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1

Overview of Twicell Batteries

1-1 Features of the Twicell

1-2 Principle and Structure of the Nickel-Metal Hydride Battery

1-1 Features of the Twicell

The progress of electronic technology has been remarkable, and high hopes are held for future achievements. As a part of this, there is a great need for smaller and lighter cordless devices, and that has created a strong demand for the high-output, high-capacity batteries which make smaller cordless devices possible.

In response to this demand, Sanyo has developed the Twicell, a nickel-metal hydride rechargeable battery which employs a hydrogen absorbing alloy.

The name Twicell derives from one of this battery's superb features: after one charging, it can be used for approximately twice as long as our standard Cadnica nickel-cadmium batteries.

Because the operating voltage of the Twicell is 1.2V, which is approximately the same as a nickel-cadmium battery, we are positioning it as a high-capacity Cadnica battery.

The features of the Twicell are as follows:

1)Approximately twice the capacity of conventional, general purpose Cadnica batteries (Figure 1).
2) Highly economical, allowing for more than 500 charging/discharging cycles (based on the conditions shown in Figure 2).
3) Quick charging in approximately one hour is possible. (A special battery charger is required.)
4) The operating voltage of 1.2 V (nominal) is approximately the same as the Cadnica, therefore the batteries are compatible during discharging.
5) The sealed structure prevents leakage of electrolyte fluid, as long as the battery is used correctly.

Fig. 1 Comparison of discharge capacities of Cadnica and Twicell.

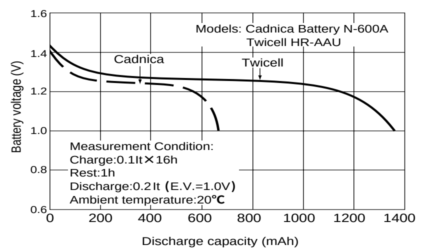
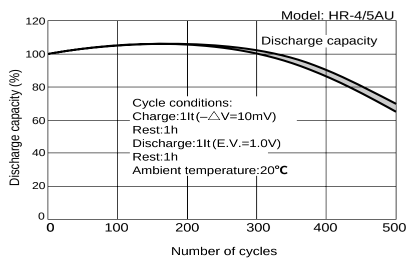


Fig.2 Charge/discharge cycle characteristics



1-2 Principle and Structure of the Nickel-Metal Hydride Battery

1-2-1 The Hydrogen Absorbing Alloy

A hydrogen absorbing alloy is used for the negative electrode of the Twicell. The hydrogen absorbing alloy can absorb as much as 1000 times its own volume of hydrogen gas which allows it to become a metal hydride. It can also reversibly release the hydrogen it has stored. Many different types of hydrogen absorbing alloys have been developed for varied uses, and materials used for the negative electrode include both rare earth nickel type ($LaNi_5$, etc.) hydrogen absorbing alloy and titanium type (TiNi, etc.) hydrogen absorbing alloy. Sanyo developed the rare earth nickel type ($LaNi_5$) hydrogen absorbing alloy because of its suitability as a battery material.

1-2-2 Principle of the Nickel-Metal Hydride Battery

The nickel-metal hydride battery makes electrochemical use of the reversibility of the hydrogen absorption/release reaction in the hydrogen absorbing alloy. The battery uses a nickel oxide compound for the positive electrode, a hydrogen absorbing alloy for the negative electrode, and an aqueous alkaline solution for the electrolyte, which includes such constituents as potassium hydroxide (KOH).

Positive Electrode: $NiOOH + H_2O + e^- \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}} Ni(OH)_2 + OH^-$

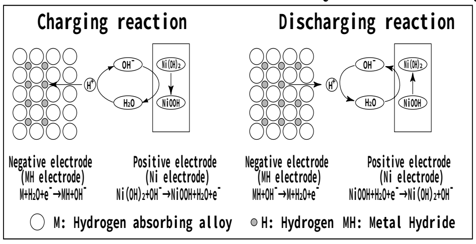
Negative Electrode: $MH + OH^- \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}} M + H_2O + e^-$

Overall: $NiOOH + MH \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftarrows}} Ni(OH)_2 + M$

(M: Hydrogen absorbing alloy, MH: Metal Hydride)

Figure 3 shows a typical mechanism of the charging/discharging reaction. During charging, the electrolytic reaction of water causes the hydrogen, which forms in atomic form on the surface of the hydrogen absorbing alloy in the negative electrode, to diffuse into and be absorbed by the alloy (charge reaction). During discharge, the absorbed hydrogen reacts with hydroxide ions at the surface of the hydrogen absorbing alloy to once again become water (discharge reaction). In other words, the active material of the electrode reaction is hydrogen, and the hydrogen absorbing alloy acts as a storage medium for the active material. Sanyo has developed a hydrogen absorbing alloy, which absorbs a large quantity of hydrogen at low pressure and which can also release it. Sanyo employs this alloy in the Twicell.

Fig. 3 Mechanism of the charging/discharging reaction of the nickel-metal hydride battery



The Twicell has the same type of sealed structure as the Cadnica battery. The principle of this sealed structure is explained in the following.

When the battery is being charged, the positive electrode becomes fully charged first due to its small capacity. After this, overcharging occurs the reaction shown in Reaction Formula **1** occurs which produces oxygen gas.

$$OH^- \rightarrow 1/2\ H_2O + 1/4\ O_2 + e^- \quad \cdots\cdots \quad \mathbf{1}$$

However, at this point the negative electrode is not yet fully charged, and therefore, in theory, hydrogen gas does not form. The oxygen gas formed at the positive electrode passes through the separator, is diffused into the negative electrode, and causes the formation of water by oxidizing the hydrogen in the hydrogen absorbing alloy which is being charged (Reaction Formula **2**).

$$4MH + O_2 \rightarrow 4M + 2H_2O \quad \cdots\cdots \quad \mathbf{2}$$

The water formed in Reaction Formula **2** is consumed by the normal charging reaction (Reaction Formula **3**).

$$M + H_2O + e^- \xrightarrow{\text{Charging}} MH + OH^- \quad \cdots\cdots \quad \mathbf{3}$$

Apart from the oxygen consuming reaction of Reaction Formula **2**, oxygen gas is also consumed by the electrochemical reaction (Reaction Formula **4**).

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \quad \cdots\cdots \quad \mathbf{4}$$

In this way, the oxygen gas formed at the positive electrode is consumed at the negative electrode, making it possible to seal the Twocell.

1-2-3 Principle Allowing High Capacity

Like the Cadnica battery, the capacity of the Twicell's negative electrode has been made larger than that of the positive electrode to enable sealing. For this reason, the capacity of the battery is determined by the capacity of the positive electrode. Because the capacity per unit volume of the hydrogen absorbing alloy electrode (negative electrode) is greater than that of the cadmium electrode (negative electrode) used in nickel-cadmium batteries, the volume of the negative electrode in the battery can be reduced, and therefore the volume of the positive electrode can be increased. This allows a greater capacity than that of Cadnica batteries.

1-2-4 Structure

The Twicell comes in two shapes: a cylindrical battery and a rectangular battery (the Twicell SLIM). The internal structure of the cylindrical battery is shown in Figure 4. It consists of positive and negative electrode sheets wrapped within the battery and separated by separators. Figure 5 shows the internal structure of the rectangular battery. It consists of layered positive and negative electrode sheets separated by separators.

As can be seen, the insides of both the cylindrical and the rectangular batteries are almost completely occupied by electrode plates. This enables a high energy battery and also allows sufficient performance in terms of discharge and temperature characteristics. Also, the positive terminal of both the cylindrical and rectangular battery is equipped with a gas release vent, allowing for the release of gas if gas pressure increases within the battery.

Fig.4 Internal structure of the Twicell

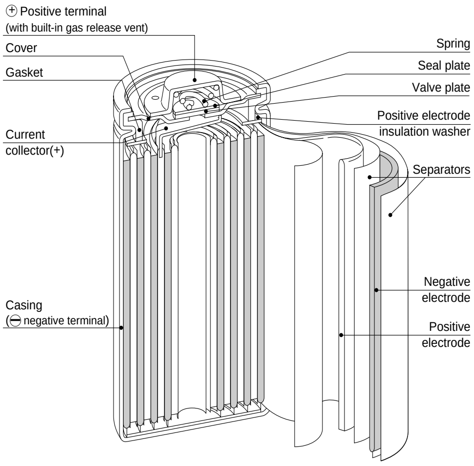
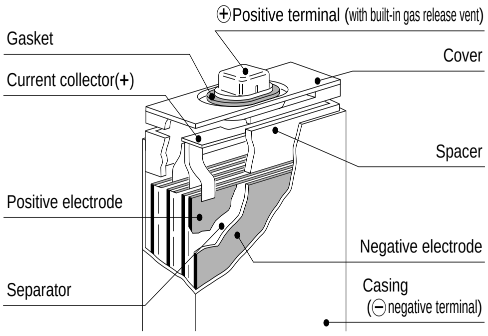


Fig.5 Internal structure of the Twicell SLIM



2

Battery Characteristics

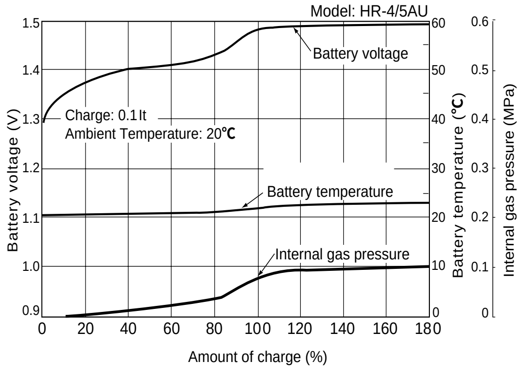
2-1 Charging Characteristics

2-1-1 Outline

Charging is the process of returning a discharged battery to a state in which it can be used again. The Twicell is normally charged with a constant current. This method has the advantage of allowing easy calculation of the amount of charging based on the charging time. The standard for determining discharge capacity is a charging time of 16 hours using a 0.1It current at 20±5˚C. Battery voltage increases as the charging current increases, and decreases as the battery temperature increases.

