remain at safe levels during operation. The main principle is to ensure that the capacity of the negative electrode exceeds that of the positive electrode. The excess capacity in the negative electrode is referred to as the charge-reserve of the cell. With the proper designs, the positive electrode is always the capacity-limiting electrode. As the cell approaches full charge, oxygen gas will start to evolve from the positive electrode in the process of electrolysis.



However, due to the excess capacity (charge-reserve) in the negative electrode, the corresponding electrolysis product of hydrogen will be prevented from forming. Instead, the oxygen gas from the positive electrode diffuses to the negative electrode and is consumed in the oxygen recombination reaction.

The oxygen recombination at the negative electrode occurs simultaneously, via two reaction mechanisms:



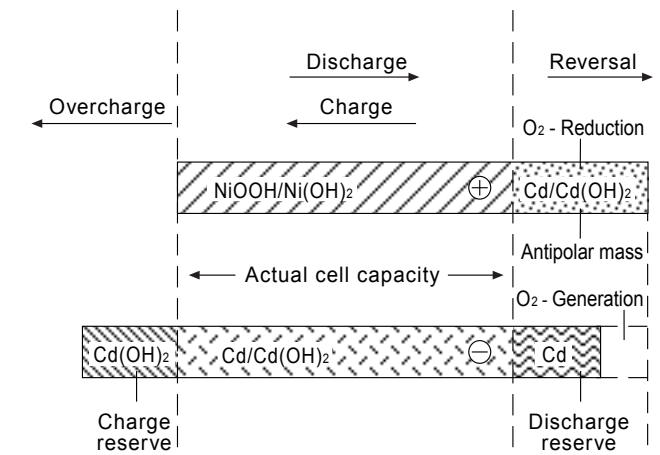
The first equation represents a direct combination of the O<sub>2</sub> gas with Cd, which is present in significant amounts at the negative electrode of a fully charged battery. The second equation is a reverse of the electrolysis reaction that originally generated the O<sub>2</sub> at the positive electrode. The end result of these two equations is that gaseous O<sub>2</sub> is reabsorbed by the negative electrode, thereby preventing unacceptably high internal pressure during the charging reactions.

In addition, most hermetically sealed rechargeable batteries are equipped with resealable or non-resealable (one time) venting systems, which safely release any internal pressure that might have built up when the batteries were exposed to unexpectedly severe conditions of operations.

### 1.2.6 Minimizing damage during deep discharge - discharge reserve

In the event of deep discharge, depreciation of battery performance may occur. To minimize the possibility of damage, the "antipolar material" (i.e. the active material used in the negative electrode) is added in the positive electrode to prevent the generation of hydrogen gas, which can increase the internal pressure and may destroy the seal or at least cause water loss with resealing valves.

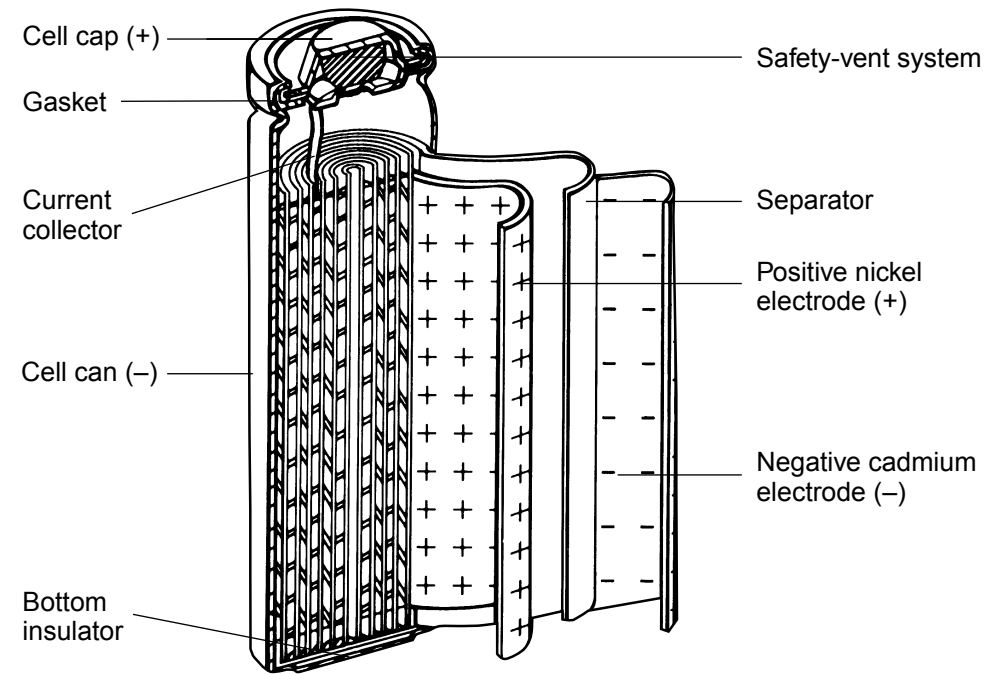
The relationship between the useful capacity, charge reserve and discharge reserve is shown in the following schematic representation.



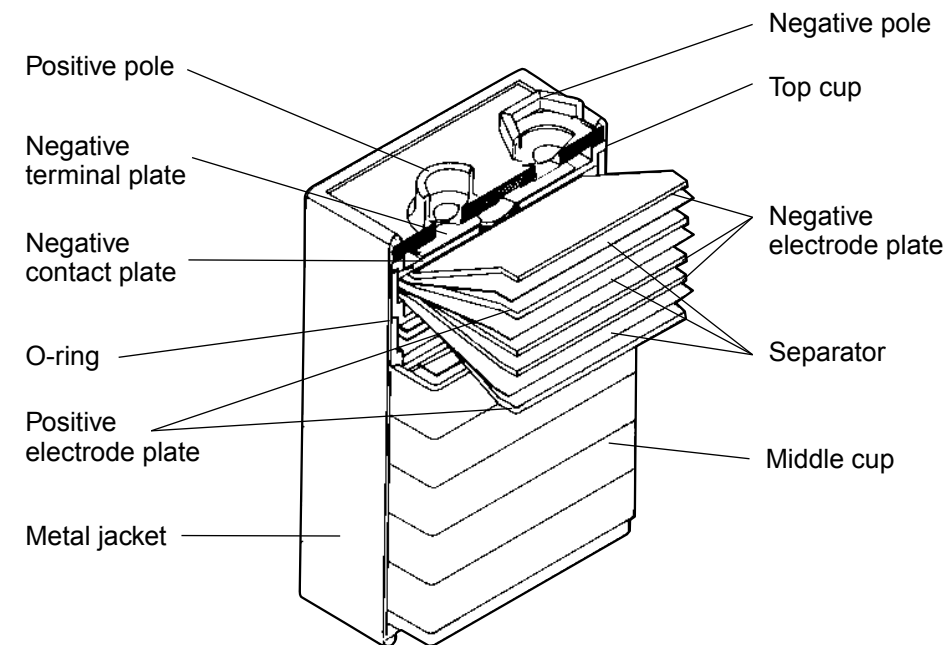
Balance of electrode capacities (cell balance) in a sealed nickel/cadmium battery with reversal protection by 'antipolar material'

## 1.3 Cell Construction

### Cylindrical



### 9V



# 2 Performance Characteristics

There are five major characteristics of NiCd battery that we should look at, which are charging, discharging, storage, cycle life and safety.

