

Panasonic

Nickel Cadmium Batteries

Technical Handbook '05/'06



PDF File Technical Handbook

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NOTICE TO READERS

It is the responsibility of each user to ensure that each battery application system is adequately designed safe and compatible with all conditions encountered during use, and in conformance with existing standards and requirements. Any circuits contained herein are illustrative only and each user must ensure that each circuit is safe and otherwise completely appropriate for the desired application.

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PRECAUTIONS FOR DESIGNING DEVICES WITH NI-CD BATTERIES

In order to take full advantage of the properties of Ni-Cd batteries and also to prevent problems due to improper use, please note the following points during the use and design of battery operated products.

Underlined sections indicate information that is especially important

1. Charging

1.1 Charging temperature

- Charge batteries within an ambient temperature range of 0°C to 45°C.
- Ambient temperature during charging affects charging efficiency. As charging efficiency is best within a temperature range of 10°C to 30°C, whenever possible place the charger (battery pack) in a location within this temperature range.
- At temperatures below 0°C the gas absorption reaction is not adequate, causing gas pressure inside the battery to rise, which can activate the safety vent and lead to leakage of alkaline gas and deterioration in battery performance.
- Charging efficiency drops at temperatures above 40°C. This can disrupt full charging and lead to deterioration in performance and battery leakage.

1.2 Parallel charging of batteries

- Sufficient care must be taken during the design of the charger when charging batteries connected in parallel.
Consult Panasonic when parallel charging is required.

1.3 Reverse charging

- Never attempt reverse charging. Charging with polarity reversed can cause a reversal in battery polarity causing gas pressure inside the battery to rise, which can activate the safety vent, lead to alkaline electrolyte leakage, rapid deterioration in battery performance, battery swelling or battery rupture.

1.4 Overcharging

- Avoid overcharging. Repeated overcharging can lead to deterioration in battery performance. ("Overcharging" means charging a battery when it is already fully charged.)

1.5 Rapid Charging

- To charge batteries rapidly, use the specified charger (or charging method recommended by Panasonic) and follow the correct procedures.

1.6 Trickle charging (continuous charging)

- Carry out trickle charge by applying the current of 0.02 to 0.05 CmA. The correct current value is determined depending on the features and purpose of the equipment.
- Note : "CmA"
During charging and discharging, CmA is a value indicating current and expressed as a multiple of nominal capacity. Substitute "C" with the battery's nominal capacity when calculating. For example, for a 1500mAh battery of 0.033CmA, this value is equal to $1/30 \times 1500$, or roughly 50mA.

2. Discharging

2.1 Discharge temperature

- Discharge batteries within an ambient temperature range of -20°C to +65°C.
- Discharge current level (i.e. the current at which a battery is discharged) affects discharging efficiency. Discharging efficiency is good within a current range of 0.1 CmA to 0.5 CmA.
- Discharge capacity drops at temperatures below -20°C or above +65°C. Such decreases in discharge capacity can lead to deterioration in battery performance.

2.2 Overdischarge

- Since overdischarging damages the battery characteristics, do not forget to turn off the switch when discharging, and do not leave the battery connected to the equipment for long periods of time. Also, avoid shipping the battery installed in the equipment.

2.3 High-current discharging

- As high-current discharging can lead to heat generation and decreased discharging efficiency, consult Panasonic before attempting continuous discharging or pulse discharging at currents larger than 2 CmA.

PRECAUTIONS FOR DESIGNING DEVICES WITH NI-CD BATTERIES-(CONT.)

3. Storage

3.1 Storage temperature and humidity (short-term)

- Store batteries in a dry location with low humidity, no corrosive gases, and at a temperature range of -20°C to +45°C.
- Storing batteries in a location where humidity is extremely high or where temperatures fall below -20°C or rise above +45°C can lead to the rusting of metallic parts and battery leakage due to expansion or contraction in parts composed of organic materials.

3.2 Long-term storage (2 year, -20°C to +35°C)

- Because long-term storage can accelerate battery self-discharge and lead to the deactivation of reactants, locations where the temperature ranges between +10°C and +30°C are suitable for long-term storage.
- When charging for the first time after long-term storage, deactivation of reactants may lead to increased battery voltage and decreased battery capacity. Restore such batteries to original performance by repeating several cycles of charging and discharging.
- When storing batteries for more than 1 year, charge at least once a year to prevent leakage and deterioration in performance due to self-discharging. When using a rapid voltage detection type battery charger carry out charge and discharge at least once every 6 months.

4. Service Life of Batteries

4.1 Cycle life

- Batteries used under proper conditions of charging and discharging can be used 500 cycles or more.
Significantly reduced service time in spite of proper charging means that the life of the battery has been exceeded.
Also, at the end of service life, an unusual increase in internal resistance, or an internal short-circuit failure may occur. Chargers and charging circuits should therefore be designed to ensure safety in the event of heat generated upon battery failure at the end of service life.
Please contact Panasonic if you have any questions.

4.2 Service life with long-term use

- Because batteries are chemical products involving internal chemical reactions, performance deteriorates not only with use but also during prolonged storage.
Normally, a battery will last 3 to 5 years if used under proper conditions and not overcharged or overdischarged.
However, failure to satisfy conditions concerning charging, discharging, temperature and other factors during actual use can lead to shortened life (or cycle life) damage to products and deterioration in performance due to leakage and shortened service life.

5. Design of Products Which Use Batteries

5.1 Connecting batteries and products

- Never solder a lead wire and other connecting materials directly to the battery, as doing so will damage the battery's internal safety vent, separator, and other parts made of organic materials.
To connect a battery to a product, spot-weld a tab made of nickel or nickel-plated steel to the battery's terminal strip, then solder a lead wire to the tab.
Perform soldering in as short a time as possible.
- Use caution in applying pressure to the terminals in cases where the battery pack can be separated from the equipment.
- When rapid charging using the voltage detection method with a large current (1It or more), or when leaving the battery installed in the equipment, be sure to follow connecting the precaution listed above. Even for other uses, if connecting the precaution listed above is used as much as possible, contact defects in the connection process can be reduced.

5.2 Material for terminals in products using the batteries

- Because small amounts of alkaline electrolyte can leak out from the battery seal during extended use or when the safety vent is activated during improper use, use a highly alkaline-resistant material for a product's contact terminals in order to avoid problems due to corrosion.

High Alkaline-resistant Metals	Low Alkaline-resistant Metals
Nickel, stainless steel, nickel-plated steel, etc.	Tin, aluminum, zinc, copper, brass, etc.

(Note that stainless steel generally results in higher contact resistance.)

PRECAUTIONS FOR DESIGNING DEVICES WITH NI-CD BATTERIES-(CONT.)

5.3 Temperature related to the position of batteries in products

- Excessively high temperatures (i.e. higher than 45°C) can cause alkaline electrolyte to leak out from the battery, thus damaging the product and shorten battery life by causing deterioration in the separator or other battery parts. Install batteries far from heat-generating parts of product. The best battery position is a battery compartment that is composed of an alkaline-resistant material which isolates the batteries from the product's circuitry. This prevents damage caused by a slight leakage of alkaline electrolyte from the battery. Be careful particularly when trickle charging is carried out (for continuous charging).

5.4 Discharge end voltage

- Overdischarge and reverse charge of the battery deteriorate battery characteristics. This can be caused by several actions, such as forgetting to turn off the power. Installing an overdischarge cutoff circuit is recommended in order to avoid overdischarge and reverse charge.
- The discharge end voltage is determined by the formula given below.

Number of Batteries Arranged Serially	
1 to 6	(Number of batteries x 1.0) V
7 to 20	((Number of batteries -1) x 1.2) V

5.5 Overdischarge (deep discharge) prevention

- Overdischarging (deep discharging) or reverse charging damages the battery characteristics. In order to prevent damage associated with forgetting to turn off the switch or leaving the battery in the equipment for extended periods, it is hoped that preventative options are incorporated in the equipment. At the same time, it is recommended that leakage current is minimized. Also, the battery should not be shipped inside the equipment.

6. Prohibited Items Regarding the Battery Handling

- Panasonic assumes no responsibility for problems resulting from batteries handled in the following manner.

6.1 Disassembly

- Never disassemble a battery, as the electrolyte inside is strong alkaline and can damage skin and clothes.

6.2 Short-circuiting

- Never attempt to short-circuit a battery. Doing so can damage the product and generate heat that can cause burns.

6.3 Throwing batteries into a fire or water

- Disposing of a battery in fire can cause the battery to rupture. Also avoid placing batteries in water, as this causes batteries to cease to function.

6.4 Soldering

- Never solder anything directly to a battery. This can destroy the safety features of the battery by damaging the safety vent inside the cap.

6.5 Inserting the batteries with their polarities reversed

- Never insert a battery with the positive and negative poles reversed, as this can cause the battery to swell or rupture.

6.6 Overcharging at high currents and reverse charging

- Never reverse charge or overcharge with high currents (i.e. higher than rated). Doing so causes rapid gas generation and increased gas pressure, thus causing batteries to swell or rupture.
- Charging with an unspecified charger or specified charger that has been modified can cause batteries to swell or rupture. Be sure to indicate this safety warning clearly in all operating instructions as a handling restriction for ensuring safety.

6.7 Installation in equipment (with an airtight battery compartment)

- Always avoid designing airtight battery compartments. In some cases, gases (oxygen, hydrogen) may be given off, and there is a danger of the batteries bursting or rupturing in the presence of a source of ignition (sparks generated by a motor switch, etc.).

6.8 Use of batteries for other purposes

- Do not use a battery in an appliance or purpose for which it was not intended. Differences in specifications can damage the battery or appliance.

PRECAUTIONS FOR DESIGNING DEVICES WITH NI-CD BATTERIES-(CONT.)

6.9 Short-circuiting of battery packs

- Special caution is required to prevent short-circuits. Care must be taken during the design of the battery pack shape to ensure batteries cannot be inserted in reverse. Also, caution must be given to certain structures or product terminal shapes which can make short-circuiting more likely.

6.10 Using old and new batteries together

- Avoid using old and new batteries together. Also avoid using these batteries with ordinary dry-cell batteries, Ni-MH batteries or with another manufacturer's batteries.
Differences in various characteristic values, etc., can cause damage to batteries or the product.

7. Other Precautions

- Batteries should always be charged prior to use.
Be sure to charge correctly.

8. Final Point to Bear in Mind

- In order to ensure safe battery use and to prolong the battery performance, please consult Panasonic regarding charge and discharge conditions for use and product design prior to the release of a battery-operated product.

RECHARGEABLE NI-CD BATTERIES

Responding to the Technological Revolution with Consistent Reliability!



Overview

Rechargeable Ni-Cd batteries are one type of alkaline storage battery, which is classified as a secondary battery. Ni-Cd batteries use nickel hydroxide as the positive electrode, cadmium as the negative electrode, and an alkaline electrolyte. They are designated by IEC 285 as alkaline secondary cells and batteries “Sealed nickel-cadmium cylindrical rechargeable single cells”. First invented by Jungner of Sweden in 1899, the basis for practical application of rechargeable Ni-Cd batteries was made possible about 50 years later by the development of the totally sealed cell by Neumann of France.

Ever since our development and practical application of rechargeable Ni-Cd batteries in 1961, for over 30 years Panasonic has continued to make innovations

and improvements in order to meet the ever-increasing needs and demands of the market. As a result, our rechargeable Ni-Cd batteries are used for all types of applications throughout the world. Panasonic has also applied many original technological developments in our rechargeable Ni-Cd batteries, including the fabrication of the negative electrode by a pasted method, the fabrication of the positive electrode by a sintered method or by using a new foamed metal material, and the use of a new thin type separator, thus achieving ever-higher levels of reliability and performance.

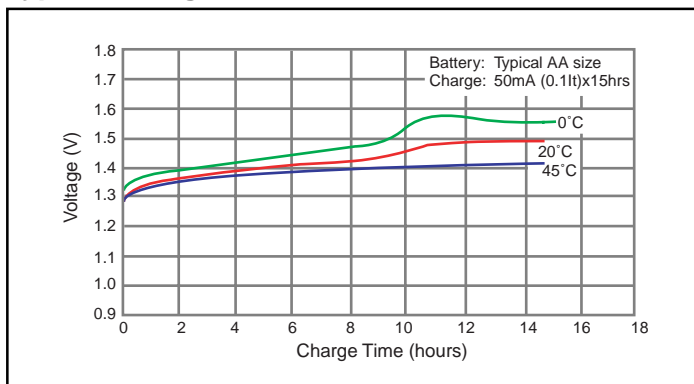
Five Main Characteristics of Ni-Cd Batteries

Ni-Cd batteries have five main characteristics: charge, discharge, cycle life, storage, and safety.

1. Charge Characteristics

The charge characteristics of Ni-Cd batteries are affected by the current, time, temperature, and other factors. Increasing the charge current and lowering the charge temperature causes the battery voltage to rise. Charge generates heat, thus causing the battery temperature to rise. Charge efficiency will also vary according to the current, time, and temperature. For rapid charge, a charge control system is required; refer to the following section on the charge methods for Ni-Cd batteries.

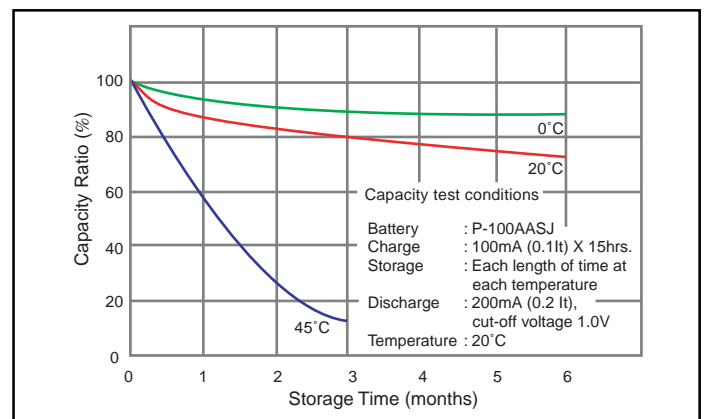
Typical Charge Characteristics



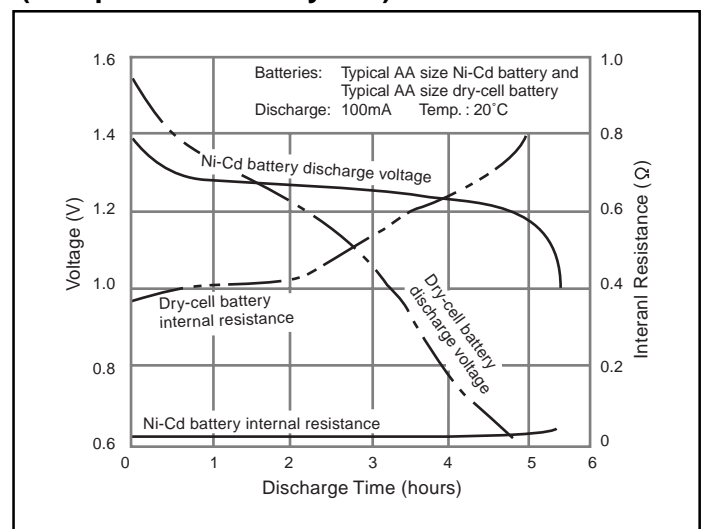
2. Discharge Characteristics

The discharge characteristics of Ni-Cd batteries will vary according to the current, temperature, and other factors. Generally, in comparison with dry-cell batteries, there is less voltage fluctuation during discharge, and even if the discharge current is high, there is very little drop in capacity. Among the various types of Ni-Cd batteries, there are models such as Panasonic's "P" type which are specifically designed to meet the need for high-current discharge, such as for power tools, and there are also models such as the Rapid Charge type which are designed to meet the need for high capacity, such as for high-tech devices.

Typical Self-discharge Characteristics



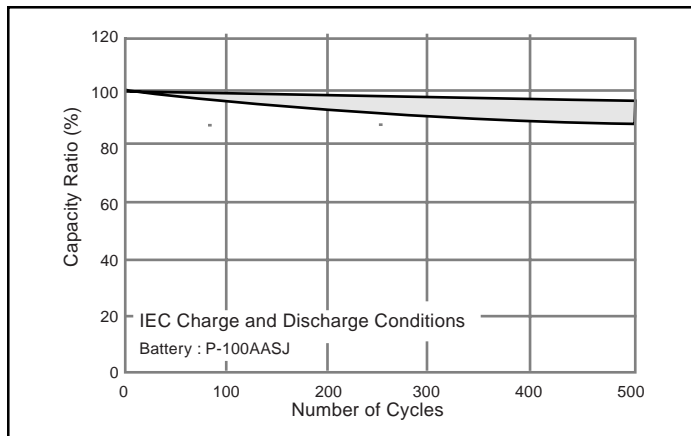
Typical Discharge Characteristics (Comparison with Dry-cell)



3. Cycle Life Characteristics

The cycle life of Ni-Cd batteries will vary according to the charge and discharge conditions, the temperature, and other usage conditions. When used in accordance with the IEC charge and discharge specifications, over 500 charge/discharge cycles are possible. The actual cycle life will vary according to which of the various charge formats is used, such as for rapid charge, and also according to how the device powered by the batteries is actually used.

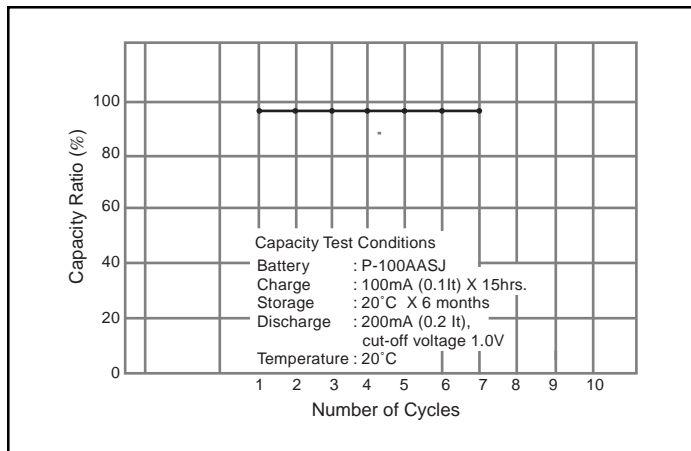
Typical Cycle Life Characteristics



4. Storage Characteristics

When Ni-Cd batteries are stored in a charged state, the capacity will gradually decrease (self discharge), and this tendency will be markedly greater at high temperatures. However, the capacity can be subsequently restored by charge. Even if the batteries are stored for an extended length of time, if the storage conditions are appropriate, the capacity will be restored by subsequent charge and discharge.