General charge characteristics of the Twicell are shown in Figure 6. Battery voltage, gas pressure within the battery, and battery temperature change as time elapses under continued charging. In addition, these charging characteristics are affected by the charging current, ambient temperature, the history of the battery, and other factors.

Fig.6 Charge characteristics



Also, as there is a limit to the negative electrode’s ability to consume oxygen gas formed at the positive electrode due to over-charging, a maximum allowed charging current has been set to assure a balance between the amount of oxygen gas formed and the negative electrode’s ability to consume it.

1It is a number which indicates the amount of current when the rated capacity is discharged in one hour. In general, charging and discharging current is expressed as a multiple of It.

For example, when the rated capacity is 1700 mAh, the charging current is as follows:

Rated capacity : 1700 mAh

Charging current :

$$0.1\text{It (mA)} = 0.1 \times 1700 \text{ (mA)} = 170 \text{ (mA)}$$

2-1-2 Battery Voltage During Charging

The battery voltage of the Twicell during charging varies depending on the charging current, ambient temperature, conditions of usage of the battery, and other factors. In general, the voltage rises gradually from the time charging begins to the time the battery becomes fully charged, and after this the voltage decreases slightly due to heat generation.

Figure 7 shows the relationship between charging current and battery voltage. As charging current increases, the battery voltage increases. This is due to the over-voltage increase in the electrode reaction and the voltage increase due to the internal impedance of the battery.

Figure 8 shows the relationship between ambient temperature and battery voltage. Battery voltage changes depending on the ambient temperature. As the ambient temperature increases, the over-voltage in the electrode reaction decreases, and therefore, battery voltage decreases.

Fig.7 Charge voltage characteristics

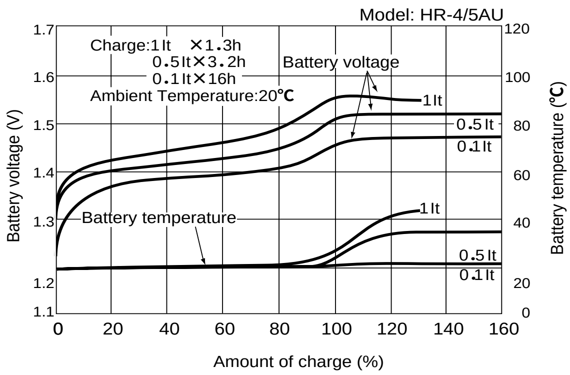
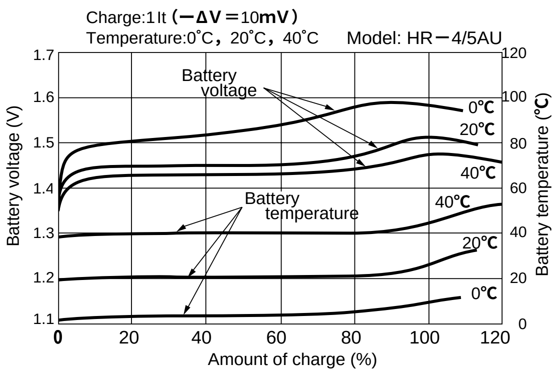


Fig.8 Charge temperature characteristics



2-1-3 Important Charging Information

Avoid overcharging. If the battery is repeatedly overcharged, its characteristics will deteriorate. The same is true of the charger. (For details, see Section 3, "Charging Methods and Charging Circuits".)

2-2 Discharge Characteristics

2-2-1 Outline

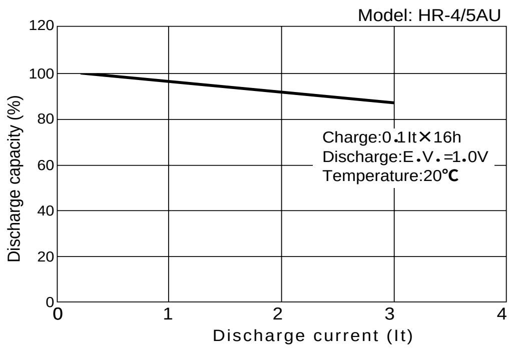
The discharge voltage of the Twicell is almost the same as the Cadnica battery, 1.2V (nominal). However, it varies depending on such factors as the discharge current, ambient temperature, and conditions of battery usage. During discharge, the battery voltage presents the characteristic of being nearly flat.

When the Twicell is discharged at a constant current, the discharge capacity of the Twicell is defined as the product of the discharge current and the time elapsed from the beginning of discharge to the point at which the battery voltage reaches the discharge end voltage (1.0V/cell). It is expressed in units of Ah or mAh. The nominal capacity is the average discharge capacity when discharge takes place within one hour of charging at 0.1It for 16 hours at 20±5˚C, and the discharge current is 0.2It (five-hour rate). However, the actual discharge capacity obtained will vary depending on such factors as the discharge current, ambient temperature, and conditions of battery usage.

2-2-2 Discharge rate

The relationship between the Twicell's discharge rate and its discharge capacity is shown in Figure 9. The discharge capacity decreases as the discharge current increases, and this is due to the fact that a higher discharge current decreases the reactivity of the active material.

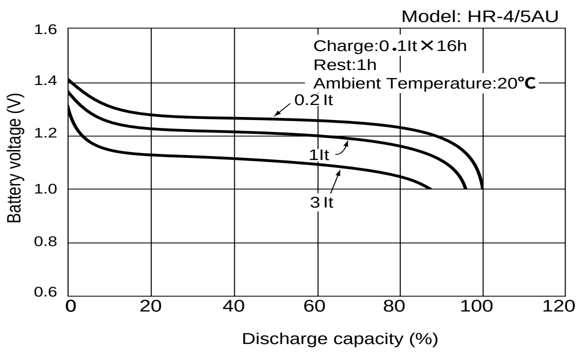
Fig.9 Discharge current and discharge capacity



The relationship between the discharge rate and the battery voltage is shown in Figure 10. The battery voltage decreases as the discharge current increases. This is caused partly by a voltage drop induced by the internal impedance of the battery, and partly by increased polarized voltage in the electrode reaction.

Since the battery voltage drops dramatically if the discharge current exceeds 3It, please use a current under 3It. In the case of batteries near the end of their charge/discharge cycle life, polarized voltage in the electrode reaction increases together with a voltage decrease due to internal impedance, and a sufficient discharge capacity cannot be obtained. For this reason, we recommend battery discharge at a current of 1It or less.

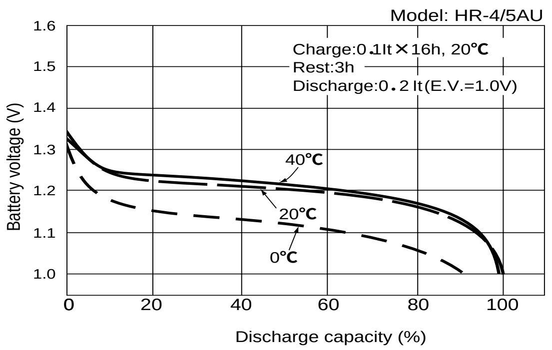
Fig.10 Discharge voltage characteristics



2-2-3 Ambient temperature

The relationship between ambient temperature and battery voltage of the Twicell is shown in Figure 11. While the discharge capacity at high temperature is about the same as that of normal temperature, the discharge capacity at low temperature decreases. This is due to the fact that electrode reactivity decreases at low temperature, and therefore the battery voltage decreases. However, this capacity loss is a temporary phenomenon, and battery performance will recover when the battery is charged and discharged at normal temperature.

Fig.11 Discharge temperature characteristics



2-2-4 Polarity reversal

When cells are connected in series, deep discharge may induce the lowest capacity cell to reverse its polarity because of the differences in capacity of each cell. Figure 12 shows the relationship between battery voltage and discharge time when Twicell are forcibly discharged until polarity reversal occurs. The change of battery voltage can be broadly divided into three stages:

Stage 1: Charged active material remains at both the positive and negative electrodes, and battery voltage is normal.