## 2.1 Charging Characteristics

### 2.1.1 Overview

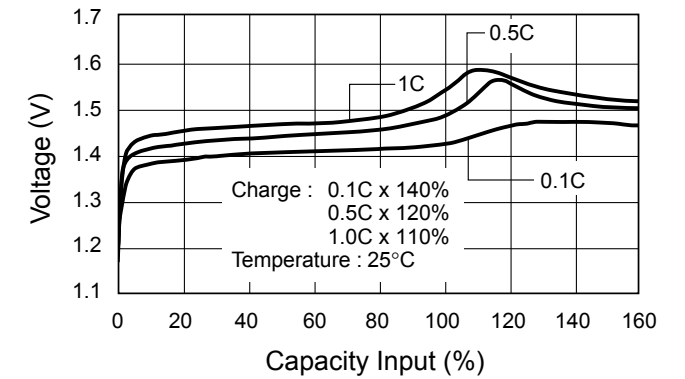
The charging process aims to restore the battery for use by charging the battery externally. The charge voltage is affected by current, ambient temperature and time. At the same ambient temperature, the basic principle is that the higher the current, the higher the charge voltage as a result of increased over-potential at both electrodes.

When almost fully charged, peak voltage is attained. However, if the battery is overcharged, a slight decrease in voltage occurs; this arises from a temperature increase due to exothermic oxygen recombination reaction. As a result, internal pressure builds up and heat is generated during overcharging. At a lower charge rate (0.1C or below), equilibrium pressure can be attained through a balanced electrode design. In addition, heat generated during overcharging is dissipated into the environment. The battery temperature is also affected by the current and ambient temperature.

### 2.1.2 Charging efficiency

In general, it is more efficient to charge the battery at or below room temperature, since the chemicals of both positive and negative electrodes are more stable at lower temperatures - resulting in higher discharge capacity. The charging efficiency of the **standard series** NiCd batteries drops rapidly when the ambient temperature exceed 40 C. Furthermore, the decrease is more pronounced at low charging rates, since the return of electrode chemicals to their lower charge state is more evident. The **high temperature series**, on the other hand, allow applications of trickle charge at temperatures as high as 70 C. The technology is a result of dedicated research by SES to enhance the stability of battery materials at high temperatures.

## Charge Characteristics



## 2.2 Discharge Characteristics

### 2.2.1 Discharge voltage

The nominal discharge voltage of a NiCd battery is 1.2V at 0.2C discharge which is affected by current and ambient temperature. The discharge voltage is depressed at lower temperature. This is because NiCd batteries employ an aqueous electrolyte system, resulting in decreased ionic mobility at lower temperatures. At higher currents, the discharge voltage is also depressed since the electrodes are more polarized. In order to meet the high power application requirement, the **high drain series** can provide a high discharge current exceeding 10C.

### 2.2.2 Discharge capacity

The nominal discharge capacity is rated at 0.2C to an end voltage of 1V after charging at 0.1C for 14-16 hours. The discharge capacity is also affected by discharge current and ambient temperature. Capacity decreases with falling temperature due to lower reactivity of the active materials and higher internal impedance. At a higher discharge current, the usable capacity is reduced due to larger IR drop, and also because the battery voltage drops off more rapidly to end voltage.

### 2.2.3 Polarity reversal during over-discharge

Most real life applications employ multi-cell, series connected batteries. When discharging, the lowest capacity cell will be the first to experience a voltage drop. If the battery discharge continues, this unit cell will be driven into an over-discharged condition.

When the cell voltage drops below 0V, its polarity is effectively reversed. The cell reaction, at different stages, is illustrated below:

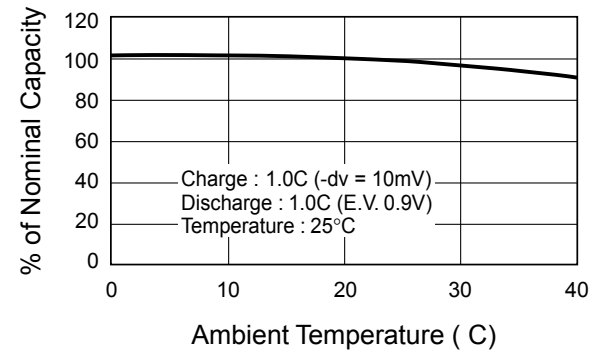
**Stage 1:** Initially, both positive and negative electrodes, as well as the discharge voltage are normal.

**Stage 2:** The active material on the positive electrode has been completely discharged and evolution of hydrogen occurs. Cell pressure builds up. Since the battery is designed with excess negative capacity (discharge reserve), the discharge continues; discharge voltage is around -0.2V to -0.4V.

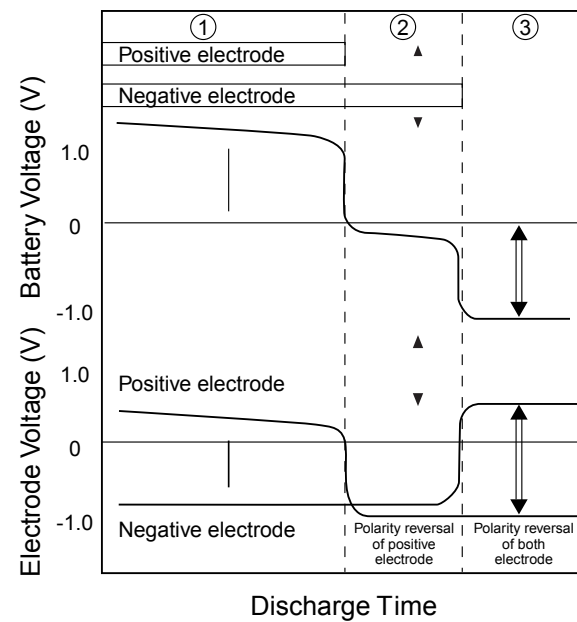
**Stage 3:** The active material on both electrodes has been depleted and oxygen generation starts at the negative electrode. Formation of gases at both electrodes leads to high internal cell pressure and opening of the safety vent, resulting in deterioration of the cell performance if this scenario occurs repeatedly.