Typical Capacity Recovery After Storage



5. Safety

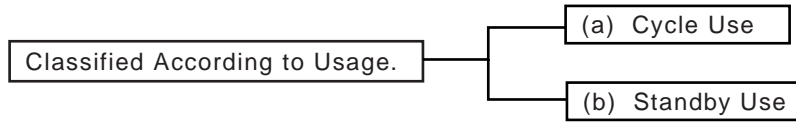
If pressure inside the battery rises as a result of improper use, such as overcharge, short-circuit, or reverse charge, a resettable safety valve will function to release the pressure, thus preventing bursting of the battery.

CHARGE METHODS FOR NI-CD BATTERIES

If the charge conditions are not appropriate, not only will the batteries not display their full performance potential, but the cycle life could also be shortened, and in extreme cases, electrolyte leakage could damage the device in which the batteries are used. Therefore, carefully select the appropriate charge method, taking into consideration the type of battery,

the state of discharge, the charge current, and the ambient temperature.

The charge methods for Ni-Cd batteries can be generally classified into two types according to the purpose for which the batteries are used: cycle use and standby use.



(a) Cycle Use

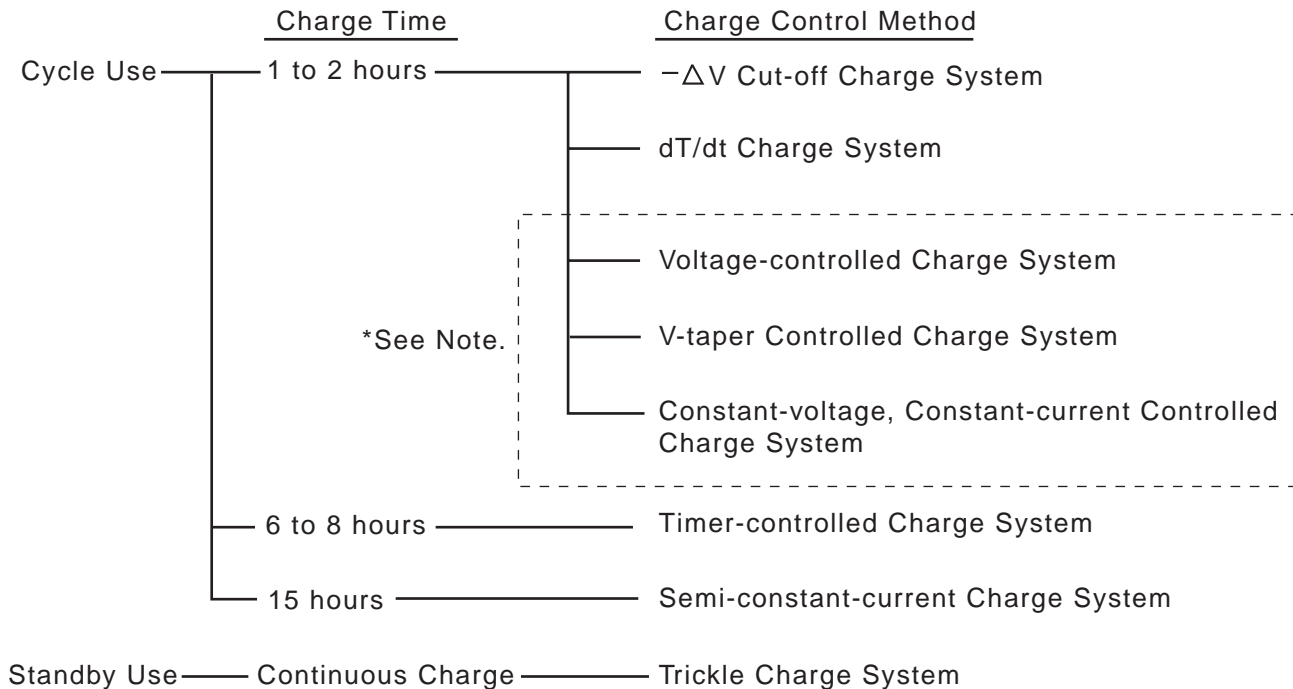
The battery is repeatedly charged and discharged. This is the most common method for using Ni-Cd batteries.

(b) Standby Use

Power is normally supplied to the load from an AC power supply, and the Ni-Cd battery is used to maintain the power supply to the load in the event that the AC power supply is interrupted.

(1) Methods of Charge for Ni-Cd Battery

The methods of charge for Ni-Cd batteries can be classified as follows according to the purpose of use and the charge time.



* Not a recommended charge method for Ni-Cd batteries

CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

(2) General Comparison of the Various Charge Systems

Charge System	Cycle (Repeated) Use				Standby Use
	Semi-constant Current Charge	Timer Controlled Charge	- ΔV Cut-off Charge	dT/dt Cut-off Charge	Trickle Charge
Operation V _B : Battery Voltage I _{ch} : Charge Current T: Battery Temperature					
Features	<ul style="list-style-type: none"> * Most typical charge system * Simple and economical 	<ul style="list-style-type: none"> * More reliable than Semi-constant current charge system * Relatively simple and economical 	<ul style="list-style-type: none"> * Most popular 	<ul style="list-style-type: none"> * Charging circuit costs more than the others but overcharge can be avoided enabling longer life cycle than - ΔV charge method 	<ul style="list-style-type: none"> * Simple and economical * Applicable to the equipment for continuous long charge
No. of Output Terminals	2	2	2	3	2
Charge Time	15 hours	6 to 8 hours	1 to 2 hours	1 to 2 hours	30 hours or longer
Charge Current	0.1 CmA	0.2 CmA	0.5 to 1 CmA	0.5 to 1 CmA	<ul style="list-style-type: none"> * frequent charge: 0.05-0.033 CmA * less frequent charge: 0.033-0.02 CmA
Trickle Current	---	0.05-0.033 CmA	0.05-0.033 CmA	0.05-0.033 CmA	
Charge Level at Charge Control	---	approx. 120%	approx. 110 to 120%	approx. 100 to 110%	---
"S" Type	---	---	⊗	○	---
"R" Type	○	○	⊗	○	---
"P" Type	○	○	⊗	⊗	---
Application Examples	<ul style="list-style-type: none"> * Shavers * Digital cordless phones * Toys 	<ul style="list-style-type: none"> * Cordless Phone * Shavers 	<ul style="list-style-type: none"> * Data Terminals * Camcorder * Wireless equipment * Cellular phones 	<ul style="list-style-type: none"> * Power Tools * Electric Tools * Notebook PC * Cellular phones 	<ul style="list-style-type: none"> * Emergency lights * Guide lights * Memory back-up

⊗: Most recommended
 ○: Acceptable

CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

(2) General Comparison of the Various Charge Systems - Continued

Charge System	For Reference Only (Not Recommended for the Main Charge Control System for Ni-Cd Batteries.)		
	Voltage Controlled Charge System	V-taper Controlled Charge System	Constant-voltage, Constant-current Controlled Charge System
Operation V _B : Battery Voltage I _{ch} : Charge Current T: Battery Temperature CV: Constant Voltage			
Features	* Not recommended for the main charge control system for Ni-Cd batteries	* Not recommended for the main charge control system for Ni-Cd batteries. * Recommended charge control system for sealed lead acid batteries.	* Not recommended for the main charge control system for Ni-Cd batteries.
No. of Output Terminals	---	---	---
Charge Time	---	---	---
Charge Current	---	---	---
Trickle Current	---	---	---
Charge Level at Charge Control	---	---	---
"S" Type	---	---	---
"R" Type	---	---	---
"P" Type	---	---	---
Application Examples	---	---	---

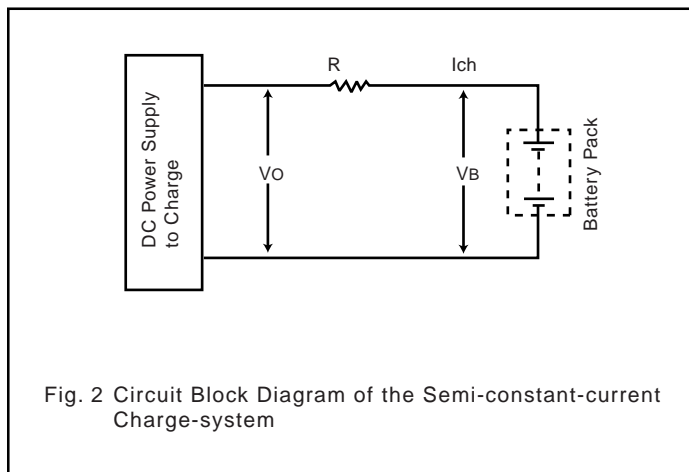
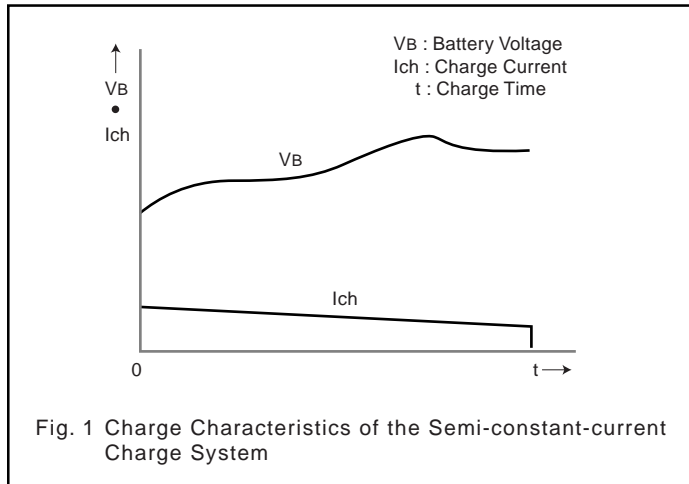
(3) Details of Each Charge Method

Semi-constant-current Charge System

(1) Mechanism

(A) Mechanism

A resistance is positioned between the DC power supply and the battery, thus stabilizing the charge current. By keeping the charge current low enough that the battery does not generate any heat, this method performs charge without using any control.



(B) Calculation Example

The calculation formula for the block diagram of the semi-constant-current charge system shown in Fig. 1 is as follows.

V_o = Output voltage of the DC power supply for charge

V_c = Single-cell battery voltage (1.45 V/cell: average battery voltage during charge at 20°C, 0.1 CmA)

N = Number of cells used

V_B = Battery voltage ($V_c \times N$)

R = Charge current stabilizing resistance

I_{ch} = Charge current

$$I_{ch} = \frac{V_o - V_B}{R} = \frac{V_c \times N \times (K) - V_c \times N}{R}$$

(K) is the stabilizing constant and must be selected in accordance with the purpose of the device in which the battery pack is used.

(2) Features

- The standard charge method for Ni-Cd batteries.
- The charger construction is simple and inexpensive.

(3) General Specifications

	Typical General Specifications
Number of Charger Output Terminals	2
Charge Current	0.1CmA
Charge Time	15 hours
Applicable Battery Types	R P

(4) Cautions

- If the specific conditions of the device require that a charge rate higher than 0.1 CmA be used, the overcharge performance and temperature rise characteristics will vary according to the battery type. Consult Panasonic for further details and specifications.
- If a large number of battery cells are used, or if batteries having a high nominal capacity are used, or if the heat dissipation of the battery pack is poor, the batteries may generate heat even when charged at 0.1 CmA. In such cases, it is necessary to re-design the construction for better heat dissipation or to lower the charge current. Design so that the battery temperature rise at saturation is no higher than 50°C.
- The value of the above-mentioned stabilizing constant (K) must be selected carefully. If the value of K is too small, the fluctuation of the charge current with respect to the fluctuation of the power supply voltage will increase, and this could cause insufficient charge or overcharge.

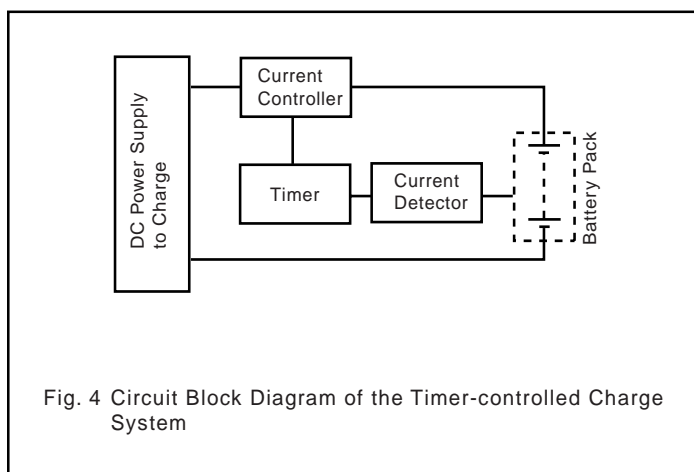
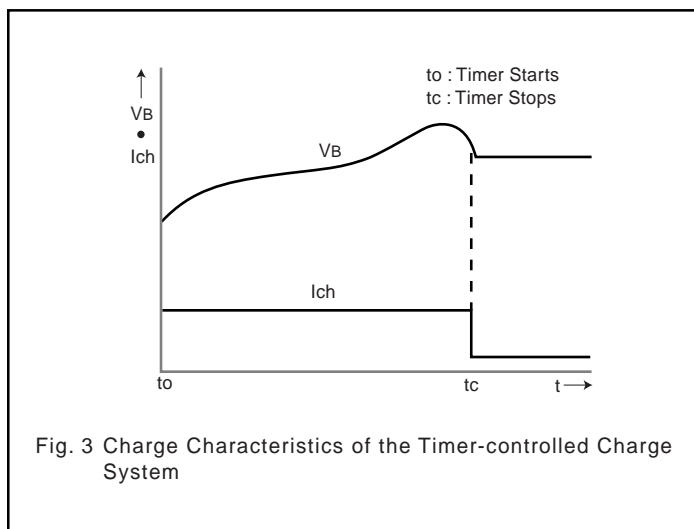
CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

- When the batteries reach the end of their cycle life, the usage time will become markedly shorter, and eventually two malfunction modes will occur: an internal short-circuit and the exhaustion of the electrolyte (the internal resistance will increase). Therefore, when designing the charger and the charge circuit, these malfunction modes (output short-circuit, etc.) at the end of the cycle life must be taken into consideration. Special care is required regarding the rated load of the charge current stabilizing resistance R so that an overload does not occur at the time of these battery malfunction modes.

Timer-controlled Charge System

(1) Mechanism

At the start of charge, an IC timer is started (counts up), and charge is continued at a current of 0.2 CmA for a specified time until the timer stops. After the timer stops, trickle charge continues at 0.05 CmA.



(2) Features

- Compared with the semi-constant-current charge system (non-controlled), the addition of a charge timer improves the long-term reliability of charge.
- The construction of the charge circuit is relatively simple and inexpensive.

General Specifications

	Typical General Specifications
Number of Charger Output Terminals	2
Charge Current	0.2CmA
Charge Time	6 hours
Charge Level Until Timer Stops	120%
Trickle	Charge Current 0.05CmA
Applicable Battery Types	S R P

(3) Cautions

- This method is not appropriate for applications in which the timer is frequently reset (charge is restarted).
- If frequent resetting of the timer is required, or if the specific conditions of the device require that a charge rate higher than 0.2 CmA be used (for example, timer-controlled charge at 0.3 CmA), it is necessary to combine this method with an absolute temperature cut-off charge system.
- The overcharge performance will vary according to the battery type.

- Δ V Cut-off Charge System

(1) Mechanism

If rapid charge Ni-Cd batteries are charged at a constant current, the battery voltage will increase as charge progresses, peak when charge is completed, and then subsequently decrease. Because this voltage drop occurs regardless of the discharge level or ambient temperature, it can be effectively used to detect the completion of charge. The -ΔV cut-off charge system controls charge by detecting the voltage drop (-ΔV) following the peak.

CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

(2) Features

- The most common control method for rapid charge.
- The most recommended and widely used method for the rapid charge of Ni-Cd batteries for use in high-tech devices (for example, portable VCR, notebook PC, digital cordless and cellular phones, etc.).