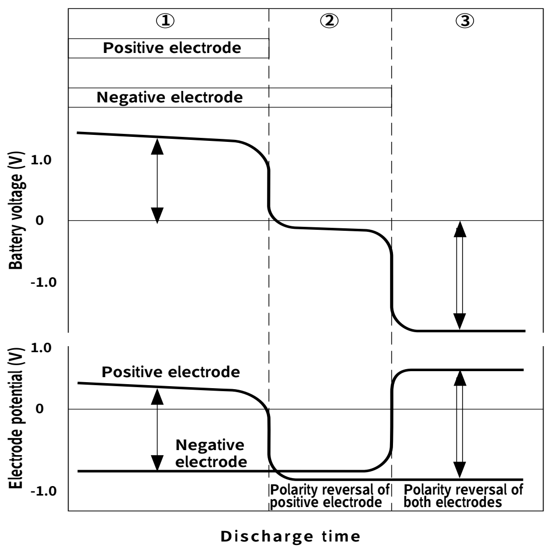
Stage 2: The active material in the positive electrode has become completely discharged, and hydrogen gas begins to form at the positive electrode. The hydrogen gas is stored within the battery, with part of it being absorbed by the negative electrode. As charged active material still remains in the negative electrode, normal discharge continues. Polarity reversal has already occurred in this stage, and the general battery voltage ranges from -0.2 to -0.4 V, which varies due to discharge current and ambient temperature.

Stage 3: Following the positive electrode, the discharge reaction at the negative electrode also ends, and oxygen gas begins to form at the negative electrode.

When this type of deep discharge that leads to polarity reversal occurs, gas pressure builds within the battery, the gas release vent of the positive terminal opens, fluid leakage occurs, and the battery suffers severe damage. For this reason, it is necessary to set a discharge end voltage and forcibly stop discharge when the battery voltage reaches this set value (normally 1.0Vper cell).

In addition, if the battery is left connected to a load for a prolonged period of time, the battery voltage will become 0 V, and the likelihood of leakage will increase. For this reason, it is necessary to avoid leaving a battery connected to a load for a prolonged period of time.

Fig.12 Polarity reversal



2-2-5 Over-discharge

When an assembled battery is discharged at high current, the variation in capacity which exists among the individual component batteries will cause those batteries with low capacity to reverse polarity and produce a negative voltage. If this reversal occurs repeatedly, battery performance will deteriorate. For this reason, with the exception of special cases, we recommend limiting the number of cells composing the assembled battery to no more than 21.

To set the discharge end voltage, use the following equation:

Number of cells × 1.0 V

However, the recommended end voltage will vary depending on the batteries and conditions of battery usage. For more detailed information, please contact a Sanyo representative

2-3 Storage Characteristics

2-3-1 Outline

Even when disconnected from a load during storage, a charged battery will lose energy through self-discharge, resulting in reduced battery capacity and voltage. The reason for self-discharge in the Twicell is explained in the following.

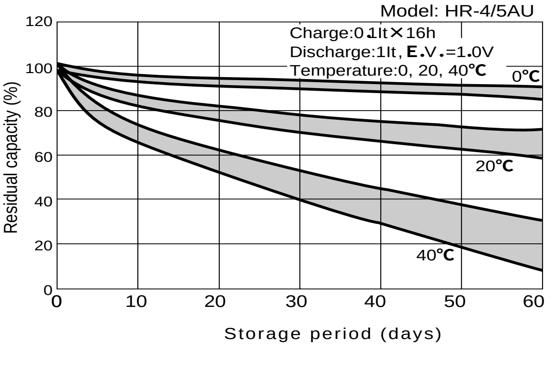
1) Low pressure hydrogen gas exists within the battery, and the hydrogen gas gradually reduces the active material of the charged positive electrode, thus decreasing battery capacity and voltage. At the same time, the quantity of hydrogen gas within the battery case decreases, and for this reason, the charged negative electrode gradually releases hydrogen gas in order to be thermodynamically more stable. This also lowers battery capacity.
   In addition to the above reaction, the following also occurs in the same way to the Cadnica battery:
2) The presence of impurities within the battery causes consumption of positive and negative electrode capacity, therefore the battery capacity is reduced.

For the above reasons, the Twicell gradually loses stored energy by self-discharge during storage.

2-3-2 Storage Temperature

The amount of self-discharge of the Twicell is affected by the storage temperature. The relationship between storage temperature and residual capacity is shown in Figure 13. When the battery is stored at high temperature, self-discharge accelerates.

Fig.13 Storage characteristics



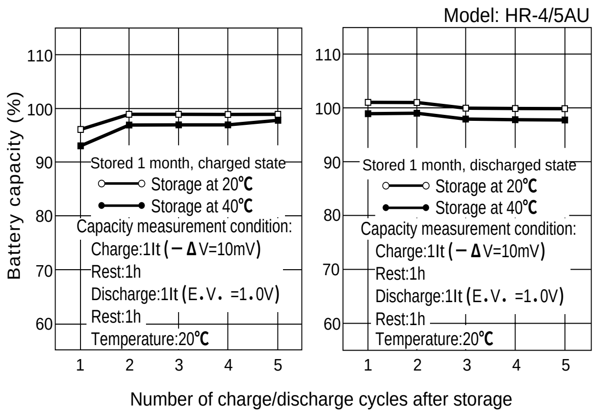
Although the duration of storage and storage temperature affect the residual battery capacity, the battery will recover almost completely if recharged after storing. And for this reason, charging and discharging characteristics do not change dramatically due to storage.

However, if the battery is stored for a prolonged time at high temperature, the materials composing the battery will gradually deteriorate and recovery of battery capacity will be impaired. For this reason, if the battery is to be stored for a prolonged period. we recommend storing it at a temperature which is low enough to prevent battery material deteriorating. (-20 to 30˚C).

2-3-3 Battery Condition

Under the recommended temperature conditions (-20 to 30˚C), the Twicell can be stored indefinitely in either a charged or a discharged state. As an example, Figure 14 shows a comparison of capacity recovery characteristics of a charged battery and a discharged battery after storage. In both cases, capacity was almost completely restored after 2 to 3 charging/discharging cycles.

Fig.14 Discharge capacity after storage



2-3-4 Important Points When Storing Batteries

To maintain top performance from batteries, observe the following when storing them:

1) Storage temperature and humidity
   Store batteries under the following conditions, making sure no corrosive gases are present.
   Less than 30 days : -20 to 50˚C
   Less than 90 days : -20 to 40˚C
   Less than 1 year : -20 to 30˚C
   Humidity: 65±20%
   Avoid storage at temperatures outside of the specified range or in extremely high humidity, as expansion and contraction of the battery materials may cause leaks and rust may form on metal parts.
2) Long-term storage
   If a battery is stored for a prolonged time connected to a load, electrolyte fluid will leak, the battery will gradually deactivate, and capacity recovery will be impaired after storage. Therefore, be sure the battery is not connected to a load during long-term storage.

During long-term storage, battery deactivation may tend to occur, and for this reason charging may stop early during recharging after storage (there may be some variation depending on charging control methods). This problem can be solved by charging and discharging the battery several times. Also, the first charging after prolonged storage may yield a lower capacity than normal. While this will vary depending on the conditions of storage, charging and discharging the battery several times will almost completely restore capacity. For this reason, we recommend including this information in the operation manual of the end device.

2-4 Charge/Discharge Cycle

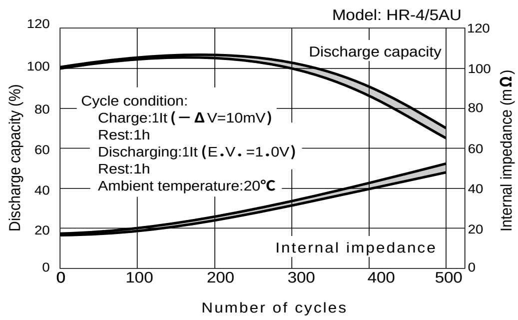
2-4-1 Outline

The charge/discharge cycle life of a rechargeable battery is generally defined to be the point at which battery capacity declines to 60% of the rated capacity and further charging/discharging does not restore battery capacity.

The cycle life is greatly affected by charging and discharging conditions such as the depth of charging and discharging, amount of current, and ambient temperature.

An example of the relationship between the battery capacity and the number of charge/discharge cycles of the Twicell is shown in Figure 15.

Fig.15 Charge/discharge cycle characteristics



If a battery is charged at a current higher than the prescribed current level, or over-discharged to the point of polarity reversal, or used at low or high temperatures exceeding the recommended range, the charge/discharge cycle life will decrease.

2-4-2 Factors Affecting Battery Service Life

1) Factors affecting battery service life

The primary factor determining battery service life is dry-out of the separators which hold the electrolyte fluid, accompanied by an increase in internal impedance. Dry-out occurs due to changes in the component materials within the battery and opening of the gas release vent, and is accelerated by charging, discharging, and storing batteries under conditions not conforming to those we recommend.

2) Battery temperature

Battery temperature is another of the factors which affect the life of the Twicell. We recommend using the Twicell within a temperature range of 0 to 40°C. In particular, to prolong the service life of the Twicell, we recommend charging it at room temperature.

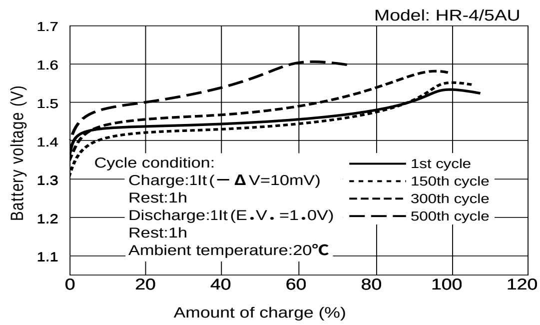
If a battery is stored for a long time at a high temperature, or charged and discharged repeatedly, the organic materials in the separator and the hydrogen absorbing alloy in the negative electrode will deteriorate, reducing the service life of the battery.