To avoid deep discharging, the capacity variation of the battery pack's unit cells should be kept to a minimum. It is also recommended that the discharge end voltage should be maintained at 1.0V times the number of unit cells connected in the battery pack. For battery packs connected with more than 8 cells in series, the recommended discharge end voltage is 1.2V times number of cells, less by one.

### Discharge - Temperature Characteristics



### Polarity Reversal



## 2.3 Storage Characteristics

### 2.3.1 Overview

The battery loses its energy during storage even without loading. The energy is lost through small, self-discharge currents inside the battery, as explained below:

#### a. Decomposition of nickel hydroxide in the positive electrode:

The nickel hydroxide is relatively unstable in a charged state and tends to return to a discharge state with the slow release of oxygen. The released oxygen then reacts with the cadmium in the negative electrode, thus establishing an internal discharge path. The reaction rate increases with higher temperatures.

#### b. Side reactions through impurities:

Some of the impurities can be oxidized in the positive electrode when it migrates to the negative electrode where it reverts to its original form. The shuttle reaction of the impurities dissipates the battery's power during storage. The reaction rate is also temperature dependent.

### 2.3.2 Storage temperature

As the self-discharge reaction rate increases with higher temperatures, prolonged storage of the battery at elevated temperatures will result in the battery materials deteriorating faster. Leakage performance will also deteriorate, resulting in a reduced battery lifetime. It is recommended that, for long storage, batteries should be kept at room temperature or below.

### 2.3.3 Storage time

As the battery loses energy during storage, the voltage also drops. In general, the battery capacity loss due to self-discharge during storage can be recovered by recharging. If the battery is stored for over one year, it is advisable to cycle the battery several times to resume the battery capacity.

### 2.3.4 Storage humidity

Leakage and rusting of metal parts are accelerated in high humidity environments, especially those with correspondingly high temperatures. The

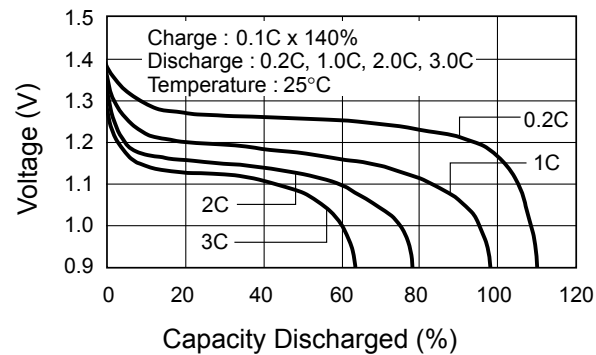
recommended humidity level for battery storage is a maximum of 60% RH.

### 2.3.5 False -dV:

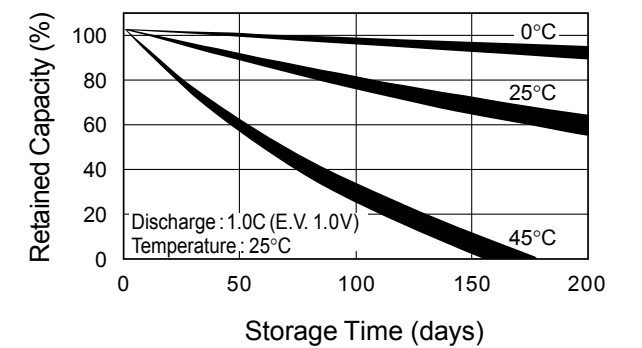
The most popular quick-charge-termination method for NiCd batteries is the -dV method. However, after the batteries have been idled for extended periods of time, a false -dV signal may occur very early during the first cycle of charging. This may result in premature charge-termination.

To avoid the occurrence of premature charge-termination, it is advisable that quick-chargers designed with -dV termination to de-activate the detection during the first few minutes of the charging operation.

### Discharge Characteristics



### Storage Characteristics



## 2.4 Cycle Life

### 2.4.1 Overview

Cycle life is the number of charges and discharges a battery can achieve before the discharge capacity (0.2C) drops to 60% of the nominal capacity per IEC 61951-1 or other guaranteed value per SES specifications. Cycle life is affected by ambient temperature, as well as depth of charge and discharge. A common phenomenon is faster self-discharge rate upon cycling due to formation of cadmium dendrite, especially at the end of cycle life. Actually, NiCd battery can attain 500 - 1000 cycles with cycling conditions of 0.1C charge / 0.2C discharge.

### 2.4.2 Ambient temperature

It is recommended to cycle the battery at room temperature. At higher temperatures, the electrodes as well as the separator material deteriorate much faster, thus shortening the cycle life. At lower temperatures, the rate of oxygen recombination during overcharge is slow, and may risk opening the vent leading to pre-mature electrolyte dry-out.

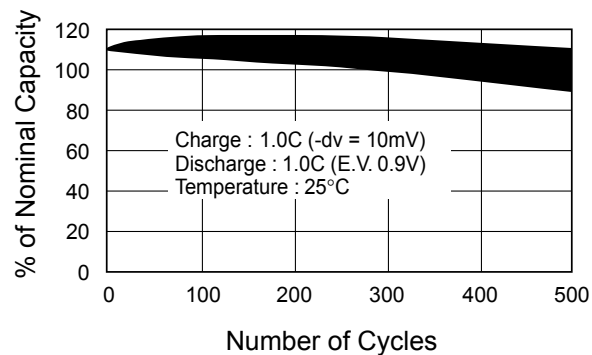
### 2.4.3 Overcharge

The cycle life of the battery is sensitive to the amount of overcharge at high charge rate. The amount of overcharge affects cell temperature and oxygen pressure inside the battery. Both factors deteriorate the electrodes, and thus the cycle life shortens. For that reason, the cycle life is affected by various charge cut-off methods.

### 2.4.4 Deep discharge

The cycle life is also affected by the depth of discharge. The number of charge/discharge cycles will decrease if the battery is repeatedly subjected to deep discharging below 1V, or to a status of polarity reversal. Considerably more cycle numbers can be obtained if the battery is cycled under shallower cycling conditions.

### Charge/Discharge Cycle Characteristics



## 2.5 Safety

If pressure inside the battery rises as a result of improper use, such as overcharge, short circuit, or reverse charging, a resealable safety vent will function to release the pressure, thus protecting the battery from bursting.

## 2.6 Characteristics of Various Series

SES NiCd rechargeable batteries had long been established as a well known choice that offers performance, reliability and value. In order to widen its field of applications and extend its full advantages, we have expanded our NiCd product range into various series to custom fit various application requirements.