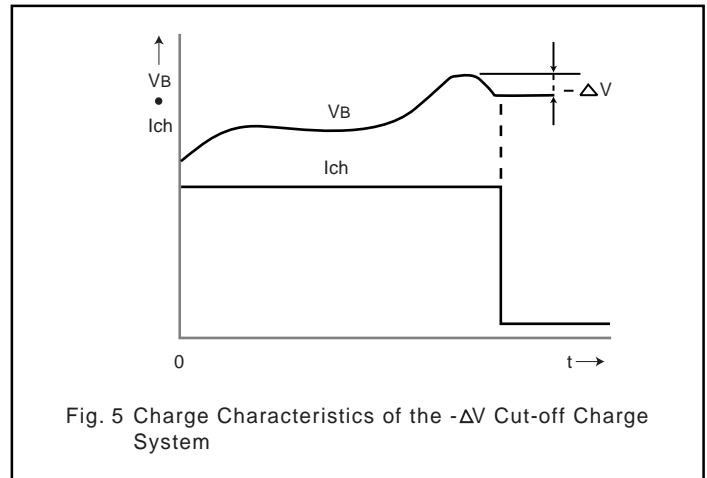


Fig. 5 Charge Characteristics of the $-\Delta V$ Cut-off Charge System

(3) General Specifications

	Typical General Specifications	Remarks
Number of Charger Output Terminals	2	
Charge Current	0.5 to 1.0 CmA	See (5) in Fig. 6
Charge Time	1 to 2 hours	
Charge Level at $-\Delta V$ Cut-off	approx. 110 to 120%	
Trickle Charge Current	0.05 CmA	See (6) in Fig. 6
$-\Delta V$ Value	15 to 20 mV/cell	See (3) in Fig. 6
Charge Mode Switching (1) (From Rapid Charge to Trickle Charge)	1.95 V/cell	See (2) in Fig. 6
Charge Mode Switching (2) (From Initial Charge to Rapid Charge)	0.8 to 1.0 V/cell	See (4) in Fig. 6
Initial Charge Current	approx. 0.2 CmA	See (7) in Fig. 6
Total Timer Time	Time corresponding to a 150% charge level of the nominal capacity at the rapid charge current	See (8) in Fig. 6
Initial Delay Timer	approx. 5 min.	See (1) in Fig. 6
Safety Device	Thermal protector (included in the battery pack)	See Fig. 7 and 8
Applicable Battery Types	S R P	

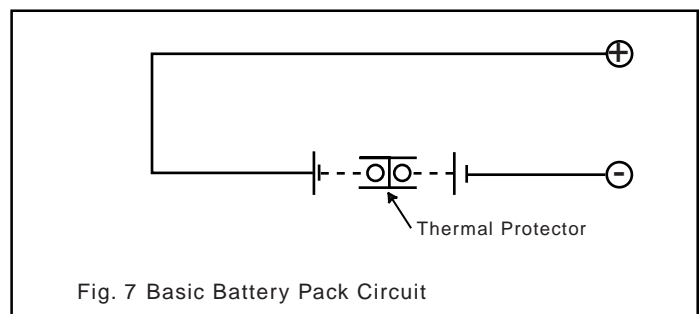
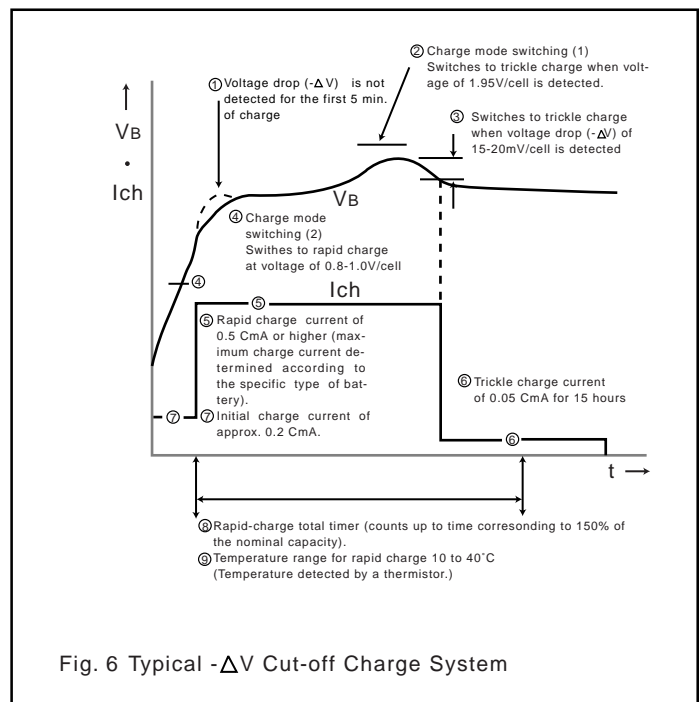
CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

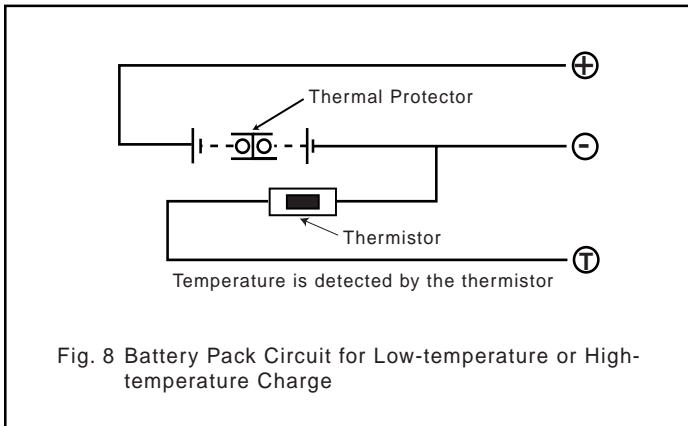
(3) Precautions

- This method is suitable for rapid charge Ni-Cd batteries.
- The charge current should be 0.5 CmA ~ 1 CmA. If charged at less than 0.5 CmA, the voltage drop after the peak voltage is reached might be too small for the $-\Delta V$ cut-off to function, resulting in overcharge. The maximum charge current will vary according to the specific type of battery, so it is important to select the appropriate charge current. (See (5) in Fig. 6)
- A constant-current power supply circuit is required. If fluctuations in the charge current occur as a result of fluctuations in the power supply voltage, the charge voltage will change, and faulty operation (stopping of charge before completion) of the charger might occur.
- The voltage detector shown in the block diagram must be provided with a noise canceller in order to prevent external noise from causing faulty operation (stopping of charge before completion) of the charger.
- An initial delay timer is needed in order to prevent faulty operation (stopping of charge before completion) of the charger from being caused by any false $-\Delta V$ phenomenon at the beginning of charge.
False $-\Delta V$ phenomenon: When Ni-Cd batteries are left unused for a long period of time or excessively discharged, the charge voltage (false $-\Delta V$) may swing at the beginning of charge. (See (1) in Fig 6)
Initial delay timer: Prevents the $-\Delta V$ detection circuit from functioning for a certain length of time after rapid charge is begun.
- Be sure that the $-\Delta V$ value is correct. If it is not, faulty operation (overcharge or insufficient charge) of the charger might occur. (See (1) in Fig. 6)
- A voltage detection switch must be provided in order to change from the rapid-charge current to the trickle charge current when the charge voltage reaches the predetermined level.
This predetermined level varies according to the type of battery, so consult Panasonic for the specific level. The trickle charge current should be 0.05 CmA. (See (2) and (6) in Fig. 6)
- If a voltage detection switch is provided in order to switch the charger to the rapid charge mode, set the voltage value to 0.8 to 1.0 V/cell. In addition, for the period of initial charge (before the start of rapid charge) until the battery voltage reaches the

predetermined level, set the charge current to approximately 0.2 CmA. (See (5) and (7) in Fig. 6)

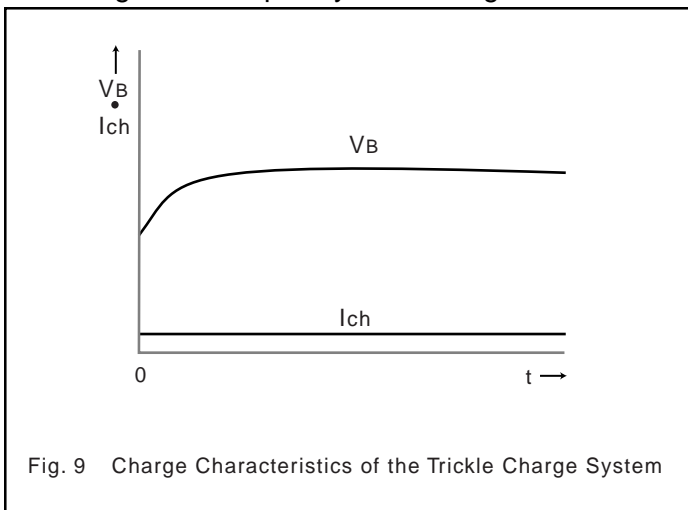
- Provide a total timer in the charge circuit as a double-safety control. (See (8) in Fig. 6)
- A thermal protector (thermostat) and other safety devices are needed inside the battery pack to ensure the safety of rapid charge. (See Figs. 7 and 8.)
- Especially for devices where charge is frequently performed at high temperatures or low temperatures (for example, chargers designed to be used in an automobile), in order to increase charge reliability, the charger is provided with a function that detects the temperature of the batteries and switches to trickle charge if the temperature is not within the specified range for rapid charge. Therefore, a thermistor or other temperature-detecting element must be provided inside the battery pack, and the battery pack will have a 3-terminal construction. (See (9) in Fig. 6 and Fig. 7)





Trickle Charge System

There are generally two types of uses for trickle charge; As a standby power supply for devices such as emergency lights, and for additional charge following rapid charge. When used as a standby power supply, the appropriate charge current varies according to the frequency of discharge.



CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

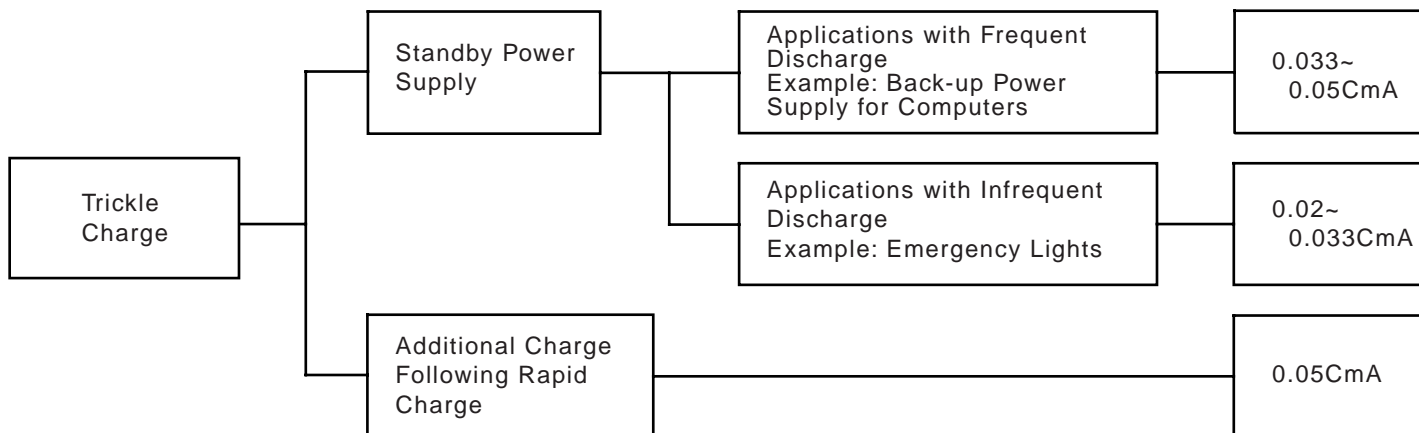
(1) Mechanism

While the AC power is being supplied, the battery is disconnected from the load and is charged by a very small current which only replenishes the self-discharge of the battery. Only in the event of an interruption in the AC power supply does power flow from the battery to the load.

(2) Features

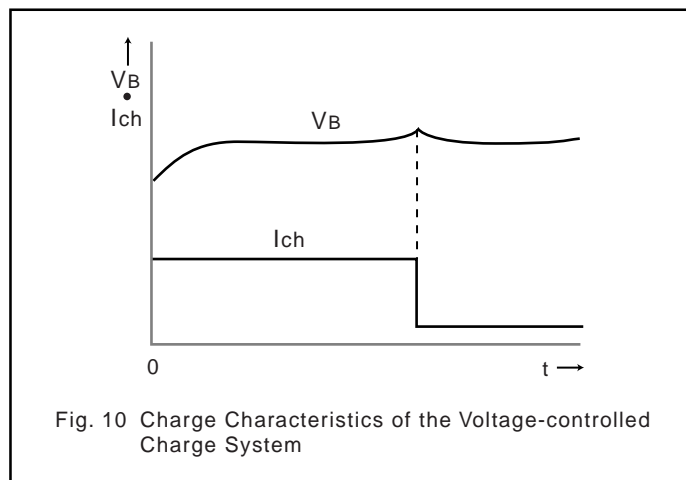
- Mainly used as a standby power supply for emergency lights and other disaster-prevention equipment.
- The main purpose of trickle charge is to replenish the self-discharge of the battery, using a very small charge current of 0.02 to 0.05 CmA. It takes many hours to completely charge.

(3) General Specifications (Trickle Charge Current)



(4) Precautions

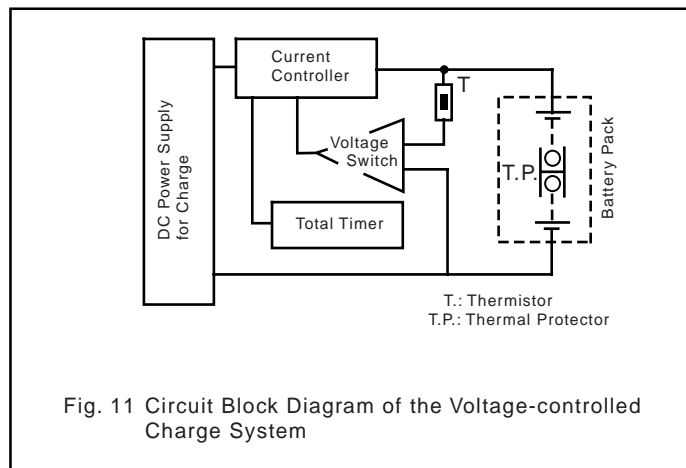
- The trickle charge current for use as a standby power supply should be set to a level at which charge will be completed by time of the next discharge, taking into consideration the frequency of discharge and the discharge current.
- If recovery charge at a relatively large current (for example, 0.1 CmA) is required, combine trickle charge with some other suitable charge control system (for example, timer-control charge).



Voltage-controlled Charge System (for Reference Only)

(1) Mechanism

The charge voltage at the completion of charge is detected (the detection voltage can be freely set) by a voltage detection circuit inside the charger, and the charger switches from rapid charge to trickle charge. To compensate for temperature-related fluctuations in the charge voltage of Ni-Cd batteries, temperature compensation is added to the detection voltage.



CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

(2) Features

This method is rarely used today, and it is not appropriate for the charge control system for Ni-Cd batteries.

Matching the charger to the batteries is extremely difficult, and if the detection voltage of the charger is not set correctly, insufficient charge or overcharge (thermal runaway) can easily occur.

General Specifications

	Typical General Specifications
Number of Charger Output Terminals	2
Charge Current	0.5 ~ 1.0 CmA
Charge Time	1 to 2 hours (complete charge is difficult even with a longer charge time)
Charge Level at Voltage Control	Approx. 70%
Trickle Charge Current	0.05 CmA
Detection Voltage	(Detection voltage must be compensated for the temperature.)
Safety Device	Thermal protector + total timer
Applicable Battery Types	(Not recommended for use as the main charge control system for Ni-Cd batteries.)

(3) Precautions

- The setting of the detection voltage is extremely difficult. The setting of the detection voltage and of the temperature compensation must be done carefully, taking into consideration the variations and fluctuations of the batteries and of the charger as indicated below, and in order to avoid overcharge (thermal runaway), the detection voltage is generally set for insufficient charge. Batteries: Single-cell and multi-cell (battery pack) variations in the charge voltage, and fluctuation of the charge voltage caused by the ambient temperature.
Charger: Variations in the adjustment of the set detection voltage, and fluctuation of the detection voltage caused by the ambient temperature.
- The charge voltage increases in batteries which have been left unused for a long period of time, and during charge the charge voltage will quickly reach the charger's detection voltage. Therefore, if the voltage-controlled charge control system is used to charge batteries which have not been used for a long period of time, the charge level will be low. Matching the charger to the batteries is extremely difficult, and if the detection voltage of the charger is not set correctly, insufficient charge

or overcharge (thermal runaway) can easily occur. Therefore, this method should never be used as the main charge control system for Ni-Cd batteries.

V-taper Controlled Charge System

This is the charge control method recommended for Sealed Lead Acid batteries, and it is not recommended for charge Ni-Cd batteries.

(1) Mechanism

This system is basically the same as the voltage-controlled charge system already described. However, in the V-taper controlled charge system, after the set voltage is detected at the completion of charge, the

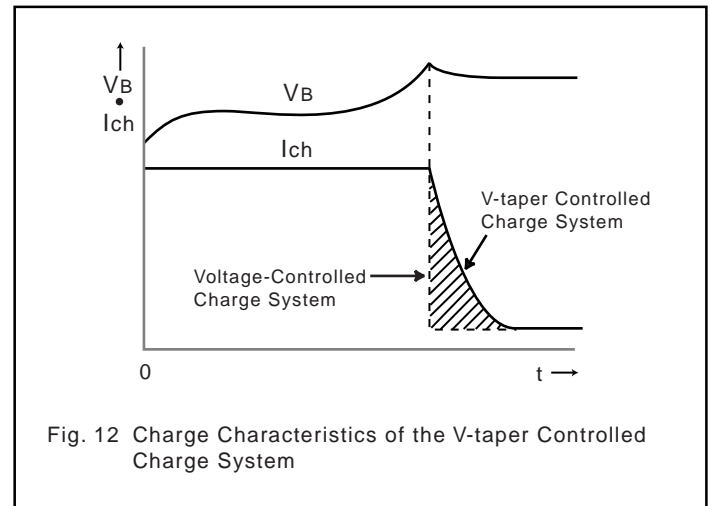


Fig. 12 Charge Characteristics of the V-taper Controlled Charge System

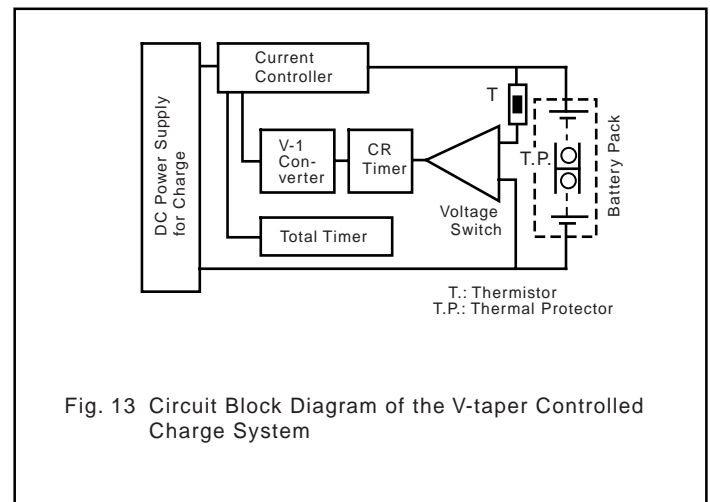


Fig. 13 Circuit Block Diagram of the V-taper Controlled Charge System

rapid charge current is supplied as a tapered current, decreased at a predetermined rate over a predetermined length of time, and then switched to trickle current. Supplying the decreasing taper current makes it possible to achieve a higher charge level than with the voltage-controlled charge system.

CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

(2) Features

- This is the recommended charge control system for Sealed Lead Acid batteries.
- In comparison with the voltage-controlled charge system, this method is capable of increasing the charge level by the amount indicated by the shaded area in Fig. 12. However, just as for the voltage-controlled charge system, the setting of the detection voltage is extremely difficult when charge Ni-Cd batteries.

(3) General Specifications

Because this system is currently used only as a rapid charge method for Sealed Lead Acid batteries, the specifications are not included here.