If a battery is overcharged at low temperature, the speed of consumption of oxygen gas by the negative electrode slows. For this reason, over-charging at a large current will cause gas pressure within the battery to rise, and this may result in the release of gas from the gas release vent.

3) Charging conditions

The relationship between the number of charge/discharge cycles and battery voltage is shown in Figure 16. When the Twicell has undergone several hundreds of charge/discharge cycles, battery voltage during charging increases. This change in battery voltage is due to an increase in internal impedance which occurs after repeated charging and discharging.

Fig.16 Charge characteristics and charge/ discharge cycles

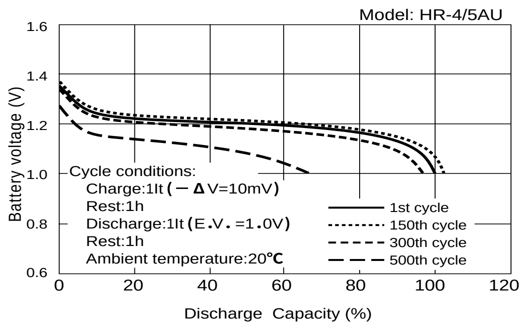


A maximum allowed charging current has been set for the Twicell. If a battery is overcharged and the negative electrode consumes oxygen gas formed at the positive electrode, the hydrogen absorbing alloy will become partially oxidized and will deteriorate the performance of the negative electrode. Therefore, when charging the Twicell it is necessary to avoid over-charging as repeated overcharging shortens battery service life.

4) Discharge conditions

When the Twicell has undergone several hundreds of charge/discharge cycles, battery voltage during discharging decreases. The relationship between the number of charge/discharge cycles and battery voltage is shown in Figure 17. This change in battery voltage is due to an increase in internal impedance which occurs after repeated charging and discharging.

Fig.17 Discharge voltage and charge/discharge cycles



If the Twicell is repeatedly subjected to deep discharge accompanied by polarity reversal, as described previously, battery service life will decrease. For this reason, it is necessary to avoid over-discharging .

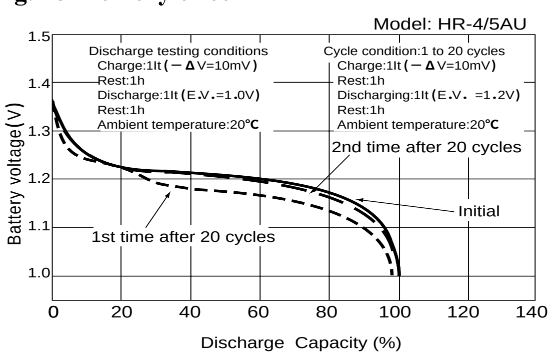
2-5 Memory Effect

If the Twicell is repeatedly charged and discharged with only shallow discharge (the discharge end voltage is 1.12 V/cell or higher), and then subjected to deep discharge (the discharge end voltage is 1.0 V/cell), levels will appear in the discharge voltage characteristics, the operating voltage will decline, and the discharge capacity will decrease. This phenomenon is called the “memory effect”, which also appears in nickel-cadmium batteries.

The decrease in discharge voltage due to the memory effect is only temporary, and will disappear (capacity will be restored) after one or two deep discharges (discharge end voltage of 1.0 V/cell).

Figure 18 shows an example of the memory effect. After charging and discharging is of 1.2 V/cell, performing deep discharge with a discharge end voltage of 1.0 V/cell causes a capacity reduction as shown in the figure. However, a single deep discharge (recommended discharge current: 1It or less) eliminates this memory effect (capacity is restored).

Fig. 18 Memory effect



Therefore, if a device is designed so that the discharge end voltage is high, or if the device is used in such a way that shallow discharge occurs repeatedly, the memory effect may result, and for this reason we recommend explaining the method for eliminating the effect in operation manuals.

3

Charging Methods and Charging Circuits

3-1 Outline

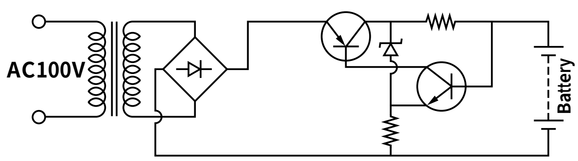
Battery charging is the process of returning a discharged battery to a condition in which it can again be used. It is necessary to consider battery characteristics and conditions of battery usage incorporated in a device when setting charging conditions. Like nickel-cadmium batteries, when the Twicell approaches a fully charged condition, a reaction occurs in which oxygen gas produced at the positive electrode is consumed at the negative electrode. There is a limit to this gas consumption ability, and for this reason a maximum allowed charging current has been established.

If a battery is charged at a current exceeding the maximum allowed charging current, gas pressure will rise within the battery and gas will be released through the gas release vent. For this reason, electrolyte fluid in the battery will decrease and the battery's life will shorten. Selecting an appropriate charging method is therefore a necessary condition for making full use of the characteristics of the battery.

3-2 Charging Methods

There are a variety of methods for charging secondary batteries, including constant current charging, constant voltage charging, trickle charging, and floating charging. The Twicell employs constant current charging as a common charging method. An example of a constant current charging circuit is shown in Figure 19. This method consists of continuously charging at a constant current from the beginning of charging to the end, and provides efficient charging. It is necessary to set the charging current within the rated range for the model of battery being charged. This method allows for easy calculation of the amount of charging based on the charging time, and it has the advantage of allowing charging at a constant current even if the number of batteries being charged are changed, as long as the output voltage range of the power source is not exceeded.

Fig.19 Example of a constant current charging circuit

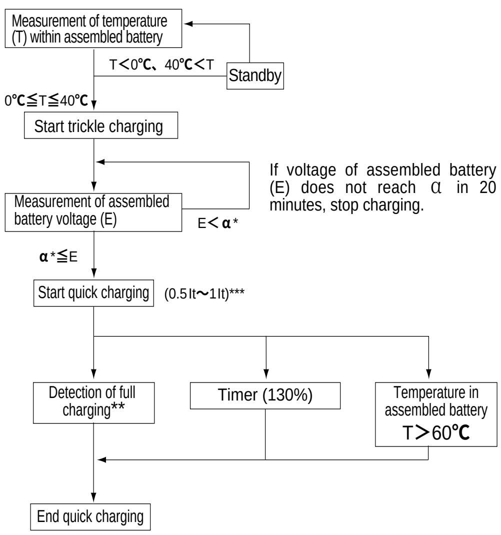


The charging method for the Twicell differs slightly from nickel-cadmium batteries. For this reason, a special charger is necessary. When charging the Twicell, we recommend that you ensure precise charging control, and use constant current charging (quick charging) with a constant current of 0.5 It to 1 It,*** taking into consideration the various characteristics of the battery. Depending on the model of battery, charging at a constant current equivalent to 0.1 It is also possible.

3-2-1 Method of fast charging

The flowchart which we recommend for quick charging of the Twicell is shown in Figure 20. In outline, charging is performed at a constant current of 0.5 It to 1 It,*** and charging is ended when the battery is fully charged by detection of the peak battery voltage, increased battery temperature, or other conditions.

Fig.20 Quick charging flowchart



*………The value α must be determined based on the trickle charging current. As a guideline, use 1.10 V/cell when the trickle current is It/50, and 1.15 V/cell when the current is It/20.

**……We recommend the following methods for detecting full charging:
1) Detection of peak battery voltage (peak voltage control)
2) Detection of temperature increase when battery becomes (dT/dt control)
3) Detection of difference between ambient temperature and battery temperature when fully charged (△T control)

***…Maximum charge current for HR-4/3AU and HR-4/3FAU is 3.0A

(1) Verifying battery temperature before charging.
As the ambient temperature affects charging efficiency, begin charging within a temperature between 0 and 40°C. In particular, a temperature within 10 to 30°C will yield the highest efficiency. The battery generates heat during charging, therefore, the battery temperature will rise higher than the ambient temperature.

In particular, charging efficiency falls at temperatures above 40°C, and battery materials will deteriorate. Conversely, repeated charging less than 0°C will cause gas pressure to build within the battery as it comes close to becoming fully charged, and opening of the vent may cause battery service life to shorten. For these reasons, we recommend that you measure battery temperature before beginning quick charging, and begin charging when the battery temperature is between 0 and 40°C.

(2) Measuring battery voltage
As a precaution in case a failure occurs for any reason in the Protective Devices or cells composing an assembled battery, we recommend that you charge the battery at a small current (It/50 to It/20), in order to measure the battery voltage of the assembled battery before beginning quick charging. When the assembled battery voltage reaches the set voltage during charging at small current, switch to quick charging.
For example, if the assembled battery voltage does not reach 1.10 V/cell after 20 minutes of charging at a current of It/50, or the voltage does not reach 1.15 V/cell after 20 minutes of charging at a current of It/20, it is possible that some kind of problem has occurred in one of the Protective Devices or cells in the assembled battery. In this case, do not begin quick charging.