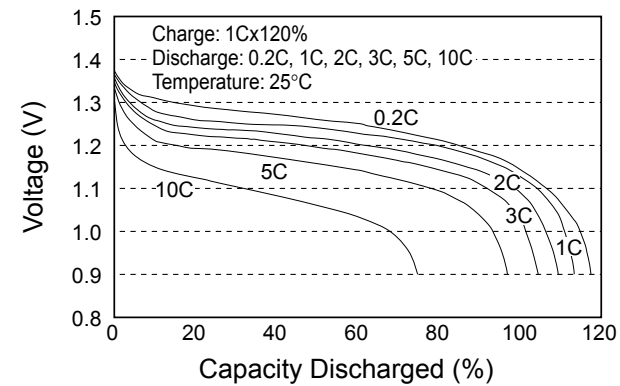
### 2.6.1 Standard Series

Our standard series is designed for a wide variety of general applications, which features a combination of superior positive and negative electrode, allowing us to provide the highest levels of capacity and quality for each size. These NiCd batteries also feature excellent discharge performance, low internal resistance and reliable characteristics across a wide range of temperatures, and they have been carefully designed for safety and reliability. Ranging from compact sizes to large sizes, the standard series is available in a wide selection of discharge capacities based on the standard sizes specified by the IEC61951-1.

### 2.6.2 High Drain Series

Our high drain series is expertly customized for powerful delivery of electrical energy on demand. It was developed through an integration of our comprehensive NiCd battery technology. Improvement in the positive and negative electrode technology, and in the current collecting system have further lowered the internal resistance and greatly enhance the 10C discharge characteristics of the high drain series batteries.

### Discharge Characteristics of High Drain Series at Various C Rates

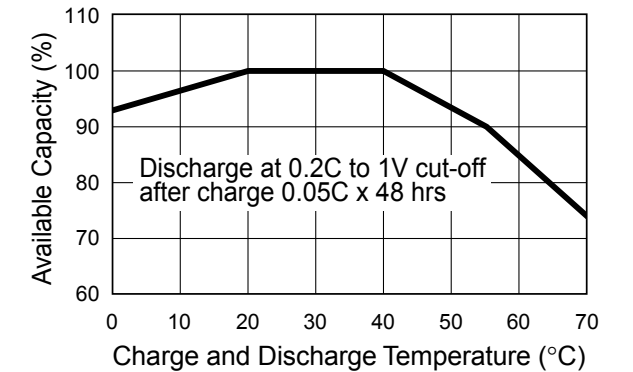


- Excellent high current discharge characteristics: It is designed to meet the need for high current discharge, such as for power tools, and can deliver a high current exceeding 10C.
- Reliable, long cycle life: In addition to excellent high rate discharge performance, high drain series batteries also provide hundreds of charge/discharge cycles, showing reliable cycle life characteristics.

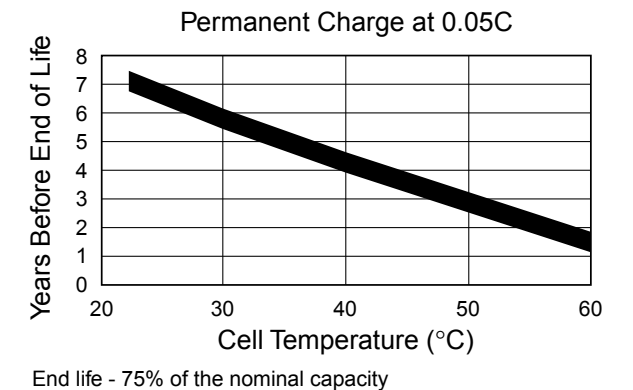
### 2.6.3 High Temperature Series

With standard series NiCd batteries, the smaller the charging current and the higher the charging temperature, the more difficult for it to charge the battery. However, for applications in which the batteries are charged continuously by a small current under relatively high temperature conditions such as emergency lights, there is a need for superior high temperature trickle charge performance. By combining SES's technology in electrodes and electrolyte, high temperature series NiCd batteries are far superior to the standard series NiCd batteries for use in high temperature trickle charge applications. Furthermore, the use of a special separator provides stable trickle charge life characteristics.

### Charge/Discharge Efficiency vs. Temperature for High Temperature Series



### Life Expectancy for High Temperature Series



## 2.7 Memory Effect

Certain NiCd cylindrical cells employing sintered type electrodes experience memory effect. The memory effect occurs due to the possibility of alloying reaction between cadmium and nickel in the cadmium electrode. However, memory effect can be eliminated if cells are completely discharged. NiCd cell employing pasted electrode technology is much less susceptible to memory effect, because less nickel is present in the cadmium electrode.

# 3 Charging Method

## 3.1 Overview

One crucial difference between the primary and secondary battery is the ability to restore energy after discharging. This restoration of energy is therefore a very important area to be considered in secondary battery applications. Since different battery systems have their own characteristics and applications have their own integrated electrical input/output requirements, it is vital to select a charging method that suits both the battery system and the application. Improper charging will lead to poor battery performance or failure of the application.

## 3.2 Charging Method

Like NiMH, the main concern in charging a NiCd battery is the build-up of temperature and internal pressure due to high overcharge rates. As previously mentioned, the cell design applies the concept of oxygen recombination in lowering the battery's internal oxygen level during standard charging. However, if the cell is subjected to severe charging conditions (such as overcharging at a current rate over 1C), the rate of oxygen evolution from the positive electrode increases rapidly, exceeding the recombination reaction rate. As the oxygen recombination reaction is exothermic, this results in excessive oxygen pressure and increased temperature. The excessive pressure will then be released through the safety vent causing a reduction in the cell electrolyte; the excessive heat will eventually degrade the cell's internal contents. These two factors are considered to be the major limitations to the battery's service life. For this reason, charge control is very important in battery charging. SES NiCd cylindrical cells are designed to be able to charge up to 1C rate. For applications that require higher charging rates, please contact SES.

### 3.2.1 Constant current charging

The advantages of the constant current charging method include high charging efficiency, flexibility, and position control of input capacity.

### 3.2.2 Constant voltage charging

Besides constant current charging, constant voltage charging could also be applied. In constant voltage charging, the power supply is regulated at a constant voltage. The charging current is proportional to the net voltage difference between the supply-voltage and the cell voltage. During charging, the cell temperature will increase, causing the cell voltage to drop at the end of charging. This causes an increase of the charging current and damage the cell if charging is not terminated. This phenomenon is called thermal runaway. Therefore, traditionally constant voltage charging is not recommended. Moreover, if one or more unit cell in a battery is short-circuited, the charge current can become excessive. However, both problems can be avoided by suitable monitoring of cell/battery parameters during charging.