(4) Precautions

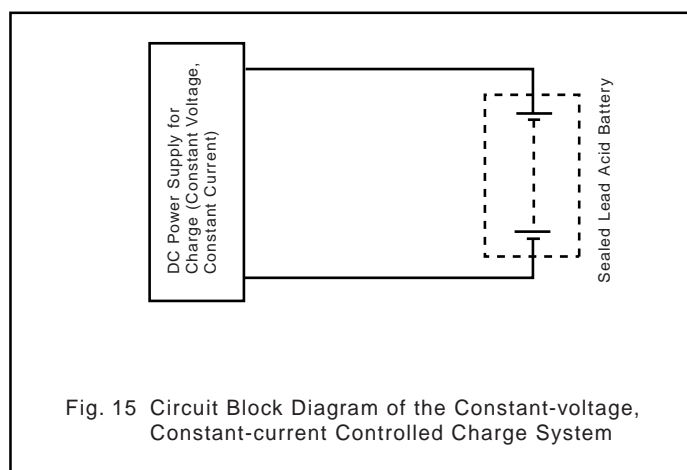
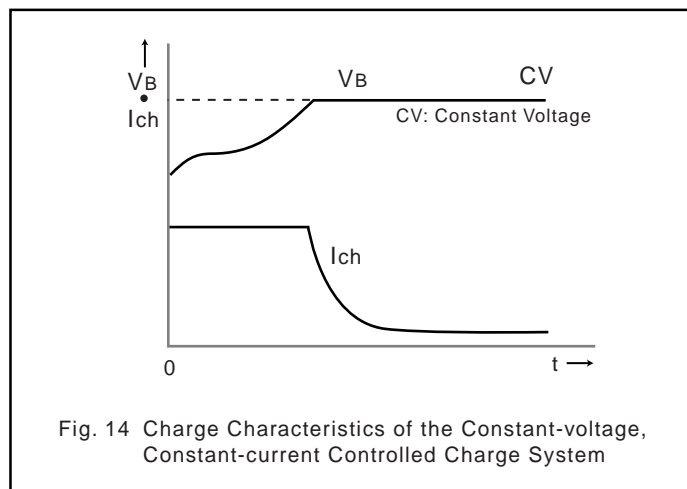
This charge method is basically the same as the voltage-controlled charge system, and it is not appropriate for charge Ni-Cd batteries.

Constant-voltage, Constant-current Controlled Charge system

This is the basic charge system for Sealed Lead Acid batteries, and it is not recommended for charge Ni-Cd batteries.

(1) Mechanism

The charge voltage of Sealed Lead Acid batteries rises sharply at the completion of charge and is subsequently maintained at that level. The constant-voltage, constant-current controlled charge system utilizes these charge voltage characteristics to complete (control) charge using only a constant-voltage power supply with no external control. When the battery voltage is lower than the constant voltage, charge is carried out in the constant-current range, and when the battery voltage reaches the level of the constant-voltage, the charge current is decreased to a trickle current.



(2) Features

Because this method is used only for charge Sealed Lead Acid batteries, the features are not included here.

(3) General Specifications

Because this method is used only for charge Sealed Lead Acid batteries, the specifications are not included here.

(4) Cautions

The charge voltage characteristics of Ni-Cd batteries exhibit a peak at the completion of charge, and subsequently drop. Therefore, if the constant-voltage, constant-current controlled charge system were to be used to charge Ni-Cd batteries, the charge current would be increased again, and thermal runaway would occur. This method is not suitable, and is not recommended for charge Ni-Cd batteries.

CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

Differences Between the Basic Charge Methods for Ni-Cd and Valve-Regulated Lead Acid Batteries (Previously SLA)

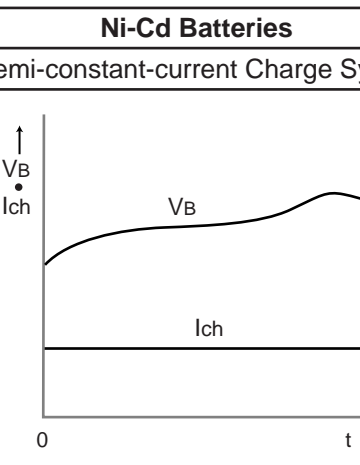
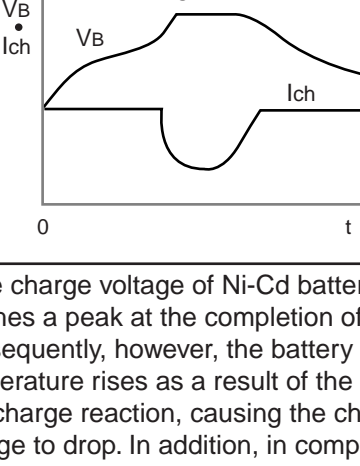
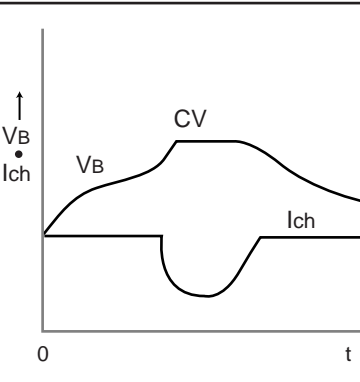
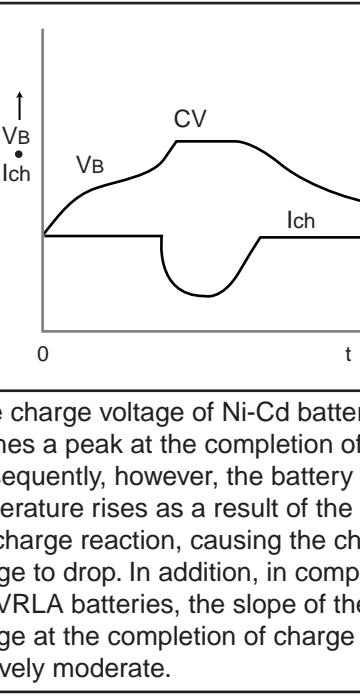
(1) Basic Charge Methods

A comparison of the charge voltage characteristics of Ni-Cd batteries and VRLA batteries shows major differences in the behavior of the charge voltage, such as at the completion of charge. With Ni-Cd batteries, the charge voltage reaches a peak at the completion of charge and subsequently drops, while with VRLA batteries, the charge voltage is maintained at the high level reached at the completion of charge and does not subsequently drop. Due to such

differences, the overcharge voltage characteristics also differ greatly between the two types of batteries. Therefore, if the incorrect type of charge system is used, it will be impossible to match the charger to the batteries, thus leading to problems. The following is a summary of the basic charge methods for the two types of batteries.

- For Ni-Cd batteries: Constant-current controlled charge system (Semi-constant-current charge system).
- For VRLA batteries: Constant-voltage, constant-current controlled charge system.

(2) General Comparison of the Basic Charge Methods

Batteries	Ni-Cd Batteries	Sealed Lead Acid Batteries
Constant-current Controlled Charge System	(Semi-constant-current Charge System) 	Suitable 
Constant-voltage, Constant-current Controlled Charge System	Not Suitable 	Suitable 
Charge Voltage Characteristics (Summary)	* The charge voltage of Ni-Cd batteries reaches a peak at the completion of charge. Subsequently, however, the battery temperature rises as a result of the overcharge reaction, causing the charge voltage to drop. In addition, in comparison with VRLA batteries, the slope of the voltage at the completion of charge is relatively moderate.	* The charge voltage of VRLA batteries rises sharply at the completion of charge, and is subsequently maintained at a relatively high level.
V _B : Battery Voltage I _{ch} : Charge Current CV: Constant Voltage		

CHARGE METHODS FOR NI-CD BATTERIES - CONTINUED

Confirming the Charge Specifications

In order to be able to fully display the characteristics of Ni-Cd batteries, it is important to confirm the

Charge Specification Checklist

- Applicable batteries _____
- Number of cells used _____
- Charge power supply
 - AC _____ V
 - DC car battery _____ V
 - Other _____
- Charge temperature _____ °C to _____ °C (Standard charge: 0°C to 45°C); (rapid charge: 10°C to 40°C)
- Charge type
 - Cycle use
 - Standby use
 - Other _____
 - Semi-constant-current charge (non-controlled)
- Charge current _____ mA
 - Trickle charge
 - Timer-control charge
- Timer time _____ hrs.
- Trickle current following timer control _____ mA
- Timer reset method
 - When charge power supply is input
 - When battery pack is loaded
- Reset frequency _____ times/day
 - ΔV cut-off charge
- Constant-current power supply
 - Yes
 - No
- Trickle current following - ΔV control
 - Yes _____ mA
 - No
- - ΔV value _____ mV/cell
- Charge mode switch (1) (See Fig. 7.)
 - Yes \pm _____ V/cell
 - No
- Charge mode switch (2) (See Fig. 7.)
 - Yes \pm _____ V/cell
 - No
- Initial charge current _____ mA
- Initial delay timer
 - Yes _____ min.
 - No

Two important points for obtaining maximum performance from Ni-Cd batteries

- (1) Select a type of battery suitable for the purpose.
- (2) Set the charge characteristics correctly. In particular, if the charge conditions are not appropriate,

not only will the batteries not display their full performance potential, but the cycle life could be shortened, and in extreme cases, electrolyte leakage could cause damage to the device in which the batteries are used. It is important to consult Panasonic from the initial stages of charger design.

- Total timer
 - Yes _____ hrs.
 - No
 - Battery temperature detection function (Detects the battery temperature and switches to trickle charge at beginning of charge.)
 - Yes, low temperature _____ °C
 - Yes, high temperature _____ °C
 - No
 - Absolute temperature cut-off charge
 - Control temperature _____ \pm _____ °C
 - Trickle current following absolute temperature control
 - Yes _____ mA
 - No
 - Temperature-detecting elements
 - Thermistor
 - B constant _____ \pm _____ %
 - R25°C _____ kW \pm _____ %
 - Manufacturer's name _____
Model No. _____
 - Thermostat (bimetal type)
 - Operating temperature _____ \pm _____ °C
Manufacturer's name _____
Model No. _____
 - Other temperature-detecting element
 - Element name _____
 - Manufacturer's name _____
 - Model No. _____
 - Retention circuit following completion of charge
 - Yes
 - No
 - Total timer _____
 - Yes
 - No
 - Other rapid charge control system
 - Trickle current _____ mA
- Summary of the rapid charge system operation

ate, not only will the batteries not display their full performance potential, but the cycle life could be shortened, and in extreme cases, electrolyte leakage could cause damage to the device in which the batteries are used. It is important to consult Panasonic from the initial stages of charger design.

SUMMARY SPECIFICATION TABLES

Cycle Use

Diameter	Size	IEC	Model Number	Type	Nominal Voltage (V)	Discharge Capacity*		Dimensions with Tube (mm)		Approx. Weight (g)	Page	
						Average (mAh)**	Rated (Min.) (mAh)	Diameter	Height			
AA	AA	KR15/51	P-100AASJ/B	S	1.2	1,080	1,000	14.5 +0/-0.7	50.0 +0/-1.0	23	30	
			P-100AASJ/FT	S		1,080	1,000			23	30	
A	4/5A	KR17/43	P-120AS	S		1,280	1,200	17.0 +0/-0.7	43.0 +0/-1.5	26	31	
	A	KR17/50	P-140AS	S		1,530	1,400			50.0 +0/-1.5	32	32
SC	4/5SC	KR23/34	P-120SCJS	R		1,300	1,200	23.0 +0/-1.0	43.0 +0/-1.5	34.0 +0/-1.5	37	33
	SC	KR23/43	P-130SCS	R		1,450	1,300			47	34	
			P-150SCS	R		1,600	1,500			44	35	
			P-170SCS	P		1,800	1,650			49	36	
			P-200SCS	P		2,100	2,000			52	37	

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

Battery performance and cycle life are strongly affected by how they are used.

In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as: $I_t(A) = C_n(Ah)/1h$.

- [It] is the reference test current in ampres
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
n = the time base [hours] for which the rated capacity is declared
/B = extended positive terminal (Button Top)

HIGH CAPACITY “S” TYPE

High Capacity “S” Type Batteries for Today’s High-tech Devices

Summary

In addition to providing the increased capacity to meet the needs of today’s high-tech devices, these cells are also capable of rapid charge in approximately 1 hour.

With their exceptionally high reliability, these batteries can be used under a wide range of ambient temperatures, and they provide excellent cycle life characteristics.

Application Examples

- Portable CD players
- Wireless equipment and Cordless phones

Battery Line-up (High Capacity “S” Type)

Model Number	Size	Nominal voltage (V)	Discharge capacity*		Individual Specification
			Average (mAh)**	Minimum (mAh)	
P-100AASJ/B	AA	1.2	1,080	1,000	Page # 30
P-100AASJ/FT	AA	1.2	1,080	100	Page # 30
P-120AS	4/5A	1.2	1,280	1,200	Page # 31
P-140AS	A	1.2	1,530	1,400	Page # 32

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as: $It(A) = Cn(Ah)/1h$.

- [It] is the reference test current in ampres
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
n = the time base [hours] for which the rated capacity is declared

RAPID CHARGE “R” TYPE

Meeting Today’s Needs

Summary

Rapid Charge “R” type batteries can be charged at a current of 1 CmA, thus making rapid charge in approximately 1 hour possible. The positive and negative electrode plates and separator have been improved from Panasonic’s original technology, resulting in a higher level of reliability.

For rapid charge, because it is necessary to suppress the rise in temperature at the completion of charge, the voltage and battery temperature during charge should be monitored in order to control the charge current.

Battery Line-up (Rapid Charge “R” Type)

Model Number	Size	Nominal voltage (V)	Discharge capacity*		Individual Specification
			Average (mAh)**	Minimum (mAh)	
P-120SCJS	4/5SC	1.2	1,300	1,200	Page # 33
P-130SCS	SC	1.2	1,450	1,300	Page # 34
P-150SCS	SC	1.2	1,600	1,500	Page # 35

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as: $It(A) = Cn (Ah)/1h$.

- [It] is the reference test current in ampres
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
n = the time base [hours] for which the rated capacity is declared

RAPID CHARGE "R" TYPE - CONTINUED

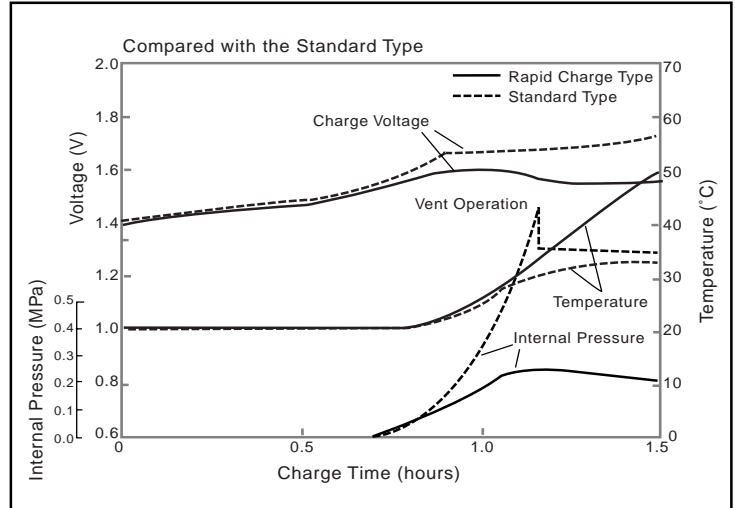
Application Examples

- Shavers
- Wireless equipment, Portable VCR, etc.

Features

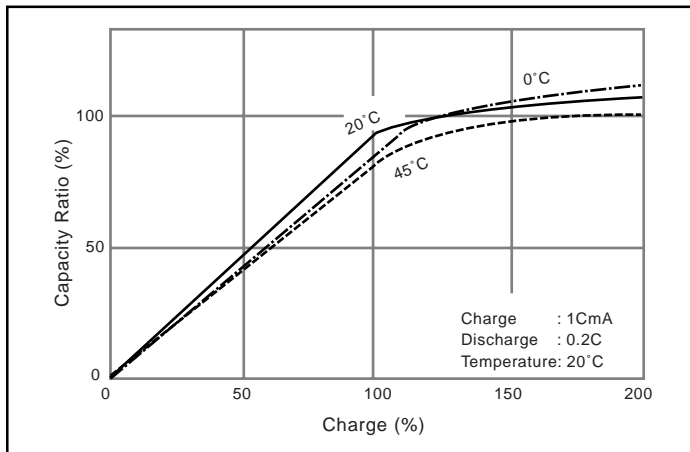
- **Rapid Charge in Approximately 1 Hour**
A temperature detection system, which utilizes the battery temperature to control the charge current, is combined with a voltage-controlled charge system that charges at a large current until the battery is approximately fully charged. This makes it possible to charge "R" type batteries in approximately 1 hour, with the battery displaying virtually 100% of its capacity.

Rapid Charge Characteristics



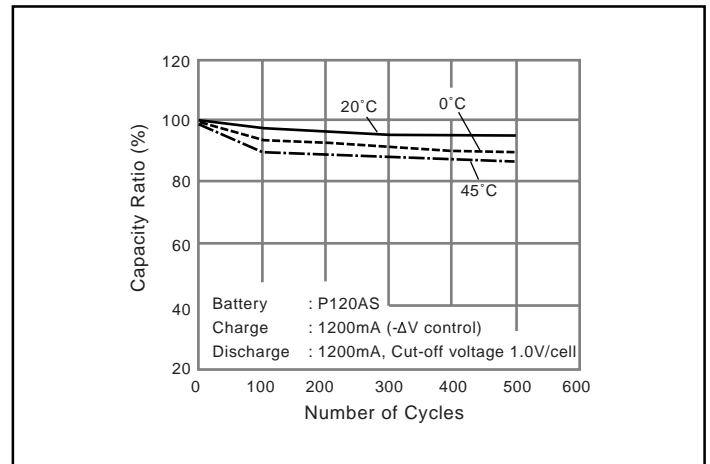
- **Excellent Temperature Characteristics**
The charge efficiency is virtually unaffected by changes in temperature.

Charge Acceptance



- **Long Cycle Life and Economical**
Combined with a correctly controlled charger, rapid charge "R" type batteries provide hundreds of charge/discharge cycles, making them very economical.

Cycle Life



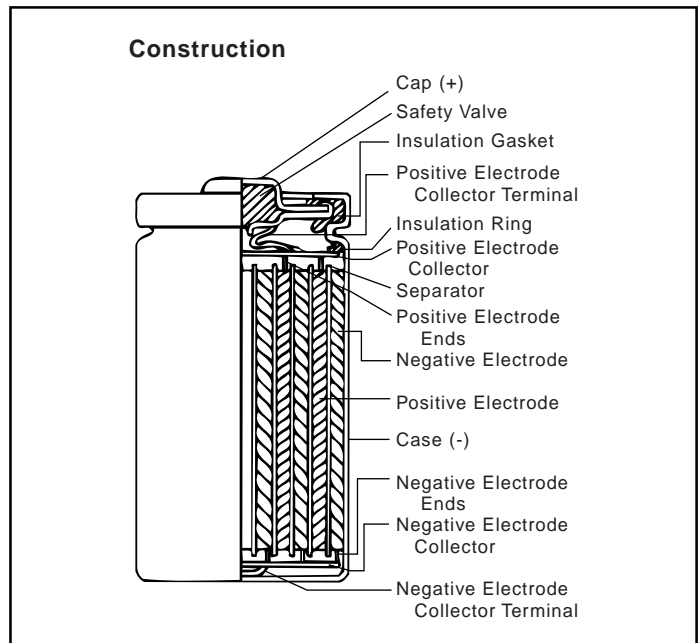
HIGH RATE DISCHARGE AND RAPID CHARGE “P” TYPE

Optimum Discharge Characteristics for Ni-Cd Batteries

Summary

High Rate Discharge & Rapid Charge “P” type batteries were developed through an integration of Panasonic’s comprehensive Ni-Cd battery technology. Combined with the technology for rapid 1 hour charge established for “R” type batteries, improvements in the positive and negative electrode plates and in the collecting system have further lowered the internal resistance and greatly improved the 10-CmA discharge characteristics of these “P” type batteries.