(3) Quick charging
Only begin quick charging if conditions (1) and (2) above have been met. Set the charging current at a value between 0.5It and 1It,*** during quick charging.
If charging is performed at a current less than 0.5 It, the voltage change and temperature rise that occurs when the battery becomes fully charged will not be sufficiently pronounced, making charging control difficult.
If charging is performed at a current exceeding the maximum allowed current (1It), the rate of oxygen gas consumption at the negative electrode will not keep up with the rate of oxygen gas generation at the positive electrode which occurs toward the end of charging, and gas pressure within the battery will rise. This may cause the gas release vent to open, with the result of decreased performance and fluid leakage.

(4) Charging control methods
When quick charging the Twicell, charging control by means of an external circuit is necessary to avoid opening of the gas release vent caused by increased gas pressure within the battery. Also, to obtain a long service life from the Twicell, over-charging must be avoided as much as possible.

A variety of methods are employed to control charging during quick charging. Several of these methods are as follows:

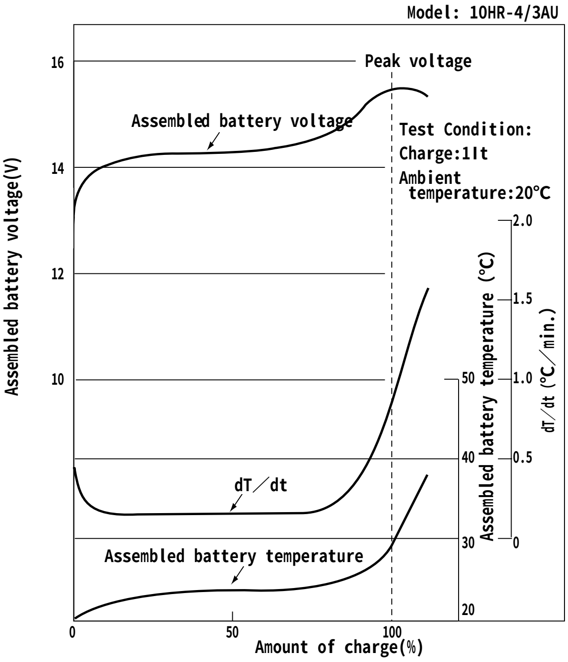
1) Detection of peak battery voltage (peak voltage control)
2) Detection of the temperature rise occurring when the battery becomes fully charged (dT/dt control)
3) Detection of the difference between the ambient temperature and the battery temperature when the battery becomes fully charged (ΔT control)
4) Detection of the time at which the battery voltage drops by a certain value after having reached a peak (-ΔV control)
5) Control based on the elapse of a certain amount of time after beginning charging (charging time control: timer control)
6) Detection of the time at which battery temperature rises to a certain level (battery temperature control)
7) Detection of the time at which battery voltage rises to a certain value (fixed voltage control)

Among the above charging control methods, methods 1), 2), and 3) are suitable for charging control of the Twicell (Figure 21). The purpose of all of these three methods is to stop quick charging when a battery becomes charged. It is necessary to set the values and measurement accuracy for voltage and temperature so that over-charging is avoided as much as possible. Selecting a suitable charging control method is an important condition for making full use of the characteristics of the battery. If you need more information regarding this, please contact a Sanyo representative.

Although -ΔV detection (method 4) which is commonly used for nickel-cadmium batteries can also be used, battery service life is reduced about 20% compared to method (1). To prevent pressure increase in the battery when using this method, set -ΔV under 10 mV/cell.

*** ...... Maximum charge current for HR-4/3AU and HR-4/3FAU is 3.0A

Fig.21 Quick charge control methods



dT/dt and assembled battery temperature rise (△T) vary depending on such conditions as ambient temperature, insulating properties of the assembled battery case, and generation of heat from the device in which the batteries are used. Therefore, the device must be used to determine the most suitable values.

(5) Charging time control (timer control)

If for any reason charging control methods 1), 2), or 3) fail to operate, it will be necessary to end charging by means of a timer. We recommend setting the timer to the time at which the amount of charging is 130% of the nominal capacity.

(6) Battery temperature control
(TCO: Temperature Cut Off)

In consideration of safety and battery characteristics, charging at high temperature must be avoided. We recommend stopping charging if the battery temperature is above 60°C.

As described above, to obtain a long service life from the Twicell, we recommend using charging control method 1), 2), or 3) together with control methods 5) and 6).

3-2-2 Low-rate Charging Methods

Over-charging shortens the service life of the Twicell, and for this reason, low-rate charging is fundamentally not suitable. However, to respond to user needs for low-rate charging, it has been made possible on some models in which improvements have been made in the internal configuration of the battery.

When charging the Twicell by low-rate charging, it is important to understand the effect that repeated charging of an already charged battery has on the service life of the battery. The service life of a battery being repeatedly charged is particularly affected by the ambient temperature, and also by the charging current.

Repeated charging causes gradual deterioration of the organic materials in the separators and the hydrogen absorbing alloy in the negative electrode, and this shortens battery service life.

If you need to use low-rate charging, please contact a Sanyo representative for further information.

3-2-3 Trickle Charging

As explained in section 2-3, "Storage Characteristic", if the Twicell is stored disconnected from any load after being charged, it will lose capacity due to self-discharge.

If it is necessary after full charging to supplement battery capacity which is being lost due to self-discharge, we recommend using trickle charging (supplemental charging). In this case, the following points should be taken into consideration.

(1) Trickle charging design

In the device in which the Twicell is installed, the battery will be repeatedly charged at a temperature higher than the ambient temperature, because the battery itself generates heat due to charging, and because the device and charger generate heat. In this situation, battery service life will shorten in proportion to the temperature increase and the amount of current.

Therefore, to prolong the service life of the Twicell as much as possible, the most suitable design is one which does not allow over-charging.

However, even in cases in which it is necessary to keep the Twicell close to fully charged, please avoid over-charging as much as possible. In other words, the basic design of the charger should be such that it only supplements the amount of electricity that the battery loses through self-discharge.

(2) Trickle charging method

As a means of supplementing electricity lost through self-discharge, we recommend trickle charging by a pulse current. An example of the pulse charging method we recommend is shown in Figure 22.

The amount of electricity which a battery loses through self-discharge at 40°C in one day following full charging is approximately 5% of the rated capacity. In theory, it is possible to supplement this self-discharge loss by continual charging at It/500, as given by the following equation.

$$It \times (5/100) \div 24h \fallingdotseq It / 500$$

However, charging efficiency at this current is low, and charging is not actually possible.

On the other hand, charging by pulse current shown in Figure 22 allows supplementation of only the electricity lost by self-discharge (the example shows a current high of It/10 for 1.2 seconds, followed by no current for 58.8 seconds).

We recommend the following conditions for trickle charging:

When current is high:

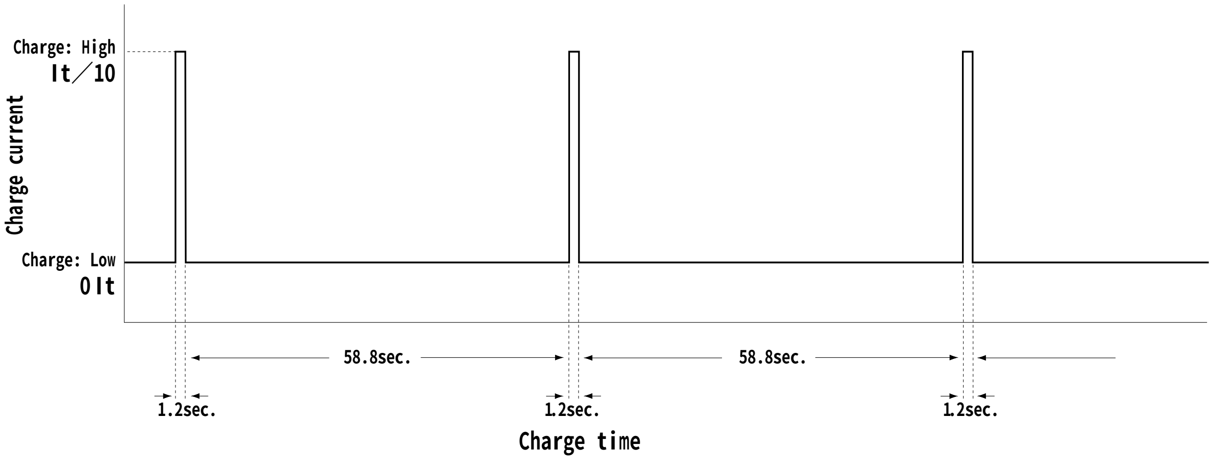
Charging current: It/20 to 1It

Charging time: 0.1 sec. to 60 sec.

Amount of charging: The amount of charging per day under the above conditions should be equivalent to 5% of the rated capacity.

For more detailed information, please contact a Sanyo representative.

Fig. 22 Trickle charge by pulse current



Charge: High		Charge: Low		Pulse interval	Charge amount per day
Current	Time	Current	Time		
It／10	1.2sec.	0It	58.8sec.	60sec.	5% of rated capacity
It／20	2.4sec.	0It	57.6sec.	60sec.	5% of rated capacity
It／10	0.6sec.	0It	29.4sec.	30sec.	5% of rated capacity
⋮	⋮	⋮	⋮	⋮	⋮

4

Assembled Batteries

When using batteries in a device, such factors as the rating of the device, space, and conditions of usage determine the battery model, number of cells, and shape of the batteries used.