### 3.2.3 Fast charging

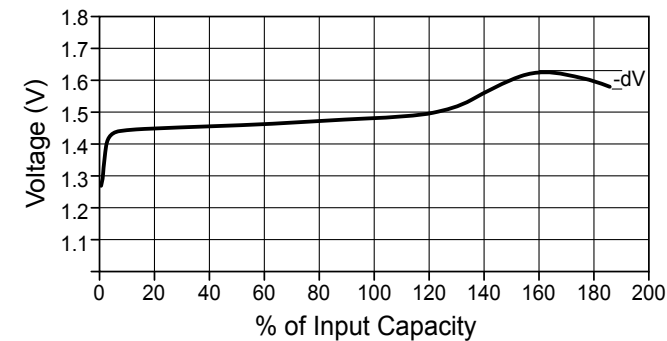
SES NiCd batteries use constant current charging as the basis of the charging method. Depending on different operational requirements, constant current charging can be further classified according to the charging rate. Charging at a current rate of 0.5C to 1C is considered fast charging. As explained earlier, if the charging current is too high (1C or above), the cell internal pressure and temperature will rise at the end, resulting in degraded cell performance and electrolyte leakage.

### 3.2.4 Charge control

Various methods are recommended to help control charging, so as to prevent gas pressure and temperature build-up due to overcharging. Proper charge control will provide a longer battery service life.

#### a) -dV control

Detecting the value of the voltage drop after reaching peak voltage is the most commonly used charge control method in fast charging SES NiCd batteries. A -dV value of 0-20mV/cell is recommended when fast charging SES NiCd batteries.



#### b) Charging time control (back up only)

An easier way to control fast charging of SES NiCd batteries is to control the elapsed time following commencement of charging. However, it is not recommended as the only cut-off method due to overcharging. A charging time between 120-140% of the cell nominal capacity is recommended.

#### c) Battery temperature control

As increased ambient and cell temperatures result in high cell internal pressure, it is highly recommended to have temperature control backup for safety and cell performance. When fast charging SES NiCd batteries, the cut-off temperature is recommended to be controlled at 55°C.

### 3.2.5 Standard charge

Apart from fast charging, SES NiCd batteries can also be charged at a lower current rate of 0.1C. As this charging method is less severe, charge termination at 160% nominal capacity input is recommended (to help avoid extended overcharging of the battery). Also, in some applications where overcharging is necessary, SES NiCd batteries can endure 0.1C continuous charging for about one year.

### 3.2.6 Trickle charging

In most applications - where cells and batteries need to be in a fully charged condition - maintaining a trickle charge current to compensate for the loss of capacity (due to self-discharge) is recommended. The suggested trickle charge current to be used is 0.05C to 0.1C.

### 3.2.7 Charging temperature

As ambient temperature affects charging efficiency and cell reliability, it is important to select a suitable temperature for optimizing charging performances. Generally speaking, a temperature within 10°C to 45°C will yield the highest efficiency, which begins to drop at or above 45°C. Conversely, repeated charging at less than 0°C may cause cell internal pressure build-up, resulting in electrolyte leakage as in high temperature conditions. For these reasons, SES NiCd batteries can be charged at temperatures of 0°C to 45°C under standard charging conditions, but preferably at 10°C to 45°C under fast charging conditions.

# 4 Battery Assembly

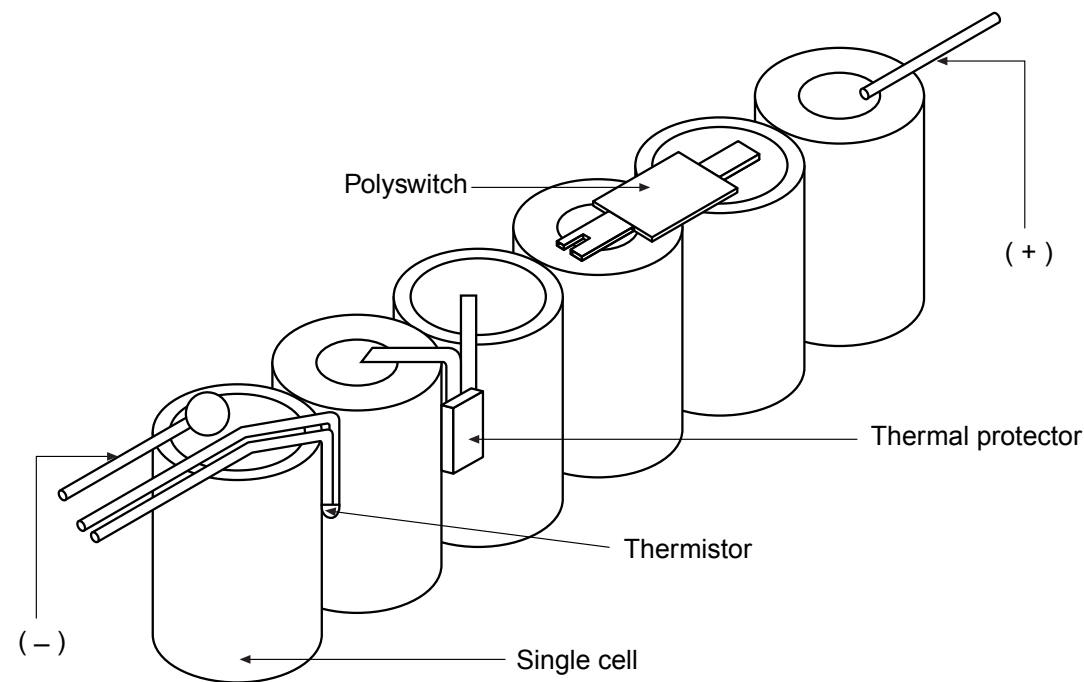
## 4.1 Connections Between Cells

The resistance spot-welding method is to be used when NiCd cells are connected in a series, to avoid an excessive increase in cell temperature, which would occur if soldered on directly. Lead used for cell connections should be nickel-plated or pure nickel measuring 0.1mm to 0.4mm in thickness and 3mm to 6mm in width.

The temperature of NiCd cells rises when the charge gets close to completion. Temperature increase is greater for a battery pack than for a single cell, due to the fact that the pack does not really allow for the dissipation of heat. The problem is further exacerbated when the pack is enclosed in a plastic case. Air ventilation should be provided in the plastic case of batteries - to allow for egress of any gasses that may result from activation of the safety vent of cells after abuse.

## 4.2 Thermal Protection for Battery Packs

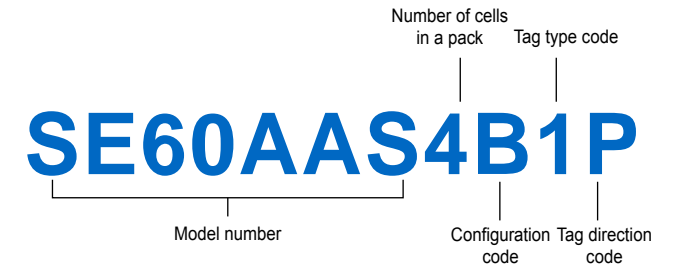
Battery packs intended for fast charging methods should have a thermal protection device. A thermistor sensing the temperature inside the pack should be employed. It is also desirable to have a thermostat/polyswitch and a thermal fuse installed in the battery pack to protect it from abnormal rises in temperature and external short-circuiting. Locations for safety devices in battery pack assembly are shown in the following diagrams.