For rapid charge, because the rise in temperature at the completion of charge has to be suppressed, the voltage and battery temperature during charge should be monitored in order to control the charge current.



Battery Line-up (High Rate Discharge and Rapid Charge “P” Type)

Model Number	Size	Nominal voltage (V)	Discharge capacity*		Individual Specification
			Average (mAh)**	Minimum (mAh)	
P-170SCS	SC	1.2	1,800	1,650	Page # 36
P-200SCS	SC	1.2	2,100	2,000	Page # 37

* 0.2C discharge capacity after charging at 0.1C for 16 hours.

** For reference only.

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Application Examples

- Drills, screwdrivers, saws and other power tools
- Toys such as radio-controlled cars and airplanes
- Cordless vacuum cleaners
- Other applications requiring high-current discharge

HIGH RATE DISCHARGE AND RAPID CHARGE “P” TYPE - CONTINUED

Features

- **Excellent High-Current Discharge Characteristics**

High rate discharge & rapid charge “P” type batteries discharge a high-current of 30 A (approx. 25 CmA), which is about 1.5 times higher than Rapid Charge “R” type batteries.

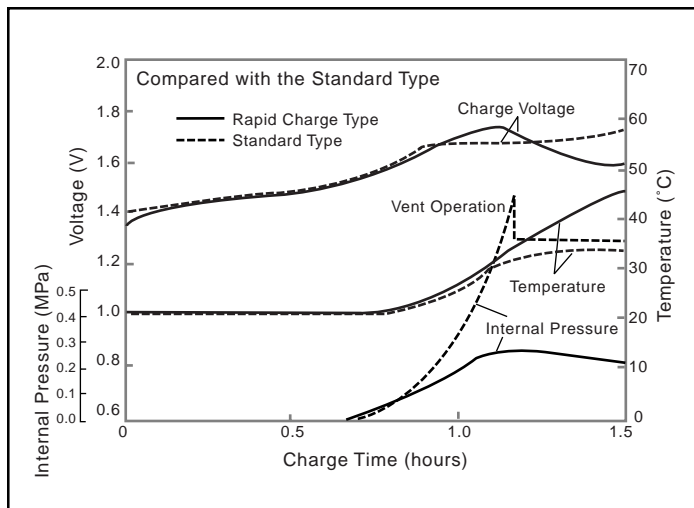
- **Rapid Charge in Approximately 1 Hour**

By combining a temperature detection system which utilizes the battery temperature to control the charge current with a ΔV cut-off charge system, it is possible to perform rapid charge in approximately 1 hour, with the battery displaying virtually 100% of its capacity.

- **Reliable, Long Cycle Life**

With conditions of charge at 1 CmA and discharge at 10 CmA, High rate discharge & rapid charge “P” type batteries provide hundreds of charge / discharge cycles, displaying reliable cycle life characteristics regarding both voltage characteristics and length of use.

Rapid Charge Characteristics



BATTERY SELECTION

The steps for selecting the type of battery for use as the power supply of a device are shown below.

- **Study of the Proposed Required Specifications**

Verify the battery specifications required for the power supply of the device and use those conditions as the standards for battery selection. For reference, the technological factors concerning battery selection are shown below.

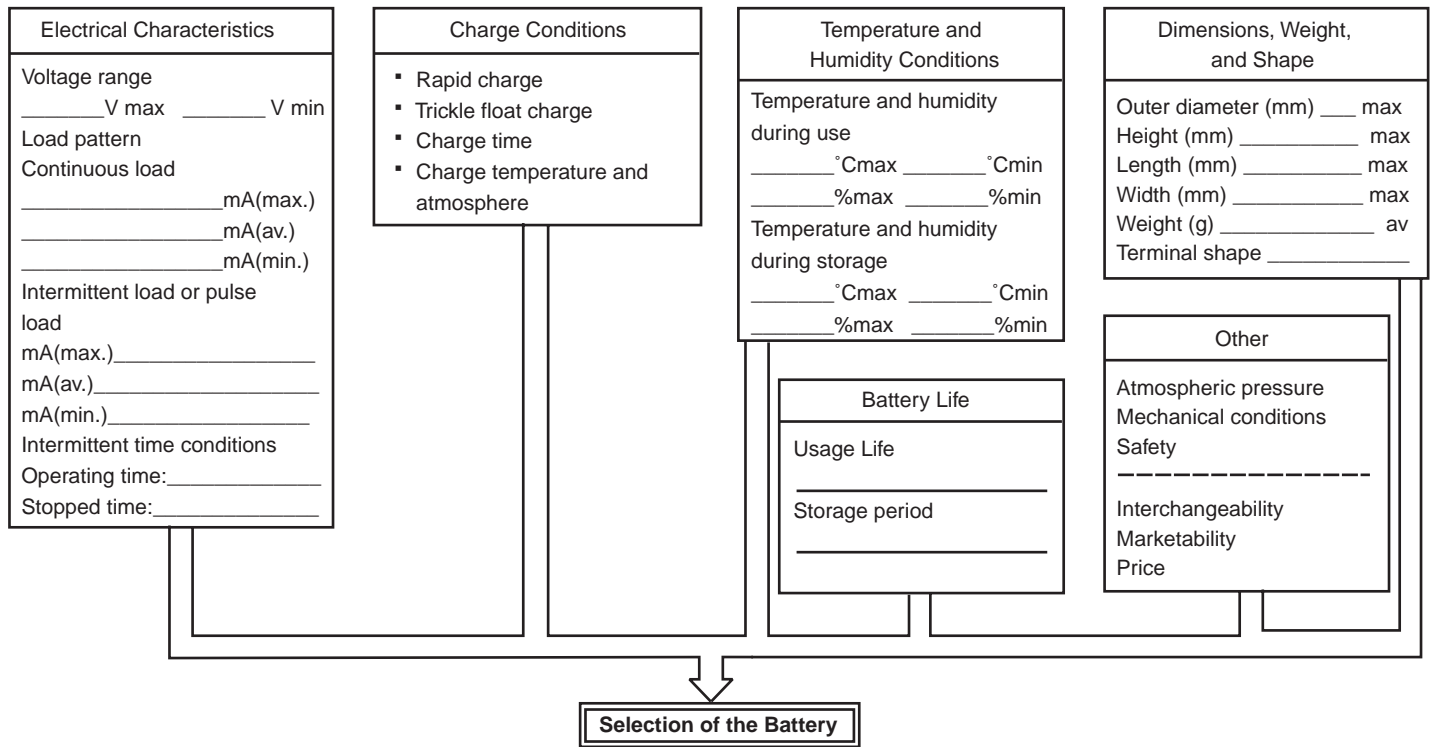
- **Battery Selection**

Using the catalogs and data sheets for the batteries currently produced and marketed, narrow down the number of candidates to a few battery types. From those candidates, select the one battery that most

closely satisfies the ideal conditions required.

In actual practice, the selection of a battery is rarely completed as easily as this. In most cases it is necessary to consider eliminating or relaxing some of the proposed specifications, and then select the most suitable battery from among those currently available to meet the adjusted conditions. This process makes it possible to select more economical batteries. If you have any doubts at this stage, consult closely with a battery engineer. In some cases, newly improved or newly developed batteries that are not yet listed in the catalog may be available. Normally, the required specifications are also finalized at this stage.

Technological Factors Concerning Battery Selection

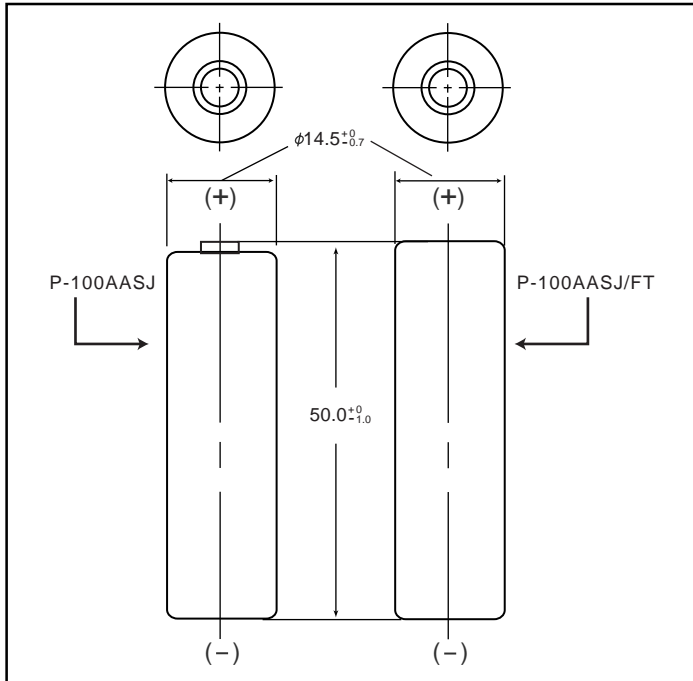


NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-100AASJ/B P-100AASJ/FT

AA size (KR15/51) Type: S

Dimensions (with tube) (mm)



Specifications

	mm	inch
Diameter	14.5 +0/-0.7	0.57 +0/-0.03
Height	50.0 +0/-1.0	1.97 +0/-0.04
Approximate Weight	Grams	Ounces
	23g	0.81

Nominal Voltage		1.2V	
Discharge Capacity*	Average**	1080mAh	
	Rated (Min.)	1000mAh	
Approx. Internal impedance at 1000Hz at charged state		17mΩ	
Charge	Standard	100mA (0.1It) x 16 hrs.	
	Rapid***	1000mA (1It) x 1.5 hrs.	
Ambient Temperature	Charge	Standard	°C
			°F
	Rapid	0°C to 45°C	32°F to 113°F
		10°C to 40°C	50°F to 104°F
Discharge		-20°C to 65°C	-4°F to 149°F
Storage	< 2 years	-20°C to 35°C	-4°F to 95°F
	< 6 months	-20°C to 45°C	-4°F to 113°F

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

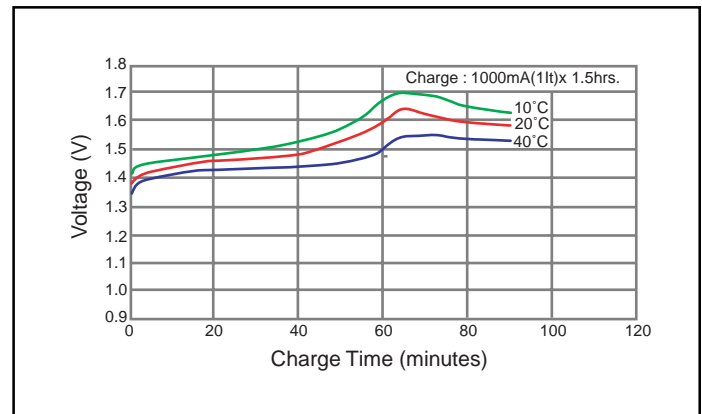
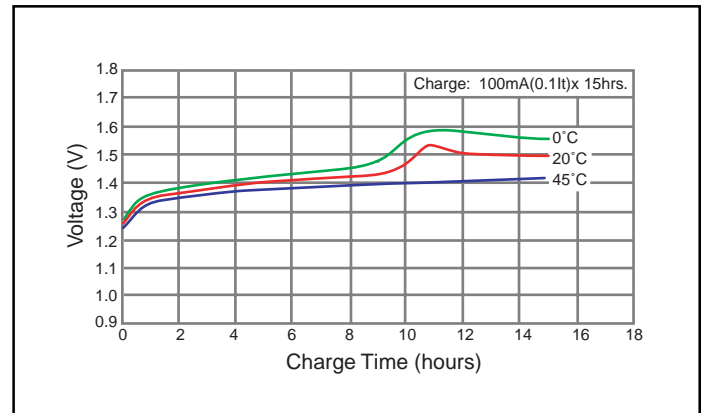
*** Refer to "Charge Methods for Ni-Cd Batteries"

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

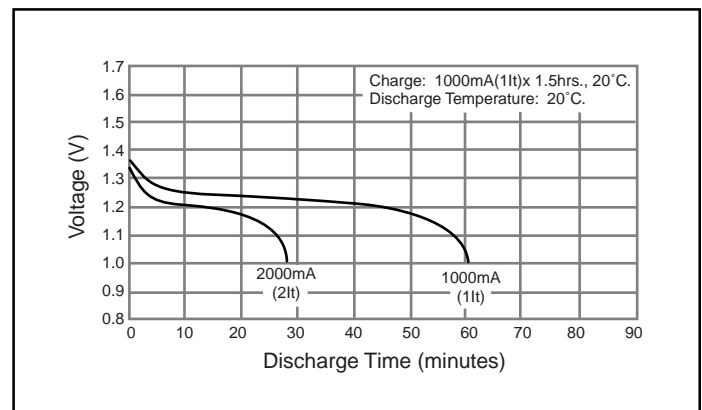
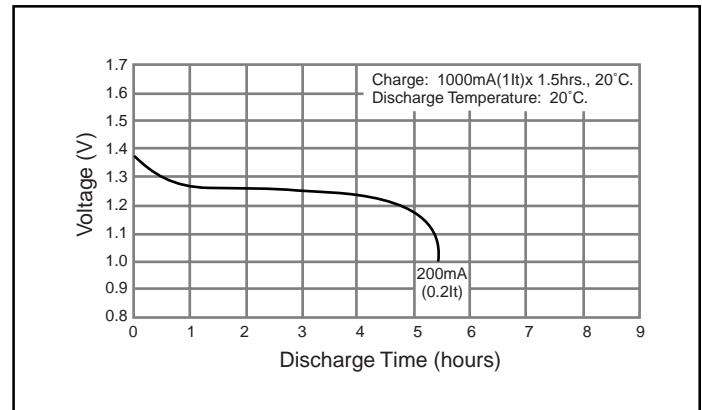
Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as:
It(A) = Cn (Ah)/1h.

- [It] is the reference test current in amperes
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
- n = the time base [hours] for which the rated capacity is declared

Typical Charge Characteristics



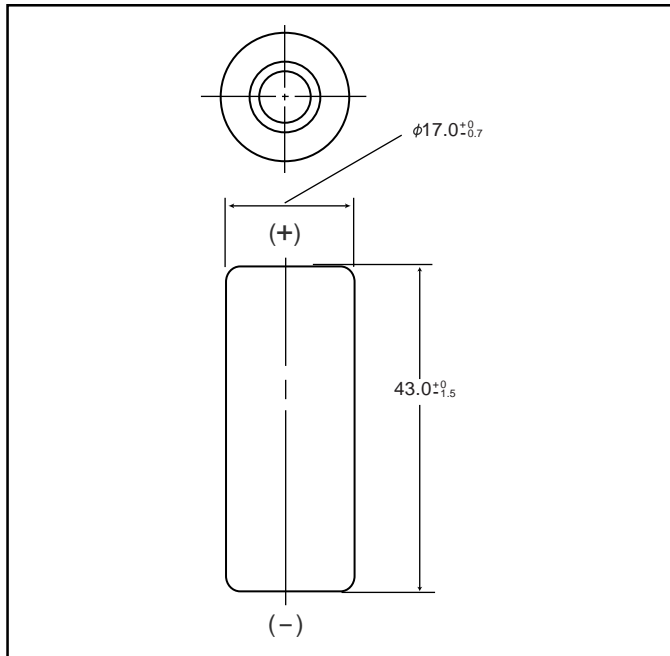
Typical Discharge Characteristics



NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-120AS 4/5A size (KR17/43) Type: S

Dimensions (with tube) (mm)



Specifications

	mm	inch
Diameter	17.0 +0/-0.7	0.67 +0/-0.03
Height	43.0 +0/-1.5	1.69 +0/-0.06
Approximate Weight	Grams	Ounces
	26g	0.92

Nominal Voltage		1.2V	
Discharge Capacity*	Average**	1280mAh	
	Rated (Min.)	1200mAh	
Approx. Internal impedance at 1000Hz at charged state		16mΩ	
Charge	Standard	120mA (0.1It) x 16 hrs.	
	Rapid***	1200mA (1It) x 1.5 hrs.	
Ambient Temperature	Charge	Standard	°C
			°F
	Rapid	0°C to 45°C	32°F to 113°F
		10°C to 40°C	50°F to 104°F
Discharge		-20°C to 65°C	-4°F to 149°F
Storage	< 2 years	-20°C to 35°C	-4°F to 95°F
	< 6 months	-20°C to 45°C	-4°F to 113°F

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

*** Refer to "Charge Methods for Ni-Cd Batteries"

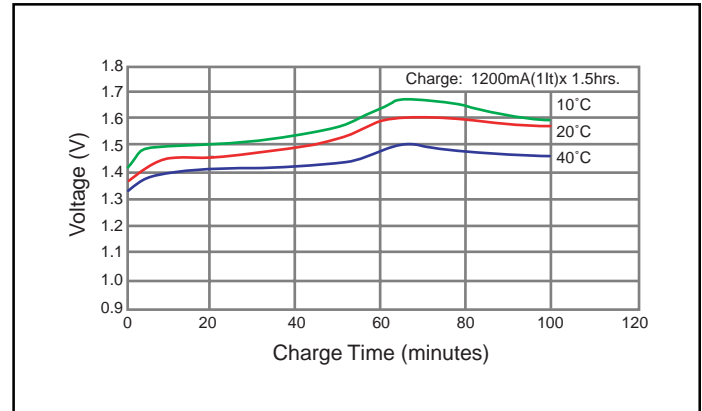
Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as:

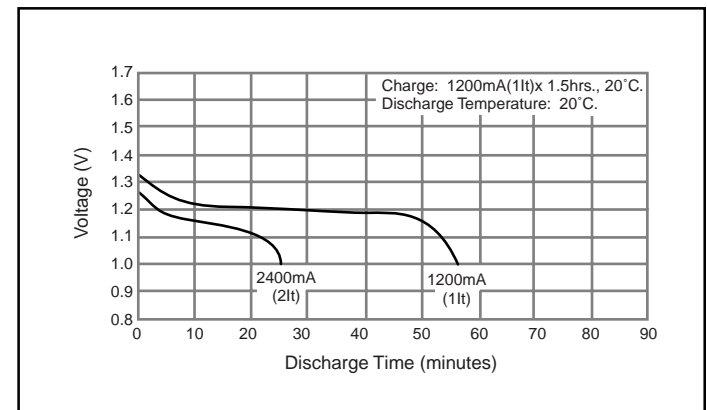
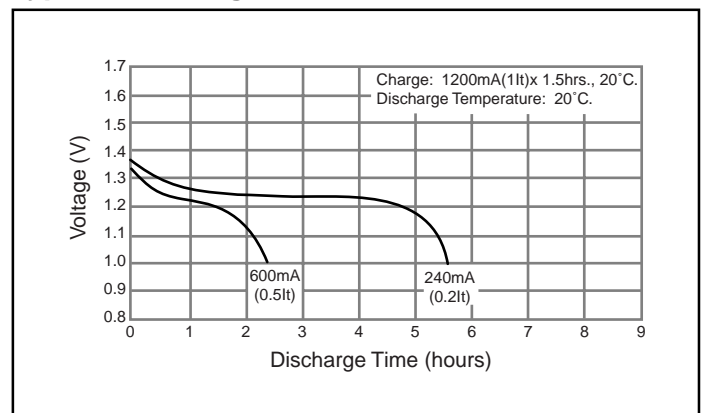
$$It(A) = C_n (Ah)/1h.$$

- [It] is the reference test current in amperes
- [C_n] is the rated capacity of the cell or battery in Ampere-hours.
n = the time base [hours] for which the rated capacity is declared

Typical Charge Characteristics



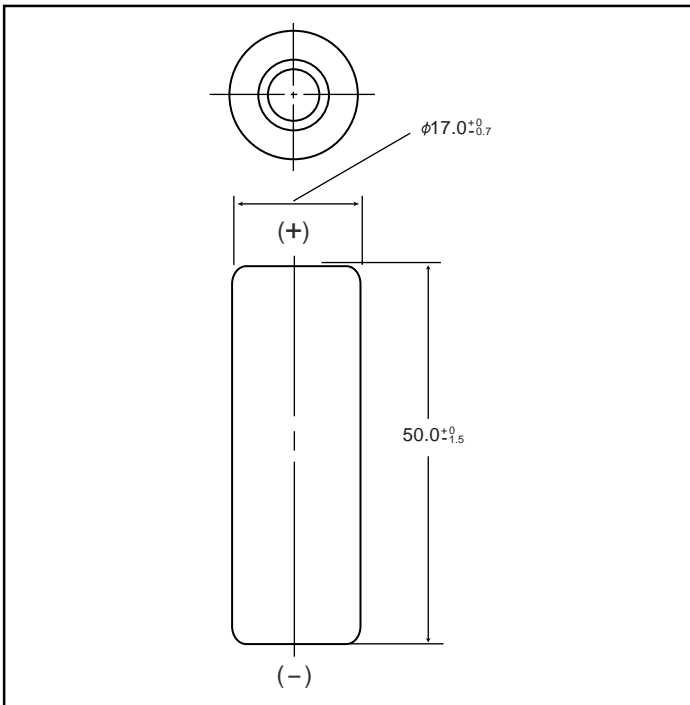
Typical Discharge Characteristics



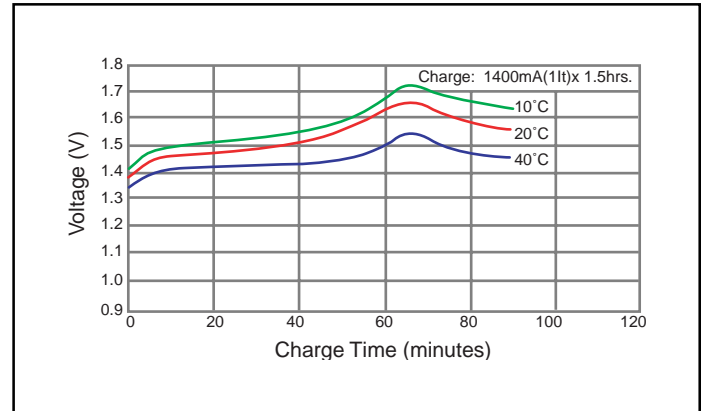
NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-140AS A size (KR17/50) Type: S

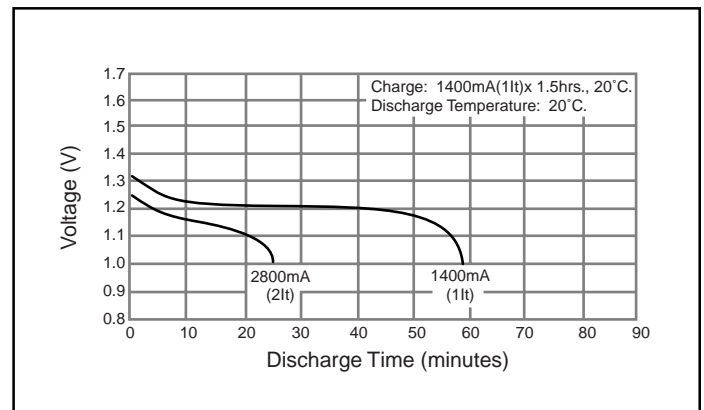
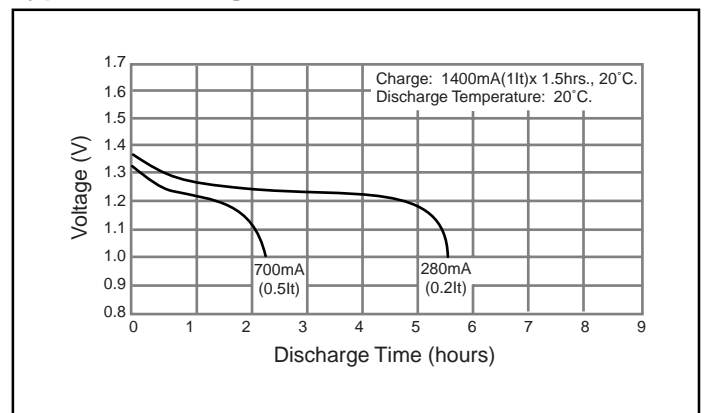
Dimensions (with tube) (mm)



Typical Charge Characteristics



Typical Discharge Characteristics



Specifications

	mm	inch
Diameter	17.0 +0/-0.7	0.67 +0/-0.03
Height	50.0 +0/-1.5	1.97 +0/-0.06
Approximate Weight	Grams	Ounces
	32g	1.13

Nominal Voltage		1.2V			
Discharge Capacity*	Average**	1530mAh			
	Rated (Min.)	1400mAh			
Approx. Internal impedance at 1000Hz at charged state		14mΩ			
Charge	Standard	140mA (0.1It) x 16 hrs.			
	Rapid***	1400mA (1It) x 1.5 hrs.			
Ambient Temperature	Charge	Standard	°C	°F	
			0°C to 45°C	32°F to 113°F	
	Rapid	10°C to 40°C	50°F to 104°F		
Storage	Discharge	-20°C to 65°C		-4°F to 149°F	
		< 2 years		-20°C to 35°C	-4°F to 95°F
		< 6 months		-20°C to 45°C	-4°F to 113°F

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

*** Refer to "Charge Methods for Ni-Cd Batteries"

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

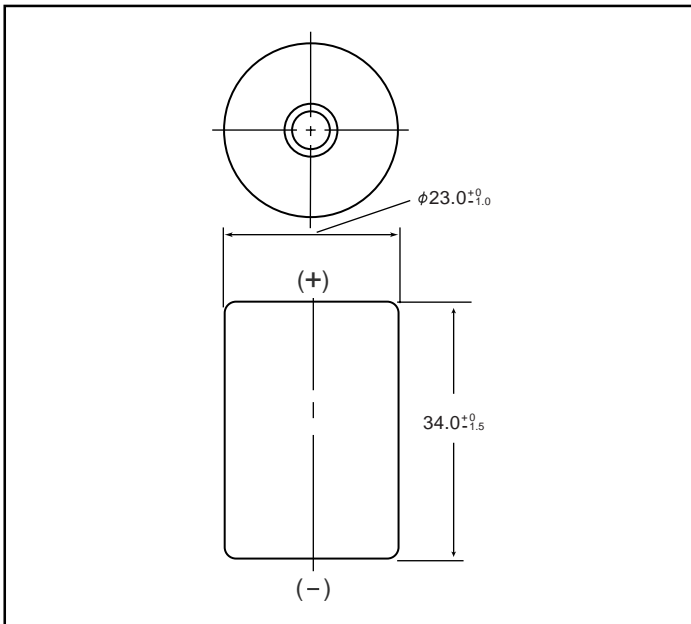
Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as: It(A) = Cn (Ah)/1h.

- [It] is the reference test current in amperes
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
n = the time base [hours] for which the rated capacity is declared

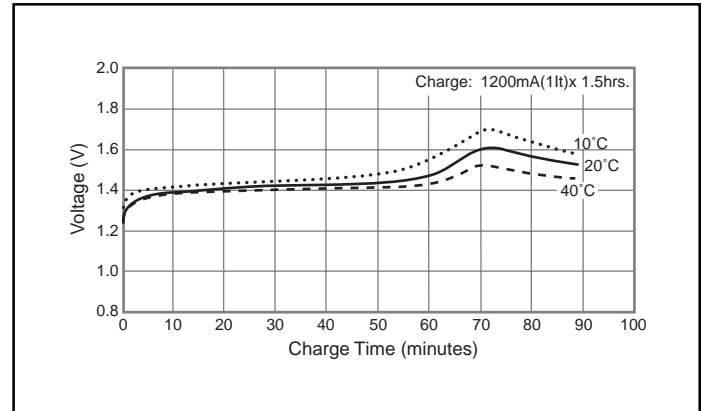
NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-120SCJS 4/5SC size (KR23/34) Type: R

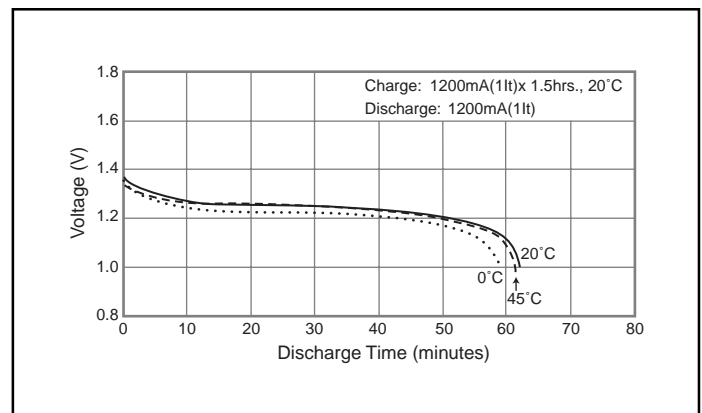
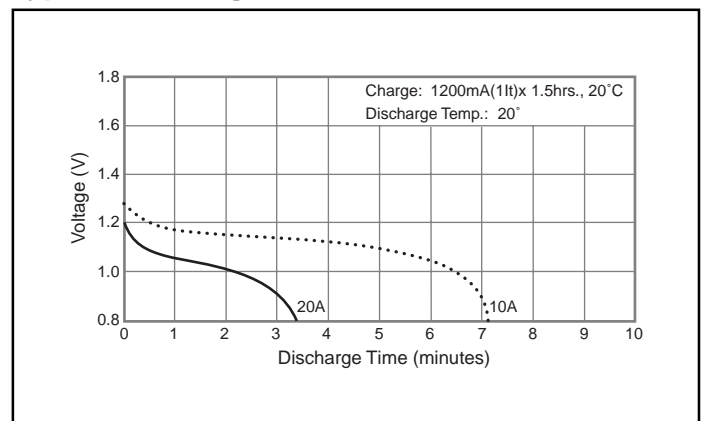
Dimensions (with tube) (mm)



Typical Charge Characteristics



Typical Discharge Characteristics



Specifications

		mm	inch	
Diameter		23.0 +0/-1.0	0.89 +0/-0.02	
Height		34.0 +0/-1.5	1.34 +0/-0.06	
Approximate Weight	Grams	37g	Ounces	
			1.31	
Nominal Voltage		1.2V		
Discharge Capacity*	Average**	1300mAh		
	Rated (Min.)	1200mAh		
Approx. Internal impedance at 1000Hz at charged state		6mΩ		
Charge	Standard	120mA (0.1It) x 16 hrs.		
	Rapid***	1200mA (1It) x 1.5 hrs.		
Ambient Temperature	Charge	Standard	°C	
			°F	
	Rapid	0°C to 45°C	32°F to 113°F	
		10°C to 40°C	50°F to 104°F	
	Discharge		-20°C to 65°C	-4°F to 149°F
	Storage	< 2 years	-20°C to 35°C	-4°F to 95°F
< 6 months		-20°C to 45°C	-4°F to 113°F	
< 1 month		-20°C to 55°C	-4°F to 131°F	
< 1 week		-20°C to 65°C	-4°F to 149°F	

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

*** Refer to "Charge Methods for Ni-Cd Batteries"

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as:

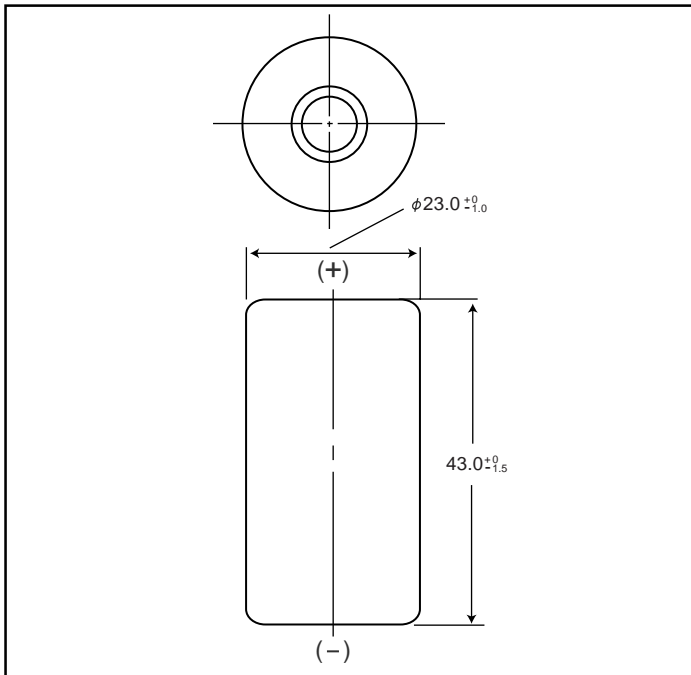
$$It(A) = C_n (Ah)/1h.$$

- [It] is the reference test current in amperes
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
- n = the time base [hours] for which the rated capacity is declared

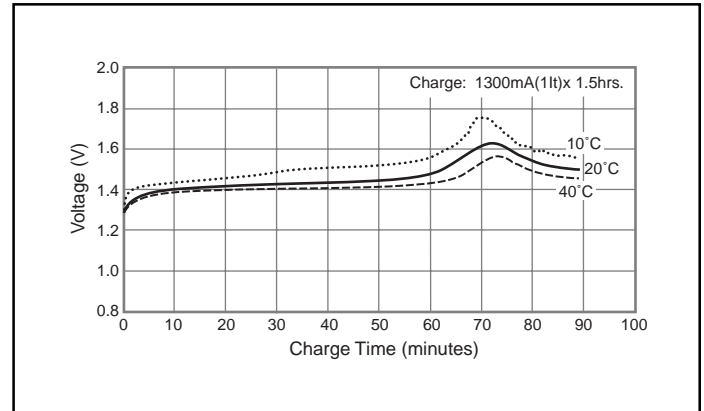
NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-130SCS SC size (KR23/43) Type: R

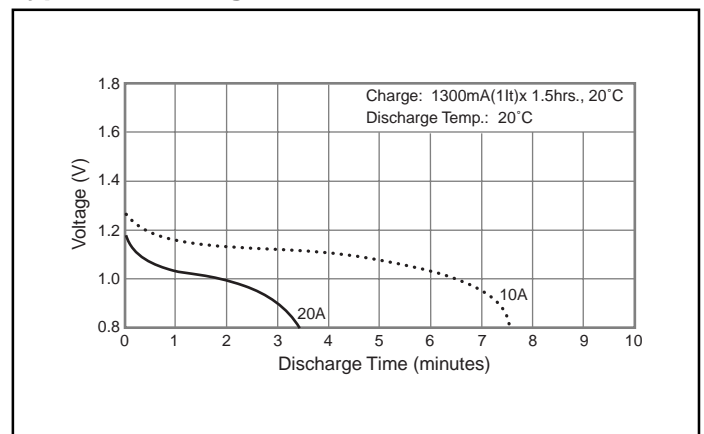
Dimensions (with tube) (mm)



Typical Charge Characteristics



Typical Discharge Characteristics



Specifications

	mm	inch
Diameter	23.0 +0/-1.0	0.89 +0/-0.02
Height	43.0 +0/-1.5	1.69 +0/-0.06
Approximate Weight	Grams	Ounces
	44g	1.55

Nominal Voltage		1.2V		
Discharge Capacity*	Average**	1450mAh		
	Rated (Min.)	1300mAh		
Approx. Internal impedance at 1000Hz at charged state		6mΩ		
Charge	Standard	130mA (0.1It) x 16 hrs.		
	Rapid***	1300mA (1It) x 1.5 hrs.		
Ambient Temperature	Charge	Standard	°C	°F
			0°C to 45°C	32°F to 113°F
	Rapid	10°C to 40°C	50°F to 104°F	
		Discharge		-20°C to 65°C
Storage	< 2 years	-20°C to 35°C	-4°F to 95°F	
	< 6 months	-20°C to 45°C	-4°F to 113°F	
	< 1 month	-20°C to 55°C	-4°F to 131°F	
	< 1 week	-20°C to 65°C	-4°F to 149°F	

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

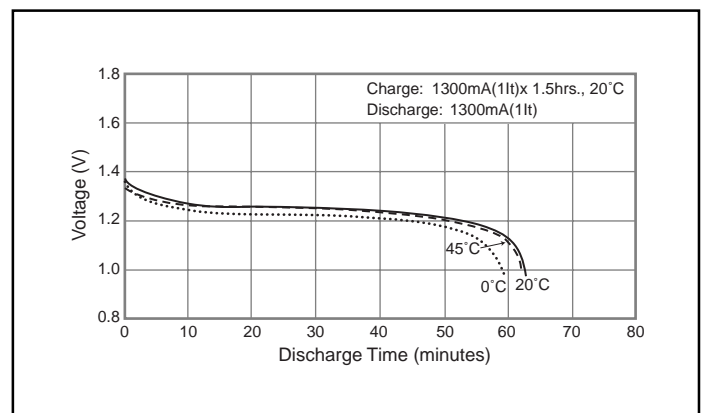
** For reference only.