4-1 Configuration

When selecting a battery model during the design stage, take into consideration such factors as the rating of the device, conditions of usage, and operating temperature range. When deciding the shape of the assembled battery, consider such factors as space and the method of holding the battery in the device. If quick charging is to be controlled by dT/dt or $-\Delta T$, take into consideration the thickness of the external case, thermal conductivity, heat dissipation ability of the assembled battery, and the heat dissipation ability of the device.

Basic assembled battery shapes are shown on page 20.

4-2 Protective Devices

It is necessary to include protective devices in the design of the assembled battery to provide for the possibility of failure in the charger, an external short circuit, or other failure. We recommend incorporating the devices shown below in the assembled battery.

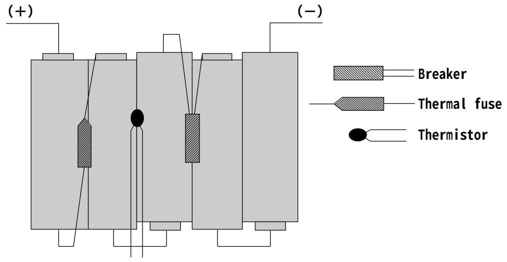
It may be possible to eliminate some of the devices depending on charging and discharging conditions. For further information, please contact a Sanyo representative.

Twicell (Cylindrical)	Thermistor Breaker (operates at 70 to 75°C) Thermal fuse (operates at 91°C) Used in combination	Depending on the charging and discharging conditions, a combination of thermistor and breaker or thermistor and PTC is also possible.
Twicell SLIM (Rectangular)	Thermistor PTC* Used in combination	Depending on the conditions, a combination of thermistor and breaker is needed.

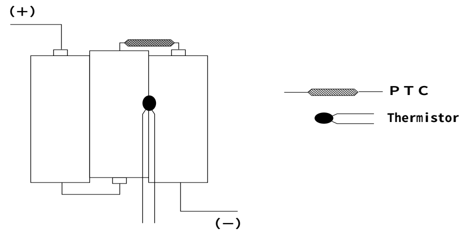
*…PTC is an acronym for "Positive Temperature Coefficient".

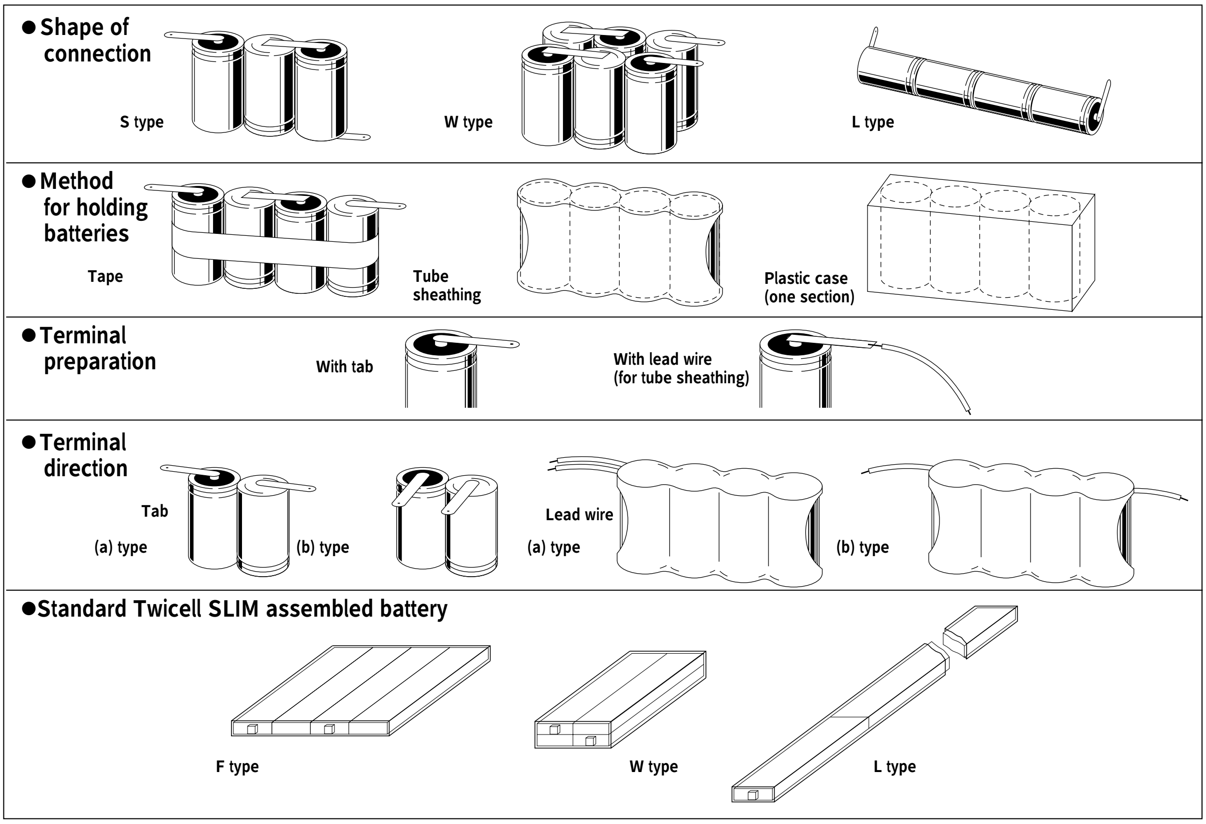
The breaker and PTC recover after operating. The thermal fuse is no longer usable after melting.

Example of installation of protective devices (Twicell - Cylindrical)



Example of installation of protective devices (Twicell SLIM - Rectangular)





4-3 Connection

Connect the batteries securely together by electrical spot welding, and use a material for the connection plates that has excellent resistance to alkaline substances and that has low electrical resistance. When welding, take care not to create a hole in the casing of a cell. In general, nickel, nickel-plated steel, or stainless steel plates are used.

Select the material for the connection plates based on such conditions as electrical conductivity and soldering capability.

If a soldered connection to the lead wire is necessary, do not use a stainless steel plate because soldering is difficult. The thickness of the plate should be from 0.1 to 0.2mm. The thicker the plate, the more difficult it is to weld. If a plate greater than 0.2mm thick is required, the plate will have to be made into a special shape to increase welding strength. To connect Twicell SLIM batteries, a special terminal plate is required. Contact a Sanyo representative for more information.

4-4 Gas Release Structure in Assembled Battery Case

4-4-1 Outline

To ensure the safety of the assembled battery, Gas Release Structure must be included in the Twicell assembled battery case.

The Nickel-Metal Hydride battery differs from the Nickel-Cadmium battery in that hydrogen gas exists within the battery. For this reason, under conditions such as overcharging, overdischarging, or charging a battery near the end of its service life, it is possible that the gas pressure within the battery will increase, the battery's gas release vent will open, and hydrogen gas will be released into the interior of the assembled battery case.

Hydrogen gas in the atmosphere can burn at a density of 4 to 75 vol% if a flame is present. The degree of combustion will vary from soundless burning, to a small explosive sound, and even to a large explosive sound accompanied by damage to the assembled battery case. The degree is largely determined by such factors as the density of the hydrogen gas, the strength of the flame, and ambient environmental conditions.

Therefore, the structure of the assembled battery case must allow for gas release so that the density of hydrogen gas within the case does not reach 4 vol% even if a battery's gas release vent opens.

To assure the safety of the assembled battery, we recommend designing the case structure so that the hydrogen gas density does not exceed 2 vol% even if a battery's gas release vent opens.

4-4-2 Required Gas Release Structure Assembled Battery Case

The gas release structure (holes or slits) required for the assembled battery case will vary depending on the shape of the assembled battery, the arrangement of the cells, and the volume of empty space within the case, as well as the position and size of the structure. To obtain efficient release of hydrogen gas from the assembled battery case, the structure should be placed close to the gas release vents in the batteries. In the case of cylindrical batteries, this means holes over each of the "valleys" between the batteries, and in the case of rectangular batteries, this means structure over the sections of open space within the case.

For your reference, some typical examples of gas release structure (holes or slits) arrangements in assembled battery cases are shown (cylindrical battery cases are shown in Figures 23 to 26, and rectangular battery cases are shown in Figures 27). Refer to these examples when designing an assembled battery case, and note that they are applicable regardless of battery size.

4-4-3 Water-resistant Assembled Battery Cases

As described above, the structure of the assembled battery case must allow for gas release, and for this reason a sealed structure must be avoided. However, it is possible to create a water-resistant structure by using gas permeable water-proof sheeting. In this case, the sheeting will slow the diffusion of the hydrogen gas within the case. It is therefore necessary to increase the gas release area by several times or even several tens of times.

Please contact a Sanyo representative for more information if you intend to make an assembled battery case water resistant.