# 5 Configurations

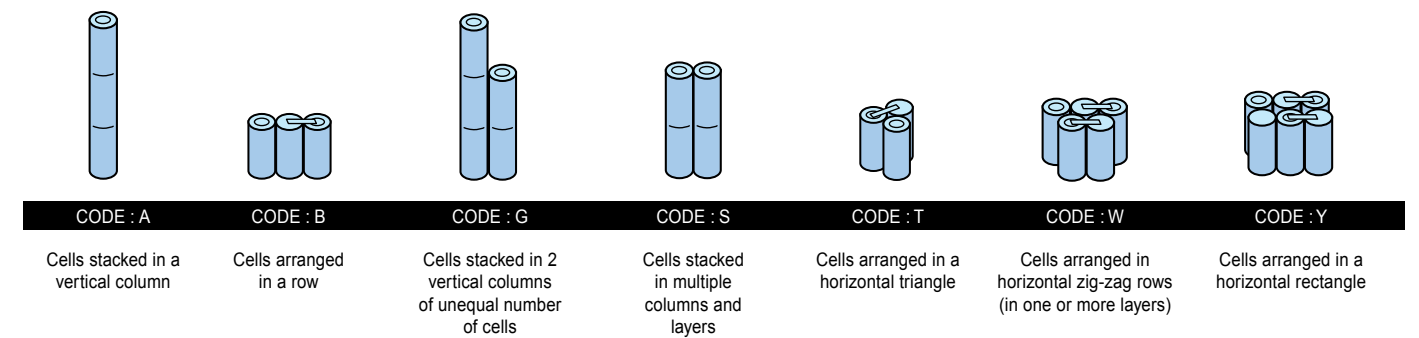
## Designation System for Battery Packs

An example:

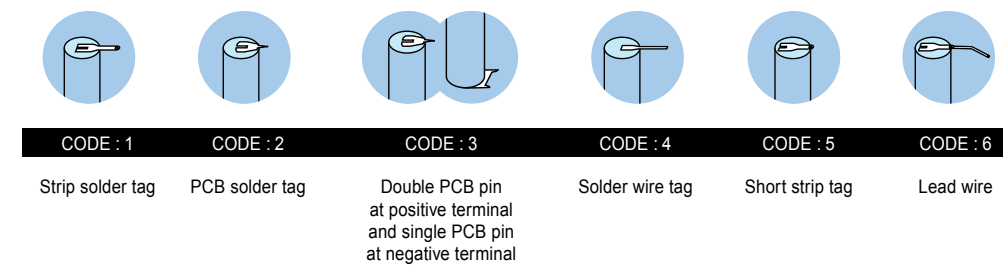


For battery packs with connectors, the **last two characters** will be used to specify connector type eg. SES60AAS4BMU.

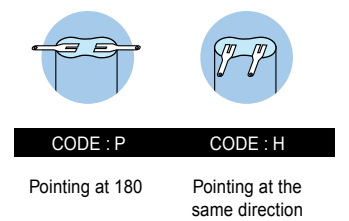
## Standard Configurations for Battery Packs



## Tag Type Specifications



## Tag Direction Codes



# 6 Proper Use and Handling

## 6.1 Restriction on Usage

Knowledge of battery maintenance is crucial to a working battery, helping to provide a longer period of operation. On the other hand, improper battery handling or maintenance may lead to unnecessary battery defects or problems, such as electrolyte leakage or cell bulging. In order to get the most out of using SES NiCd rechargeable cells, special care in the following areas should be considered:

### 6.1.1 Charging / discharging current

For fast charging SES NiCd batteries, the current rate should be 0.5C to 1C. Trickle charging, which is common in various applications (such as memory backup), requires a current charging range of 0.05C to 0.1C to maintain the long-term standby power of the battery. In addition, SES NiCd batteries can be trickle-charged at 0.1C continuously for one year without leakage or explosions. Charging current rates higher than 1C are generally not recommended. However charging with pulses higher than 1C is not uncommon in some applications. Please contact authorized SES personnel to determine the applicability of special charging schemes not mentioned in SES product specifications.

Special attention should be paid to the charge termination method, which is a critical element in providing an optimized cycle life, yet one which is easily overlooked. Several charging cut-off mechanisms with related parameters can be considered:

Negative delta voltage: within 20mV  
Temperature control: 45-55°C  
Timer control: 120-140%

These charging cut-off mechanisms can be incorporated into the application - either together or individually, with the choice of method depending largely on the charging profile of the application. To avoid unnecessary battery problems, which might look like quality issues, please contact authorized SES personnel for implementing the appropriate charging cut-off method.

A wide range of required discharge current rates will be encountered in different applications, and SES has a variety of battery types for specialized use. Apart from the standard series for general applications, high temperature and high drain series are specially designed for applications in high ambient temperatures and discharge current rates respectively. The maximum discharge current recommended for standard series and high drain series are generally 3C and 5C respectively. However, there are situations where higher currents of shorter duration are permissible.

### 6.1.2 Reverse charging

Reverse charging is one of the battery misuses that can appear to be a battery defect. If the positive and negative polarities are reversed when charging, the battery might bulge due to internal gassing. Electrolyte leakage consequently results due to venting at the safety valve, which leads to a decrease in capacity. Caution has to be exercised to avoid such misuse.

### 6.1.3 Parallel charging

Parallel charging is generally not recommended. Please consult authorized SES personnel for possible exceptions to connecting the batteries in parallel charging.

### 6.1.4 Charging / discharging temperature

It is important to understand how ambient temperature affects the charging and discharging of batteries, especially for obtaining maximum efficiency in conditions that exceed room temperature. SES recommends the following temperature range.

Standard and high drain series - cylindrical  
Standard charge: 0 to 45°C  
Fast charge: 10 to 45°C  
Discharge: -20 to 50°C  
Storage: -20 to 35°C

High temperature series - cylindrical  
Charge: 0 to 70°C  
Discharge: -20 to 70°C  
Storage: -20 to 35°C

9V Series  
Charge: -10 to 30°C  
Discharge: -20 to 40°C  
Storage: 0 to 35°C

Using or storing the battery beyond the recommended temperature range leads to deterioration in performance. For example: leakage, shortening of battery life, and lowering of charging efficiency may occur at higher temperatures.

At sub-zero temperatures, discharge capacity will decrease due to lower mobility of the ions inside the battery.

### 6.1.5 Over-discharging / overcharging

Other than discharging C-rate and temperature, another factor affecting battery life and performance is the discharge cut-off voltage. An appropriate choice of end voltage not only determines the battery performance, it also provides the bottom line to avoid over-discharging the battery. SES recommends 1V/cell as the end voltage in most situations. However, there are occasions when slightly higher than 1V/cell is necessary (to avoid scenarios such as over-discharge, when the number of batteries in the series is large). In addition, discharge cut-off lower than 1V/cell should be considered especially when the discharge rate is very high.