*** Refer to "Charge Methods for Ni-Cd Batteries"

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as:
 $It(A) = C_n (Ah)/1h.$

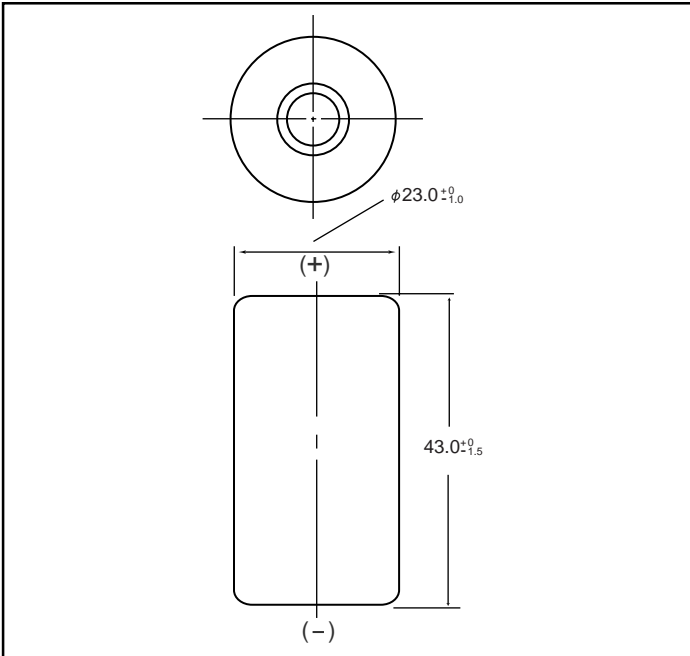
- [It] is the reference test current in amperes
- [C_n] is the rated capacity of the cell or battery in Ampere-hours.
 n = the time base [hours] for which the rated capacity is declared



NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-150SCS SC size (KR23/43) Type: R

Dimensions (with tube) (mm)



Specifications

	mm	inch
Diameter	23.0 +0/-1.0	0.89 +0/-0.5
Height	43.0 +0/-1.5	1.69 +0/-0.06
Approximate Weight	Grams	Ounces
	44g	1.55

Nominal Voltage		1.2V	
Discharge Capacity*	Average**	1600mAh	
	Rated (Min.)	1500mAh	
Approx. Internal impedance at 1000Hz at charged state		6mΩ	
Charge	Standard	150mA (0.1It) x 16 hrs.	
	Rapid***	1500mA (1It) x 1.5 hrs.	
Ambient Temperature	Charge	Standard	°C
			°F
	Rapid	10°C to 40°C	50°F to 104°F
	Discharge	-20°C to 65°C	-4°F to 149°F
Storage	< 2 years	-20°C to 35°C	-4°F to 95°F
	< 6 months	-20°C to 45°C	-4°F to 113°F
	< 1 month	-20°C to 55°C	-4°F to 131°F
	< 1 week	-20°C to 65°C	-4°F to 149°F

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

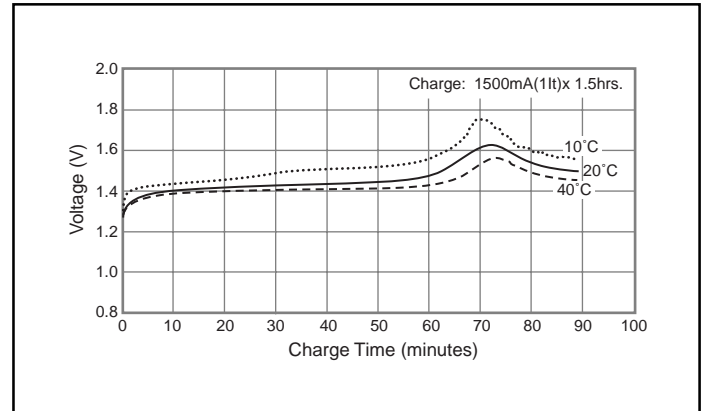
*** Refer to "Charge Methods for Ni-Cd Batteries"

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

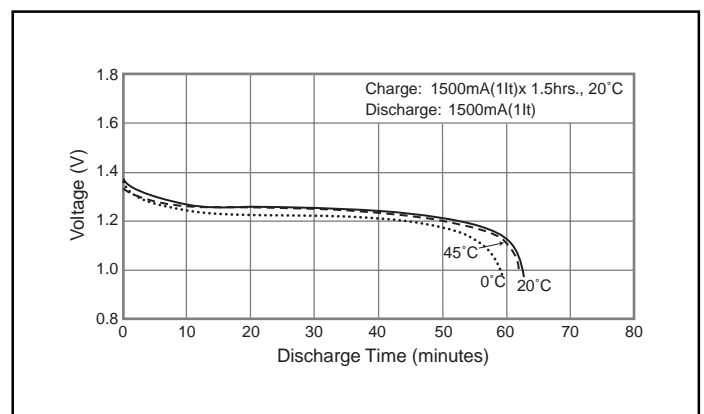
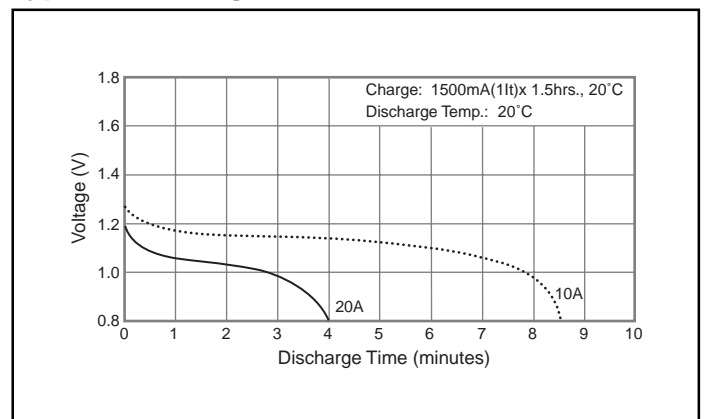
Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as:
It(A) = Cn (Ah)/1h.

- [It] is the reference test current in amperes
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
n = the time base [hours] for which the rated capacity is declared

Typical Charge Characteristics



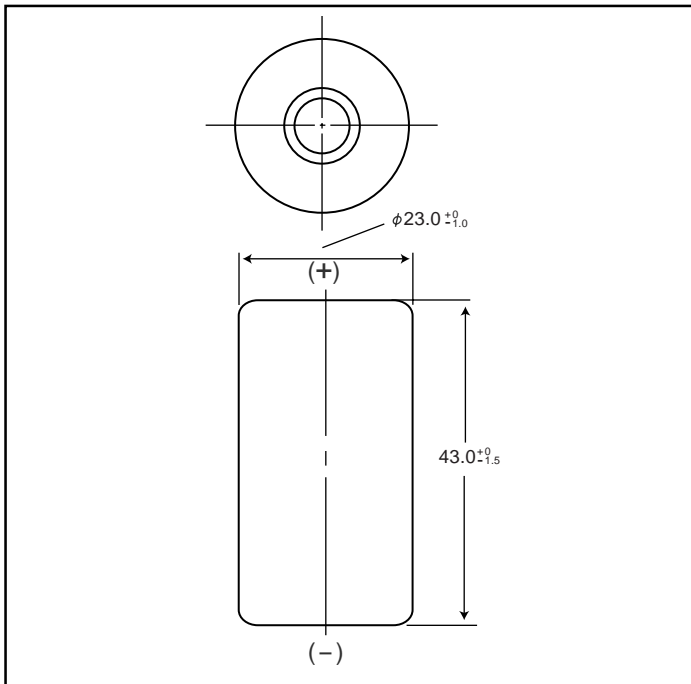
Typical Discharge Characteristics



NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-170SCS SC size (KR23/43) Type: P

Dimensions (with tube) (mm)



Specifications

	mm	inch
Diameter	23.0 +0/-1.0	0.91 +0/-0.04
Height	43.0 +0/-1.5	1.69 +0/-0.06
Approximate Weight	Grams	Ounces
	48g	1.69

Nominal Voltage		1.2V		
Discharge Capacity*	Average**	1800mAh		
	Rated (Min.)	1700mAh		
Approx. Internal impedance at 1000Hz at charged state		5mΩ		
Charge	Standard	170mA (0.1It) x 16 hrs.		
	Rapid***	1700mA (1It) x 1.5 hrs.		
Ambient Temperature	Charge	Standard	°C	°F
			0°C to 45°C	32°F to 113°F
	Rapid	10°C to 40°C	50°F to 104°F	
		Discharge		-20°C to 65°C
	Storage	< 2 years	-20°C to 35°C	-4°F to 95°F
		< 6 months	-20°C to 45°C	-4°F to 113°F
< 1 month		-20°C to 55°C	-4°F to 131°F	
< 1 week		-20°C to 65°C	-4°F to 149°F	

* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

*** Refer to "Charge Methods for Ni-Cd Batteries"

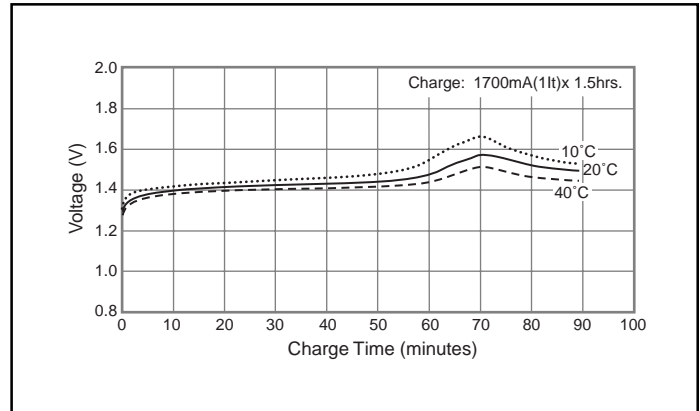
Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as:

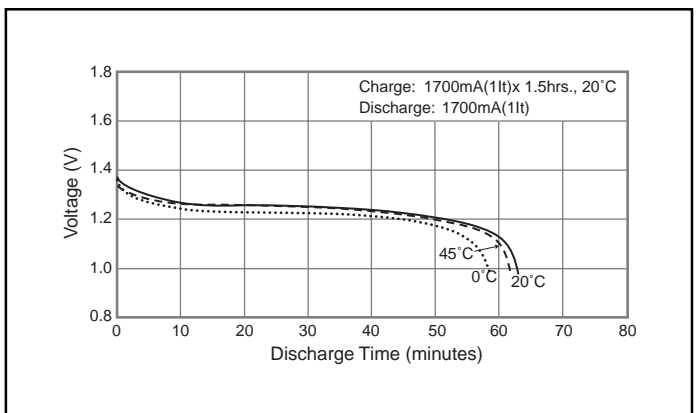
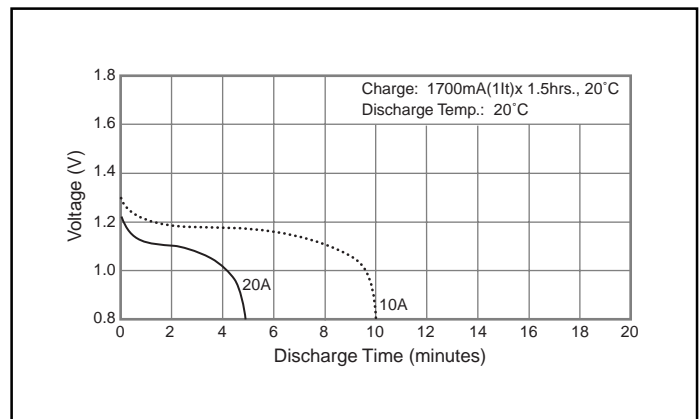
$$It(A) = C_n (Ah)/1h.$$

- [It] is the reference test current in amperes
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
- n = the time base [hours] for which the rated capacity is declared

Typical Charge Characteristics



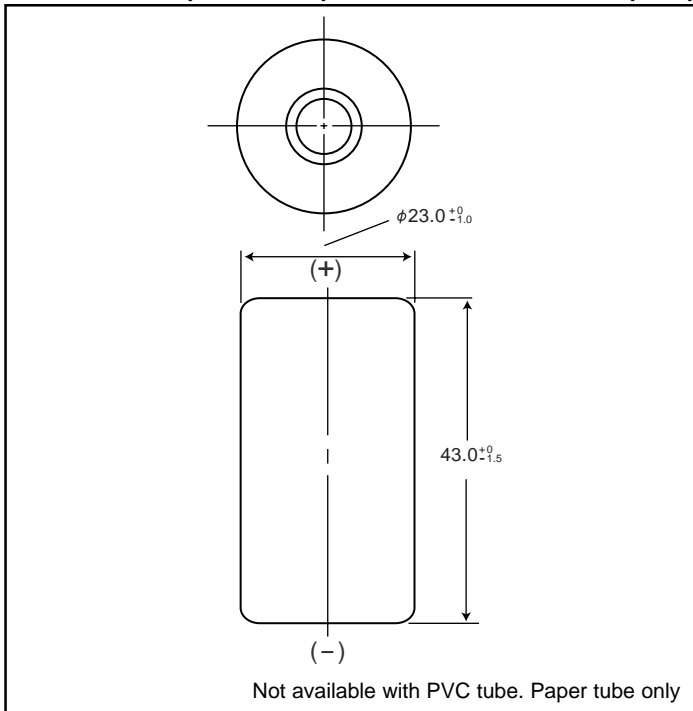
Typical Discharge Characteristics



NICKEL CADMIUM BATTERIES: INDIVIDUAL DATA SHEET

P-200SCS SC size (KR23/43) Type: P

Dimensions (with tube) (mm)



Specifications

		mm	inch	
Diameter		23.0 +0/-1.0	0.91 +0/-0.04	
Height		43.0 +0/-1.5	1.69 +0/-0.06	
Approximate Weight	Grams	51g	Ounces	
			1.80	
Nominal Voltage		1.2V		
Discharge Capacity*	Average**	2100mAh		
	Rated (Min.)	2000mAh		
Approx. Internal impedance at 1000Hz at charged state		5mΩ		
Charge	Standard	190mA (0.1It) x 16 hrs.		
	Rapid***	1900mA (1It) x 1.5 hrs.		
Ambient Temperature	Charge	Standard	°C	
			°F	
	Discharge	Standard	0°C to 45°C	32°F to 113°F
		Rapid	10°C to 40°C	50°F to 104°F
Storage	< 2 years	-20°C to 35°C	-4°F to 95°F	
	< 6 months	-20°C to 45°C	-4°F to 113°F	
	< 1 month	-20°C to 55°C	-4°F to 131°F	
	< 1 week	-20°C to 65°C	-4°F to 149°F	

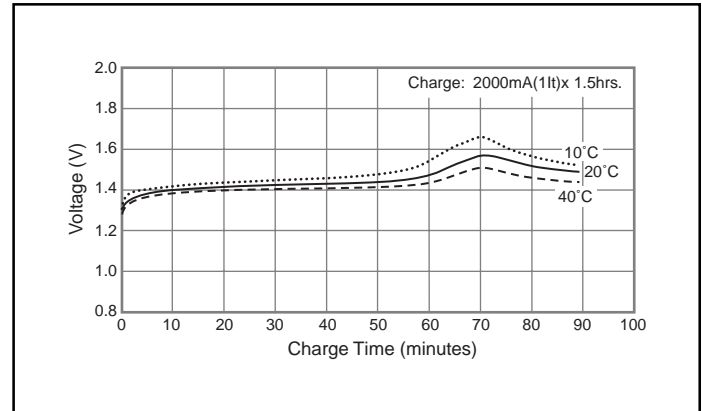
* 0.2It discharge capacity after charging at 0.1It for 16 hours.

** For reference only.

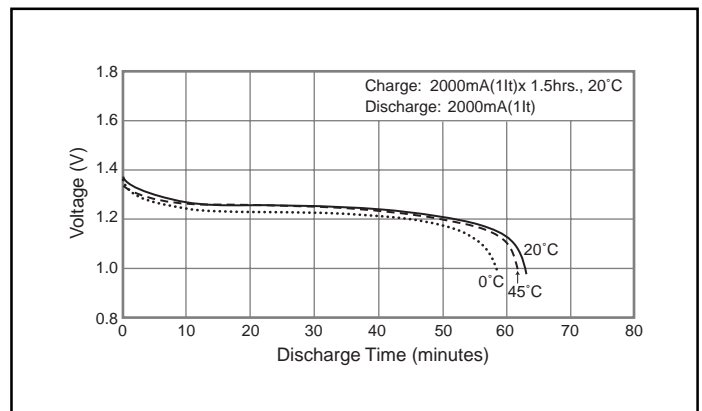
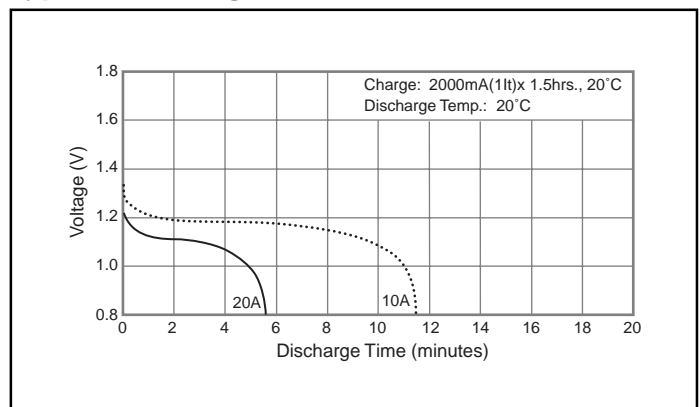
*** Refer to "Charge Methods for Ni-Cd Batteries"

Battery performance and cycle life are strongly affected by how they are used. In order to maximize battery safety, please consult Panasonic when determining charge / discharge specs, warning label contents and unit design.

Typical Charge Characteristics



Typical Discharge Characteristics



Note: [It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as: $It(A) = Cn (Ah)/h$.

- [It] is the reference test current in amperes
- [Cn] is the rated capacity of the cell or battery in Ampere-hours.
n = the time base [hours] for which the rated capacity is declared

BATTERY PACKS

Purpose of Battery Packs

Ni-Cd cells are most commonly used in battery packs. In using Ni-Cd batteries, the type of battery, the number of cells, the shape of the battery pack, and the components of the battery pack will be determined by the ratings (voltage and load current) of the device, the charging specifications, the amount

of space available inside the device, and the usage conditions.