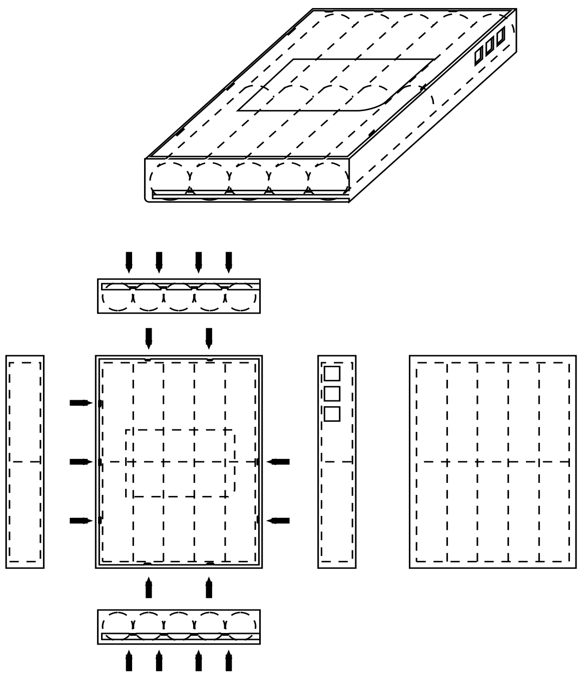
4-4-4 Other Considerations

If space is limited for creating Gas Release Structure in the assembled battery case, or if it is not possible to create holes in the positions we recommend, it will be necessary to determine the necessary gas release structure by actual measurement. In this case, please contact a Sanyo representative.

4-5 Incorporation Into a Device

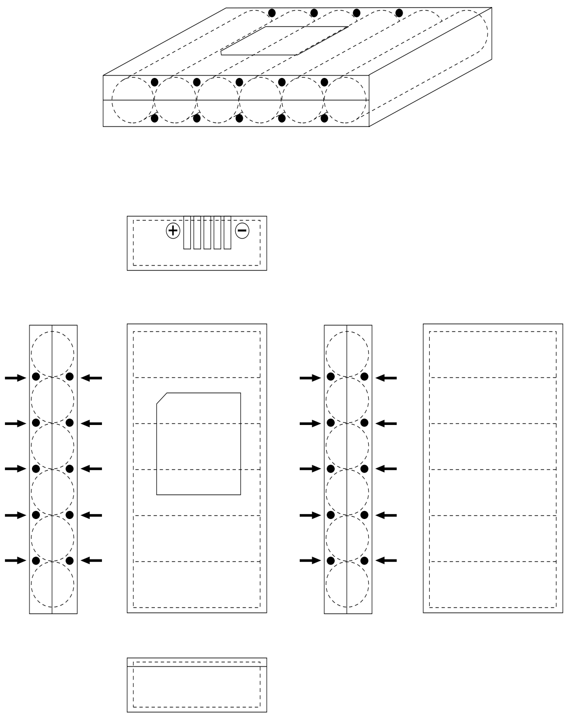
If by any chance a problem occurs within a battery that causes the gas pressure to rise and the electrolyte fluid (strong alkalinity) to leak, the fluid may cause deterioration of insulation, corrosion of device components, and other problems. Take the possibility of fluid leakage into consideration when deciding the position of the batteries within the device.

Fig.23 Cylindrical assembled battery: 10HR-4/3AU



Gas release slits: 1 mm x 5 mm x 17 slits

Fig.24 Cylindrical assembled battery:
6HR-AU

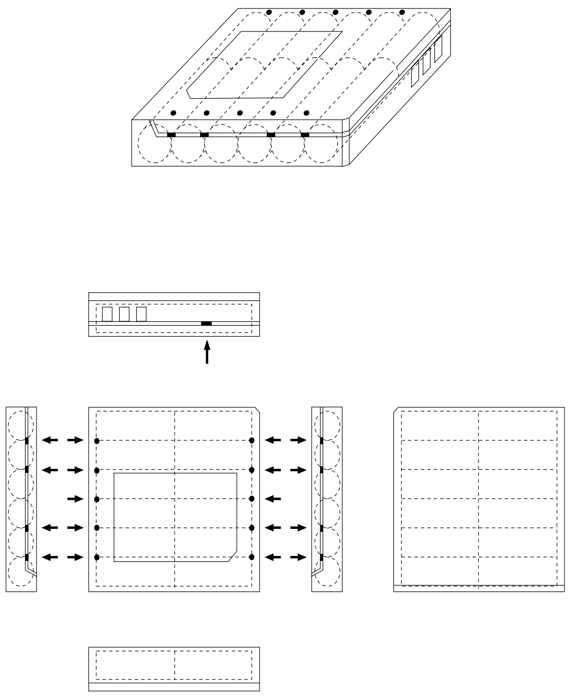


Gas release holes:φ1.5 mm × 20 holes

Also, avoid, if at all possible, direct attachment to a printed board, as leakage will corrode the board (copper leaf, etc.).

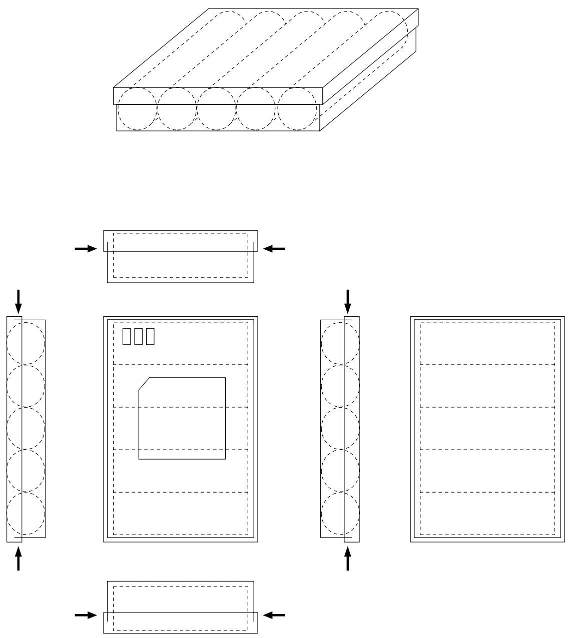
It is also necessary to avoid building Twicell batteries into a device with a completely sealed structure. For more information, contact a Sanyo representative.

Fig.25 Cylindrical assembled battery:
2 × 6HR-AU



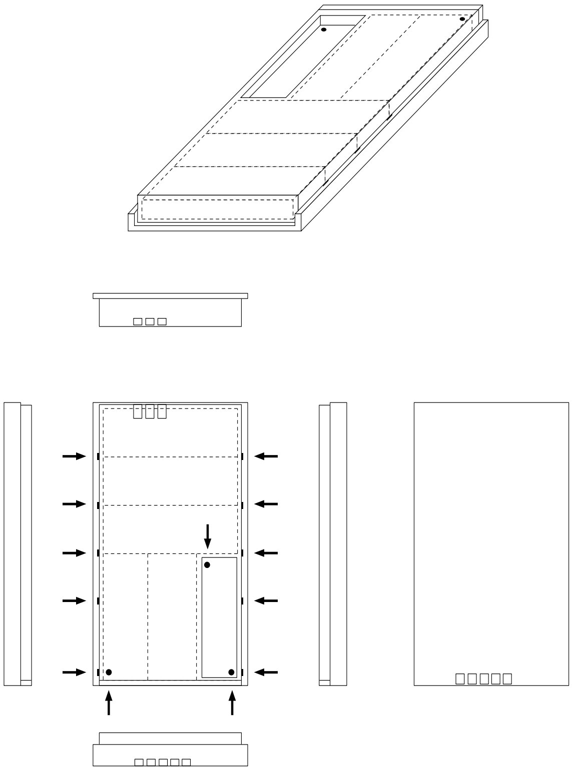
Gas release holes:φ1.5 mm× 10 holes
Gas release slits: 0.5 mm× 5 mm × 9 slits

Fig.26 Cylindrical assembled battery:
5HR-AAU



Gas release slits: Where case parts fit together
(No ultrasonic welding)

Fig.27 Rectangular assembled battery: 5HF-B1U



Gas release holes: φ1.5 mm × 3 holes
Gas release slits: 0.5 mm × 3 mm × 10 slits

5

Important Cautions for Handling Batteries

5-1 Outline

Various safety features have been included in the design of the Twicell, however, misusing or mishandling batteries can lead to fluid leakage, heat generation, fire, or explosion. To prevent these situations from occurring and to ensure safe use of Twicell batteries, please strictly observe the following precautions.

5-2 Restrictions on Usage

5-2-1 Restrictions on Usage Environment

- The temperature range for use of the Twicell is as follows. Using the Twicell outside of this range may impair battery performance and shorten battery service life.
  Use (discharging): 0 to 50˚C
  Storage: -20 to 30˚C
  The temperature range for charging the battery is as follows. Charging a battery outside of this range may cause fluid leakage and generation of heat, as well as impair battery performance and shorten battery service life.
  Charging: 0 to 40˚C
- Do not use or store a battery at high temperature, such as in strong direct sunlight, in cars during hot weather, or directly in front of heaters. This may cause battery fluid leakage, impaired performance, and shortening of battery service life.
- Do not charge a battery when it is cold (below 0˚C), or outdoors in cold temperatures (below 0˚C). This may cause battery fluid leakage, impaired performance, and shortening of battery service life.
- Do not splash fresh or saltwater on a battery, or allow the terminals to become damp. This may cause heat generation and formation of rust on the battery and its terminals.