Overcharging also adversely affect battery life, the major cause of which is the extra heat generated by overcharging. When overcharging repeats from cycle to cycle, the accumulated heat will eventually degrade the battery life. Therefore, incorporating a proper charging cut-off mechanism is a critical element in ensuring a long battery life.

## 6.2 Precautions for Designing Application Devices

### 6.2.1 Battery compartment

Bear in mind that there is always a chance of battery abuse, where internal gassing is highly probable; and as a result, the gasses will be released through cell venting. However, generation of hydrogen gas from overcharging is particularly dangerous when mixed with oxygen. Caution should be focused on

the ventilation of battery compartments. Airtight battery compartments are strongly discouraged. Ventilation should be provided in the plastic case of batteries, otherwise oxygen and hydrogen gas generated inside can cause explosion when exposed to fire sources such as motors or switches.

### 6.2.2 Charging / discharging / operating temperature

To optimize battery performance and service life, certain aspects related to charging, discharging and the operating temperature should be taken into careful consideration. A customer application questionnaire is provided in this technical handbook. Please provide as much information as possible. Alternatively, contact authorized SES personnel for advice and help with your application.

## 6.3 Methods of Use

### 6.3.1 Operation

Avoid combining used and fresh batteries, or batteries at different state-of-charge, which may lead to electrolyte leakage. Always cycle the battery several times to restore its capacity if the battery has been stored for an extended period of time.

### 6.3.2 Connection between battery and application devices

Be sure to connect the positive and negative battery terminals to the corresponding terminals of the application device, in order to prevent reverse charging.

## 6.4 Precautions in Battery Handling

- Never incinerate the battery.
- Never solder a battery directly.
- Avoid subjecting a battery to strong vibrations.
- Never connect the battery terminals to the device without verifying the polarities.
- Never carry a battery with other metallic belongings to avoid short-circuiting.
- Never disassemble a battery.
- Never mix SES batteries with other battery brands or batteries of a different type.
- Never short together the positive and negative terminals of a battery with any metal.

- Never obstruct the safety vent, which is located near the positive terminal of the cylindrical/prismatic cell, and on the positive side of the button cell-indicated by a vent mark.
- Never alter the factory-configuration or remove/modify a component of a battery.
- Never charge/discharge a battery under conditions which are not within SES specifications, or without consulting authorized SES personnel on special applications.
- Never use other charger than specified to avoid possible heating, burning or rupture.
- Never leave a battery connected to a device for long periods without charging the battery, especially for devices that constantly drain standby current.
- If any abnormality or problem is found while using the battery, stop its use, and bring it to your local dealer.
- Never use cells or batteries for any other applications than specified, that may result in damage to the batteries and the appliances.

## 6.5 Battery Maintenance

### 6.5.1 Regular inspection

Periodic visual inspection of the battery is recommended. It is also advisable to store the battery at room temperature, with low humidity, when the battery is not expected to be used for a long period of time; the aim of which is to prevent cell leakage and rust.

### 6.5.2 Storage

Bear in mind that self-discharge has to be taken into consideration when storing a charged battery. The remaining battery capacity should be at least 50% after a month of storage at room temperature for a fully charged battery. High storage temperatures will accelerate the self-discharge, and reduce the remaining capacity.

In order to maintain battery performance when being stored for an extended period of time, cycling (charging and discharging) of the battery within a 6 to 9-month period is recommended. This procedure is recommended to maximize performance of the battery and prevent low OCV in long-term storage conditions. Failure to do so may result in a shorter battery life.

### 6.5.3 Battery disposal

Under normal conditions, when the battery has reached its end of life, it is advisable to properly insulate the positive and negative terminals of the battery prior to disposal. Please note that it is dangerous to dispose of the battery in fire, as it will lead to electrolyte spill-out and bursting of the battery.

Recycling of the battery is an important environmental issue nowadays. We recommend you contact your local government concerning the location of recycling sites, or enquire about local regulations on methods of disposal for NiCd batteries in your region.

### 6.5.4 Transportation

SES NiCd batteries should not be thought of as wet batteries (like traditional, non valve-regulated batteries). As a result, SES batteries can be shipped or transported in normal packaging without special handling.



# 7 Customer Application Questionnaire

## I. Customer Information

Customer: \_\_\_\_\_  
Address: \_\_\_\_\_

<b>Cap#</b> _____
Customer: _____
Salesperson: _____
Sales Order# _____ Date: _____

City: \_\_\_\_\_ Contact person: \_\_\_\_\_  
State: \_\_\_\_\_ Electrical: \_\_\_\_\_ Title: \_\_\_\_\_ Email: \_\_\_\_\_ Tel: \_\_\_\_\_  
Zip: \_\_\_\_\_ Mechanical: \_\_\_\_\_ Title: \_\_\_\_\_ Email: \_\_\_\_\_ Tel: \_\_\_\_\_  
Fax: \_\_\_\_\_ Commercial: \_\_\_\_\_ Title: \_\_\_\_\_ Email: \_\_\_\_\_ Tel: \_\_\_\_\_

## II. Product Description

A. Model No.: \_\_\_\_\_ Capacity: \_\_\_\_\_ mAh Voltage: \_\_\_\_\_ V

B. Application: \_\_\_\_\_ Qty/year: \_\_\_\_\_ Tentative production date: \_\_\_\_\_

C. Sample request: Cell qty: \_\_\_\_\_ Quote: \_\_\_\_\_ Requested delivery date: \_\_\_\_\_  
Pack qty: \_\_\_\_\_ Testing: \_\_\_\_\_

D. Type of designs:  Preliminary  Mechanical only  Electrical only  Final

E. Ship to:  Salesperson \_\_\_\_\_  
 Others  
Name: \_\_\_\_\_ Company: \_\_\_\_\_  
Address: \_\_\_\_\_  
City: \_\_\_\_\_ State: \_\_\_\_\_ Zip: \_\_\_\_\_

F. Specifications: (from customer)  
 Customer drawing: \_\_\_\_\_  Customer sample(s): \_\_\_\_\_ (pcs).  
 Parts & assembly drawing: \_\_\_\_\_  Circuit diagram: \_\_\_\_\_  Bill of material: \_\_\_\_\_  
 Written specification: \_\_\_\_\_ Title: \_\_\_\_\_ Date: \_\_\_\_\_  
 Others: (please specify) \_\_\_\_\_

Sketch

- Details:
1. Show all critical dimension with tolerance or max.
  2. Show connector polarity.
  3. Show label orientation.
  4. Show and list any special features or materials.