After consultation concerning specifications, if so desired, Panasonic can also provide assembly services for battery packs.

Configurations of Tube Battery Packs

The following are the standard pack configurations for Ni-Cd batteries. Refer to these configurations when designing the battery pack.

F Type

The required number of single cells are lined up in the radial direction of the cells and connected by nickel plates, and covered with an external heat-shrink tube.

Composite F Type

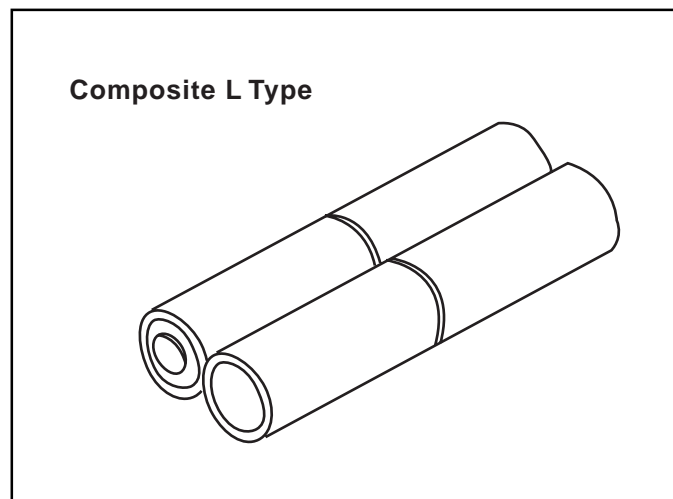
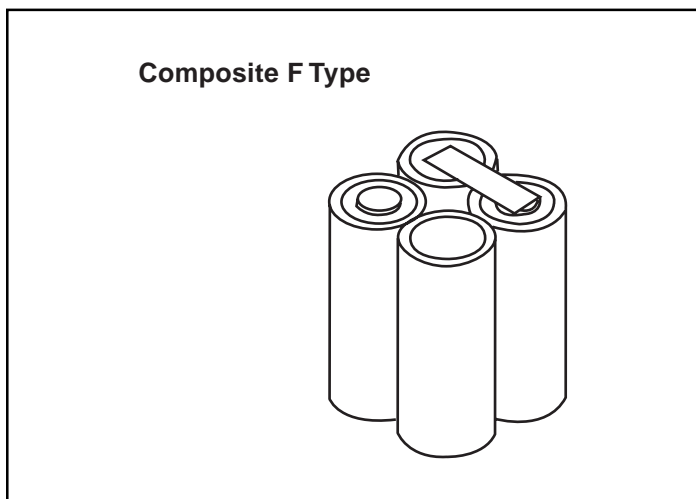
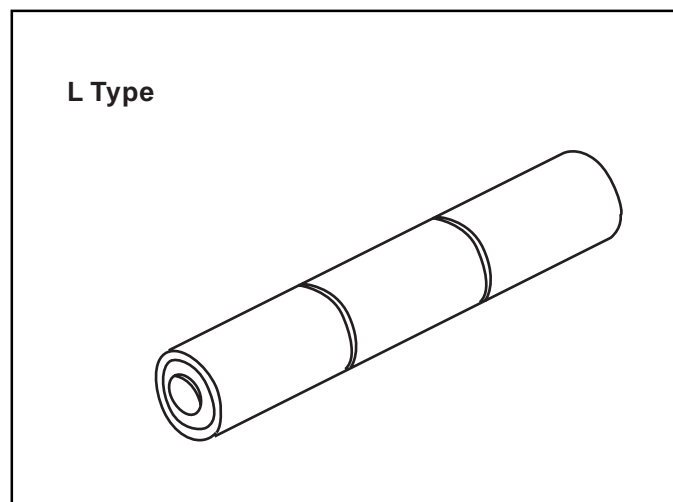
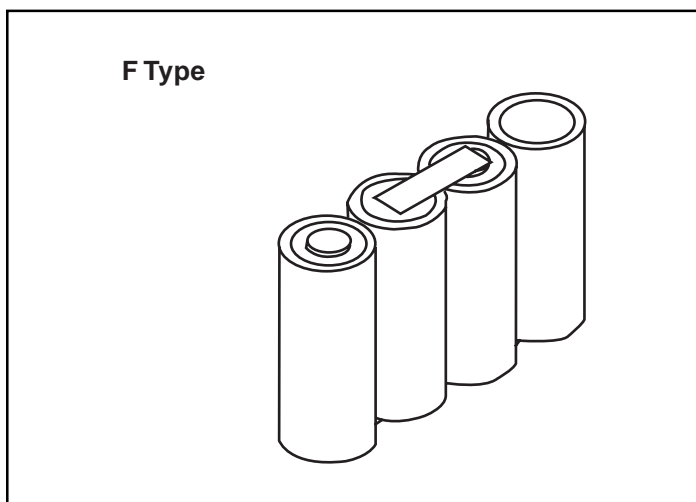
Single cells are connected in 2 to 5 rows, and then packed in a heat-shrink tube.

L Type

The required number of single cells are lined up in the axial direction of the batteries and connected by nickel plates, and covered with an external heat-shrink tube.

Composite L type

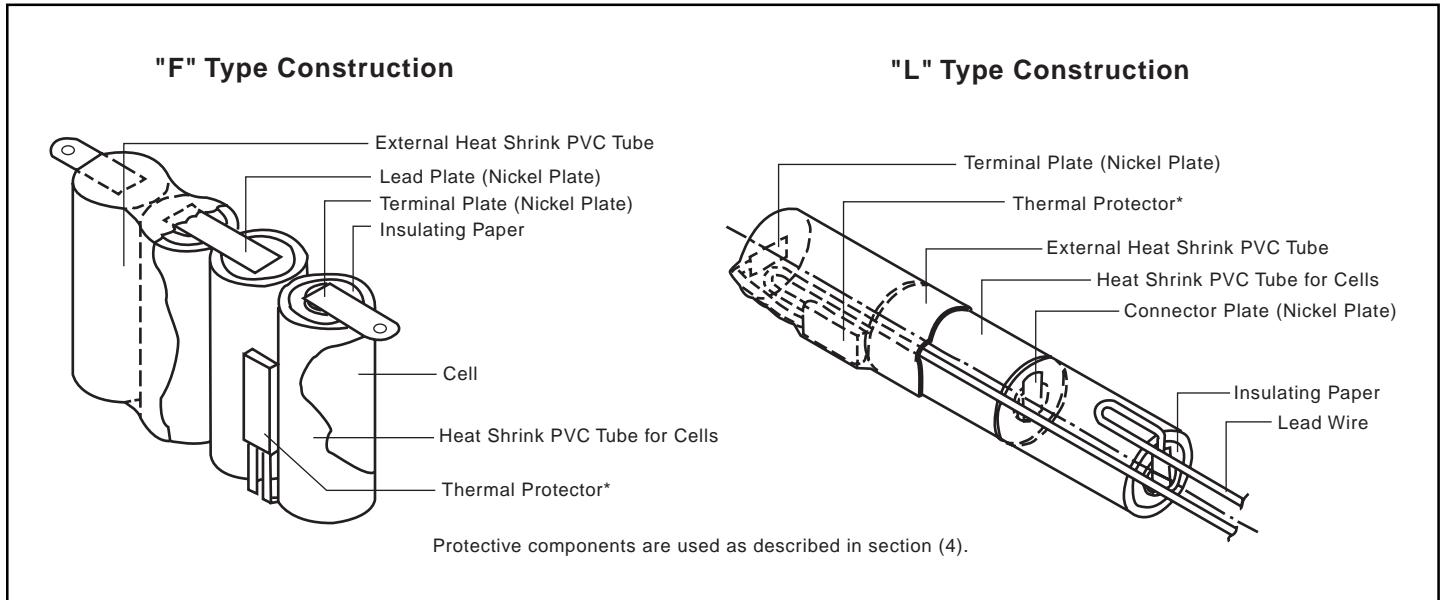
Groups of single cells connected in an L type configuration are further connected in 2 to 5 rows, and then packed in a heat-shrink tube.



BATTERY PACKS - CONTINUED

Construction of Battery Packs

The basic constructions for battery packs are as shown below.



Special Battery Pack Configurations

Custom specifications (battery packs in plastic cases, etc.) can also be prepared upon request. Consult Panasonic for details.

Also feel free to consult Panasonic's Design Department concerning specifications and production schedules.

(1) Batteries in Injection-molded Plastic Cases

It is important to take into consideration the lead time required for the preparation of production molds and the procurement of custom parts.

Parts for Battery Packs

(1) Terminal Plates

Because the lead wires are soldered to the terminal plates, the terminal plates must be made of a material that has good solderability, that can be securely

(2) Battery Packs with Built-in Charge Level Indicators and Charging Systems

If so desired, Panasonic can also provide technological assistance concerning battery packs with a built-in charge level indicator or a built-in charging system.

spot-welded to the cells, and that is highly electroconductive and alkaline-resistant. The most common material used is high-quality nickel plate.

Recommended Terminal Plate Dimensions (Material: Nickel)

No.	Dimensions (mm)			Applicable Battery Size	Configuration
	T	W	L		
1	0.15	4	15	AA size and smaller	
2	0.15	4	15	A size	
3	0.15	5	20	SC size	

BATTERY PACKS - CONTINUED

(2) Lead Wires

To connect the batteries to the device, vinyl-clad electrical wire for heat-resistant device wiring conforming to UL-1007 is generally used. Red for the

positive side and black for the negative side are the standard colors. The ends of the lead wires may be bare cut ends or connected to connectors, etc.

Standard Lead Wires

Applicable battery size	Lead Wires			Reference Diagram
	Size	Length (A) (mm)	Color	
AA size and smaller	UL1007 AWG24	approx. 200	+ Red	
			- Black	
A size	UL1007 AWG22	approx. 200	+ Red	
			- Black	
SC size	UL1007 AWG20	approx. 200	+ Red	
			- Black	

(3) Heat-shrink PVC Tube

Heat-shrink tubes made of polyvinylchloride are used on many packs as the external cover. Tube thickness ranges from 0.1 mm to 0.2 mm depending on battery type and configuration.

(4) Protective Components

Thermal protectors to prevent overcharge and over-heat, PTC elements, temperature fuses, current fuses, and other protective components, either singly or in combinations, are connected via a direct-line circuit to the batteries. Upon request, Panasonic can provide the necessary components for protecting both the battery pack and the device in which it is used.

(5) Others

Depending on the configuration of the battery pack, adhesive materials, tape, paper cylinders, or other parts or materials may be used. If so desired, temperature sensors for charge control and other electronic components can be installed inside the battery pack.

TRANSPORTATION AND DISPOSAL

Disposal: Assure Proper Recycling!

All Panasonic Nickel Cadmium batteries are classified by the federal government as a hazardous waste and must be recycled. These batteries are accepted for recycling by the Rechargeable Battery Recycling Corporation's (RBRC) Battery Recycling Program. Please call 1-800-8-BATTERY for information on recycling your used Nickel Cadmium battery or go to the RBRC website at www.rbrc.org for additional information.



Panasonic strongly recommends that all of its customers join the RBRC Nickel Cadmium Recycling Program thus, allowing you to use the following License Seal, which meets all the labeling requirements of the 1996 Federal Battery Law. Nickel Cadmium batteries destined for recycling can be managed under the federal *Universal Waste Rule* codified at 40 CFR Part 273.

In the event of disposal, dispose only in accordance with federal, state and local regulation. Batteries generated as a waste are subject to the Resource Conservation and Recovery Act (RCRA) as a D006 (cadmium) hazardous waste.

Transportation

Panasonic sealed Nickel Cadmium batteries are considered to be "dry cell" batteries and are unregulated for purposes of transportation by the U.S. Department of Transportation (DOT), International Civil Aviation Administration (ICAO), International Air Transport Association (IATA) and the International Maritime Organization (IMO). The only requirements for shipping these batteries by DOT is Special Provision 130 which states: "Batteries, dry are not subject to the requirements of this subchapter only when they are offered for transportation in a manner that prevents the dangerous evolution of heat (for example, by the effective insulation of exposed terminals). The only requirements for shipping these batteries by ICAO and IATA is Special Provision A123 which states: "An electrical battery or battery powered device having the potential of dangerous evolutions of heat that is not prepared so as to prevent a short-circuit (e.g. in the case of batteries, by the effective insulation of exposed terminals; or in the case of equipment, by disconnection of the battery and protection of exposed terminals) is forbidden from transportation."

All Nickel Cadmium batteries are classified as a D006 hazardous waste because of the presence of cadmium. This waste code is assigned because of toxicity, not corrosiveness. These batteries do not meet the definition of a corrosive waste.

For additional information on the transportation and disposal of batteries, please contact your local Panasonic Battery Sales Group sales office or visit our website at: www.panasonic.com/batteries

- **Active Material**

The electro-chemical materials of the electrodes. In rechargeable Ni-Cd battery, nickel-hydroxide is the active material of the positive electrode and cadmium is the active material of the negative electrode.

- **Alkaline Storage Battery**

A storage battery which uses an alkaline water solution as its electrolyte. Generally refers to nickel-metal hydride batteries and nickel-cadmium batteries.

- **C (Coulomb)**

Used to express the amount of the charge or discharge current. Expressed by attaching the current units to a numerical multiple that represents the rated capacity of the battery. The charge and discharge current are generally expressed using a C multiple. For example, for a battery having a rated capacity of 1500 mAh:

$$0.1 \text{ CmA} = 0.1 \times 1500 = 150 \text{ mA}$$

$$0.2 \text{ CmA} = 0.2 \times 1500 = 300 \text{ mA}$$

- **Cadmium**

Expressed in chemical notation as Cd, this indicates that the negative electrode material of the Ni-Cd battery is in a charged state. When in the discharged state, the negative electrode material becomes cadmium hydroxide, or Cd(OH)₂.

- **Capacity**

The electrical capacity of a rechargeable battery. Normally used to mean the capacity as measured in ampere-hours. Indicated in units of Ah (ampere-hours) or C (coulombs).

- **Cell**

Each of the individual batteries which comprise a rechargeable battery.

- **Charge Efficiency**

A general term meaning either ampere-hour efficiency and watt-hour efficiency. More commonly used to mean ampere-hour efficiency.

- **Charge Level**

The amount of electricity used for charge. For constant current charge, it is the product of multiplying the current value by the charge time. Measured in units of ampere-hours (Ah).

- **Cut-off Discharge Voltage**

The voltage that indicates the limit at which discharge is completed. In practical use, this voltage is the limit to which the battery can be used.

- **Cycle Use**

A method of use in which charge and discharge are repeated over and over again.

- **Electrolyte**

The medium through which ions are conducted during the electro-chemical reaction inside a rechargeable battery. In rechargeable Ni-Cd batteries, a potassium hydroxide water solution is generally used as the electrolyte.

- **Electrolyte Leakage**

The penetration of the electrolyte to the outside of the battery.

- **Energy Density**

The amount of energy that can be obtained per unit weight or per unit volume of a rechargeable battery. Unit: wh/kg, wh/l.

- **Excessive Discharge**

The discharge of a rechargeable battery to a lower than the specified cut-off discharge voltage.

- **High Rate Discharge**

Discharge at a relatively large current with respect to the battery capacity. Also called high-efficiency discharge and high-current discharge.

- **IEC Standards**

The standards established by the International Electrotechnical Commission (IEC).

- **[It]**

[It] was previously expressed as [C]. [It] is an IEC standard expression for the amount of charge or discharge current and is expressed as: $It(A) = Cn (Ah)/1h$.

- [It] is the reference test current in amperes

- [Cn] is the rated capacity of the cell or battery in Ampere-hours.

n = the time base [hours] for which the rated capacity is declared

- **Negative Electrode**

The electrode that has a lower electrical potential than the positive electrode to which electrical current flows from the external circuit during the discharge of a storage battery.

- **Nickel Oxyhydroxide**

Expressed in chemical notation as NiOOH, this indicates that the positive electrode material of the Ni-Cd battery is in a charged state. When in the discharged state, the positive electrode material becomes nickel hydroxide, or Ni(OH)₂.

- **Nominal Voltage**

The voltage used to indicate the battery voltage. Generally a value slightly lower than the electromotive force is used. For example, the nominal voltage of rechargeable Ni-Cd batteries is 1.2 V per cell.

- **Open Circuit Voltage**

The voltage of a battery when that battery is electrically cut-off from the external circuit.

- **Overcharge Current**

Charge after the fully charged state has been reached. In a rechargeable battery which requires water replenishment, the electrolysis of the water causes a sharp decrease in the amount of electrolyte. Generally, the overcharge of a rechargeable battery will shorten the battery's cycle life.

- **Pasted Type Electrode Plate**

An electrode plate made by applying as the active material a cadmium compound in a paste form onto a nickel-plated steel porous plate. Used as the negative electrode.

- **Positive Electrode**

The positive electrode that has a higher electrical potential than the negative electrode from which electrical current flows to the external circuit during the discharge of a rechargeable battery.

- **Rapid Charge**

Charge quickly using a large current.

- **Rated Capacity**

The standard value for the amount of electricity which can be obtained from the battery in a fully charged state at the specified temperature, discharge current, and cut-off discharge voltage. Measured in units of ampere-hours (Ah). Note that CN is used as a symbol to express the rated capacity at a rate of N hours.

- **Reverse Charge**

Charge with the polarities reversed.

If the polarities are reversed, all of the electrical energy will be used to generate gas.

- **Safety Vent**

Functions to release the gas when the internal pressure exceeds a predetermined level. In addition to preventing the absorption of external air into the rechargeable battery, this vent also prevents the rupture of the rechargeable battery that would result from the increase in the internal pressure caused by the generation of gas during charge or at other times.

- **Self-discharge**

A decrease in the capacity of a rechargeable battery without any discharge of current to the external circuit.

- **Separator**

A porous or micro-porous thin plate, cloth, bar, or frame which is inserted as a spacer between the positive and negative electrode plates for the purpose of preventing short-circuits. The separator must be non-oxidizing, resistant to chemicals, and be an electrical insulator, and it must not obstruct in any way the ionic conduction or diffusion of the electrolyte. The separator also functions to retain the electrolyte.

- **Sintered Electrode Plate**

An electrode plate in which the active material is impregnated into a porous thin-plate substrate prepared by sintering nickel powder to a porous plate made of nickel or nickel-plated steel. Used as the positive electrode plate.

- **Sintered Substrate (Plaque)**

The substrate for the active material, made by sintering nickel powder to a porous plate.

- **Trickle Use**

A method of use in which the battery is cut-off from the load and constantly charged at a very small current in order to replenish the self-discharge. Mostly used for emergency power supply applications, such as in the event of an interruption in the normal power supply.