G. Protection/Safety:  
 Customer will protect battery externally.  
 Built-in protection requirements

Component	Short circuit	Overcharge	Rating	Manufacturer	Model no.
Polyswitch:	_____	_____	_____	_____	_____
Thermostat:	_____	_____	_____ °C	_____	_____
Thermistor:	_____	_____	_____ Ohms	_____	_____
Thermal fuse:	_____	_____	_____ °C/Amps	_____	_____
Current fuse:	_____	_____	_____ A	_____	_____
Others:	_____				

\*All Packs should be protected against short circuit and over charging.

\*Li-ion packs must have safety circuit to protect over charging.

\*Air ventilation should be provided in the plastic case of batteries, otherwise it may have a risk generating gases inside them (oxygen and hydrogen gas) resulting explosion triggered by fire sources (motors or switches). Caution should be focused on the ventilation of battery compartments. Airtight battery compartments are strongly discouraged.

H. Charging parameter

\*Fill out as much of the following table as possible.

<b>Cap#</b> _____
Customer: _____
Salesperson: _____
Sales Order# _____ Date: _____

For NiCd & NiMH

Charge Mode	Charge		Termination					
	Constant current (mA)	Max. volts (V)	-Delta V (mV/cell)	DV/dt (mV/min)	TCO (°C)	DT/dt (°C/min)	Timer (hr)	Vmax (V)
Ultra Fast (>2C)								
Fast (>0.5C)								
Standard (0.1C)			N/A	N/A		N/A		
Trickle (<0.1C)			N/A	N/A		N/A	N/A	

For Li-ion

Charge Mode	Charge			
	Current to voltage limit (mA)	Voltage limit (V) (<4.2V/cell)	Time (hr)	Charge control chip
Standard (0.8C) to 4.2V		4.2	2.5	
Customer proposed				

Safety Protection					
Over charge limit (V)	Over discharge limit (V)	Over discharge current limit (A)	Over discharge current delay time (mins)	TCO (°C)	Timer (hr)

\*The method of charging and discharging Li-ion battery is very important to the safety and performance of the battery. Please consult engineer for optimal safety and performance.

For Smart Battery

Fuel Gauge Parameter Table (provided by customer)

IC Type (provided by customer)

Yes: \_\_\_\_\_ (please attached) No: \_\_\_\_\_

Remarks: \_\_\_\_\_

J. Discharge method

Discharge mode: Constant current \_\_\_\_\_ mA      Battery low alarm voltage \_\_\_\_\_ mV  
 Average current \_\_\_\_\_ mA      Discharging cut-off voltage \_\_\_\_\_ mV  
 Power \_\_\_\_\_ W      Stand-by current after cut-off \_\_\_\_\_ mA  
 Resistance \_\_\_\_\_ Ohm

Discharge termination method: Cut off voltage \_\_\_\_\_ (V)

K. Operation temperature	Max.	Min.
In charge		
In discharge		
In storage		

L. Specific testing requirement:

Please describe \_\_\_\_\_

### III. Remarks

### IV. Approvals (SES internal use only)

Sales: \_\_\_\_\_ Engineering: \_\_\_\_\_

# 8 Glossary

**Active Material**

Chemicals that give rise to electro-chemical reactions, and which generate electrical energy in the battery.

**Alkaline Electrolyte**

An aqueous alkaline solution (such as potassium hydroxide) which provides a medium for the ionic conduction between the positive and negative electrodes of a cell.

**Ampere-hour**

Unit of capacity of a cell/battery. Capacity is defined as the product of the discharge rate and the discharge time.

**Battery**

Consists of one or more connected cells.

**Capacity**

The amount of electrical energy that can be supplied by a cell/battery - expressed in mAh, and in specified discharge conditions.

**Cell**

An electrochemical unit constituting positive and negative electrodes, separator, and electrolyte to provide electrical energy.

**Cell Reversal**

In reversal, the normal terminal polarities of a cell in a multiple cell battery are switched. Cell reversal normally occurs only if three or more unit cells are connected, and the battery is deeply discharged. Cell reversal is detrimental to performance, and should be avoided by proper selection of cut-off voltages during discharge.

**Charge**

The operation which inputs electrical energy to a cell/battery.

**Charge Efficiency**

A measurement of accumulated efficiency during the charging operation.

**Charge Rate**

The rate of current supplied to a cell/battery.

**Charge Retention**

The percentage of capacity remaining after a charged cell/battery has been stored for a period of time.

**Closed-circuit Voltage**

The voltage of the cell/battery with loading.

**Constant Current Charging**

Charging with a fixed current value.

**C-Rate**

Relative rate used in cell/battery, defined as the quotient of current (mA)/nominal capacity (mAh).

**Cut-off Voltage**

A set voltage that determines when the discharging of a cell/battery should end.

**Cycle Life**

The number of cycles a cell/battery can run under specific conditions, while still delivering specified minimum capacity.

**Depth of Discharge**

The percentage of the available capacity from a cell/battery during discharge.

**Discharge**

The operation which removes stored electrical energy from a cell/battery.

**Discharge Rate**

The rate of current drained from a cell/battery.

**Electrode**

A conducting plate containing active materials.

**Exothermic Reaction**

A chemical reaction which results in the release of heat energy as it proceeds.

**Memory Effect**

The phenomenon whereby the capacity of a cell may be temporarily decreased when it is repeatedly used in a shallow discharge pattern. Memory effects are erased when the cell is discharged to the normal cut-off voltage (e.g. 1.0V at the 0.2C discharge rate).

**Negative Electrode**

The electrode with negative potential. Current flows through the external circuit to this electrode during discharge.

**Nominal Voltage**

A general value to indicate the voltage of a battery in application.

**Open-circuit Voltage**

The voltage of the cell/battery without loading.

**Overcharge**

The continued charging of a cell/battery after it is fully charged.

**Positive Electrode**

The electrode with positive potential from which current flows through the external circuit to the negative electrode during discharge.

**Overcharge Current**

The charge current supplied during overcharge. Cells/batteries can accept continuous overcharging at recommended rates and temperatures specified by the manufacturer.

**Rated Capacity**

A nominal capacity available from a cell at specific discharge conditions.

**Safety Vent**

This is a device to release the gas when the internal pressure of the battery exceeds the pre-set value.

**Self-discharge**

The loss of capacity by a cell/battery during storage or in an unused condition. The rate of self-discharge is affected by ambient temperature.

**Separator**

The thin and porous membrane between the positive and negative electrodes to prevent short-circuit and hold the electrolyte.

**Short Circuit**

The direct connection of the positive electrode/terminal to the negative electrode/terminal of the battery.

**Standard Charge**

The normal charge rate used to charge a cell/battery in 16 hours. Normally 0.1C.

**Thermal Fuse**

A component assembled into batteries, which breaks the current when the temperature reaches a predetermined value.

**Thermistor**

A component with a negative temperature coefficient - built into batteries and/or used to detect the ambient and battery temperature.

**Trickle Charge**

A continuous and very low rate charging to keep a cell/battery on full capacity.

NiCd

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