5-2-2 Restrictions on Conditions of Use

- Use our specified charger to charge Twicell batteries, or observe the specified charging conditions. Failure to follow proper charging procedures may cause excessive current flow, loss of control during charging, leakage of battery fluid, heat generation, bursting, or fire.
- Do not connect more than 21 batteries in series. This may cause electrical shocks, fluid leakage, and heat generation.
- Do not connect assembled batteries together. This may cause electrical shocks, fluid leakage, and heat generation.

5-3 Preparations Before Use

5-3-1 Please Read the Operation Manual

- Before using Twicell batteries, please be sure to read the operation manual and precautions. After reading the manual, keep it on hand and refer to it as necessary. If you do not sufficiently understand the manual or precautions, please contact a Sanyo representative.
- For the procedure for charging Twicell batteries, please read the operation manual for the charger.
- For the procedures for installing batteries in a device or removing batteries from a device, please read the operation manual for the device.

5-3-2 Do Not Connect Batteries to a Power Source

- The Twicell has (+)(positive) and (-) (negative) terminals. If a battery does not work when connected to a charger or device, do not attempt to force the connection. Verify the positions of (+) and (-) terminals. Charging the battery with the terminals reversed may drain rather than charge the battery, or cause abnormal chemical reaction inside the battery, abnormal current flow during discharge, leakage of battery fluid, heat generation, bursting or fire.
  Do not connect a Twicell directly to a power outlet or insert it into a cigarette lighter socket in a car. High voltage may cause excessive current flow, leakage of battery fluid, heat generation, bursting or fire.

5-3-3 Inspection of Batteries Before Use

- If a newly purchased battery has rust, generates heat, or is abnormal in any other way, do not use it. Take it back to the store where you purchased it.
- If a battery is to be used for the first time or it has not been used for a long time, be sure to charge it.

5-4 Non-specified Use

5-4-1 Do Not Use for Other Than Specified Uses

- There are some devices for which the Twicell is not suitable. Please carefully read the operation manual and precautions for the device in which you want to use the Twicell.
- Do not use the Twicell in any device other than those specified by Sanyo. Depending on the device being used, doing so may cause abnormal current flow, leakage of battery fluid, heat generation, bursting or fire.

5-5 Methods of Use

5-5-1 Precautions for Users with Small Children

- Keep Twicell batteries out of reach of babies and small children. When charging or using a battery, do not let babies or small children remove the battery from the charger or the device being used.
- If a small child is permitted to use a Twicell battery, be sure to carefully instruct the child on the contents of the operation manual before use. During the time that the child is using the battery, be sure to monitor this and make sure that the battery is being used according to the directions in the manual.
- To avoid accidental swallowing, keep the batteries and the device using them out of the reach of babies and small children, If by any chance a battery is swallowed, contact a physician (doctor) immediately.

5-5-2 Operation

Do not use old and new batteries together, or batteries at different charge levels. Do not use the Twicell battery together with a dry cell or other batteries of different capacity, type, or brand name. This may cause leakage of battery fluid or heat generation. When two or more batteries are used together, charge them simultaneously prior to use. Charging at different times can cause leakage of battery fluid or heat generation.

5-5-3 Do Not Misuse Batteries

When using Twicell batteries, be sure to observe the following precautions:

- Never dispose of Twicell batteries in a fire or heat them. Doing so may melt the insulation, damage the gas release vents or protective devices, cause combustion through chemical reaction with generated hydrogen, ejection of battery fluid (electrolyte) from the batteries, bursting or fire.
- Do not connect the (+) (positive) and (-) (negative) terminals of Twicell batteries with a wire or electrically conductive materials . Do not carry or store Twicell batteries together with metal necklaces, hairpins, or other electrically conductive materials.
  Doing so may short circuit the battery, which could result in excessive current flow and possibly cause leakage of battery fluid, heat generation, bursting or fire. When carrying or storing batteries, use an electrically nonconductive (insulated) case.
- Use Sanyo’s specified charger to charge Twicell batteries, or observe the specified charging conditions. Failure to follow proper charging procedures may cause excessive current flow, loss of control during charging, leakage of battery fluid, heat generation, bursting, or fire.
- Never solder a lead wire or plate directly to Twicell batteries. The heat generated by the soldering may melt the insulation, damage the gas release vents or protective devices, cause leakage of battery fluid, heat generation, bursting or fire.
- Do not charge or use Twicell batteries with the (+) (positive) and (-) (negative)terminals reversed. Charging the battery with the terminals reversed may drain rather than charge the batteries, or cause abnormal chemical reaction inside, abnormal current flow during discharge, leakage of battery fluid, heat generation, bursting or fire.

- Do not connect a Twicell battery directly to a power outlet or insert it into a car cigarette lighter socket. High voltage may cause excessive current flow, leakage of battery fluid, heat generation, bursting or fire.
- Do not remove the outer tube from a battery or damage it. Doing so will expose the battery to the risk of a short circuit, and may cause leakage of battery fluid, heat generation, bursting or fire.
- Do not strike or drop Twicell batteries. A sharp impact can cause leakage of battery fluid, heat generation, bursting or fire.
- Do not connect two Twicell batteries in parallel as this may cause leakage of battery fluid, heat generation, bursting or fire.
- Do not transport Twicell batteries by holding onto the connectors or lead wires, as this may damage the batteries.

5-5-4 Do Not Alter or Remove Protective Mechanisms or Other Parts

Never disassemble Twicell batteries. Doing so may cause an internal or external short circuit or result in the exposed material chemically reacting with the air. It may also cause heat generation, bursting or fire. There is also the danger of alkaline fluid being spilt.

Never alter or reconstruct Twicell batteries. Protective Mechanisms (devices) to prevent danger are built into the batteries(single cell or packed cells).If these are damaged, this could result in excessive current flow, control loss during charging or discharging, leakage of battery fluid, heat generation, bursting or fire.

5-5-5 Do Not Use in Ways Which Reduce Battery Safety

The gas release vent which releases internal gas is located at the (+) (positive) terminal section of the Twicell battery. Never deform this section or cover or obstruct the release of gas. If the gas release vent cannot function properly, this could result in leakage of battery fluid, heat generation, bursting or fire.

The Twicell battery pack is structured to release internal gas. Do not obstruct the gas release structure, as this may cause bursting.

5-5-6 Do Not Use Continuously for Periods Longer Than the Rated Time or With Loads Exceeding the Rated Load

Do not overcharge Twicell batteries by exceeding the predetermined charging period specified by the battery charger’s instructions or indicator. Also, do not recharge a battery which is fully charged. This may cause leakage of battery fluid, heat generation bursting or fire. It could also impair performance or shorten the operating life of Twicell batteries.

5-5-7 When Batteries Are Not In Use

Be sure to turn off the equipment or the device after using Twicell batteries. Failure to do so may cause leakage of battery fluid.

During non-use, do not leave the Twicell battery connected to the equipment or the device for a long period of time. To prevent leakage of battery fluid and corrosion(rust)during the period when the Twicell is not being used, remove the battery from the equipment or the device and store it in a place with low humidity and at a temperature of -20 to +30˚C. Batteries that have not been used for a long time may not be fully charged.

5-5-8 Other Precautions for the Design and Installation into Equipment Incorporating Twicell Batteries

Do not install Twicell batteries near transformers or other heat sources. This may cause leakage of battery fluid, impair performance or shorten the operating life of Twicell batteries.

Design the equipment or the device so that battery current will not leak into the equipment or the device when it is switched off or in a non-operating status. Failure to observe this may cause leakage of battery fluid, impair performance or shorten the operating life of Twicell batteries.

5-6 Maintenance and Inspection

5-6-1 Sanyo Recommends Regular Inspections

Twicell batteries have a predetermined operating life. If the operating time shortens excessively, this means that the battery life has expired. If that is the case, terminate use immediately and replace with new batteries.

5-6-2 Inspection and Cleaning (including label on unit)

If the Twicell battery terminals become dirty, clean them with a soft, dry cloth prior to use. Dirt on the terminals can result in poor contact with the equipment or the device, loss of power, or inability to charge.

5-7 Countermeasures

5-7-1 Do Not Use a Defective or Abnormal Battery

If Twicell batteries are not fully charged after the battery charger’s predetermined charging period has elapsed, stop the charging process. Prolonged charging may cause leakage of battery fluid, heat generation, or bursting.

If Twicell batteries leak fluid, change color, change shape, or change in any other way, do not use them. Usage may cause heat generation, bursting or fire.

5-7-2 Emergency Measures

If any fluid from a Twicell battery comes in contact with the eyes, flush the eyes immediately, washing them thoroughly with clean water from a tap or other source, and consult a doctor. Strong alkaline fluid can damage the eyes and lead to permanent loss of eyesight.

If skin or clothing comes in contact with any fluid from the Twicell battery, wash the area immediately with clean water from a tap or other source. Battery fluid can cause skin damage.

5-8 Procedures for Disposal of Batteries

When a battery is no longer usable, attach tape to the “(+)” terminal to insulate the battery and then dispose of it in accordance with all applicable local state and federal lows and regulations.

When an assembled battery is no longer usable, attach tape to the terminals or connection cord to insulate the battery, and then dispose of it in accordance with all applicable local state and federal lows and regulations.

For more information on battery disposal, contact a Sanyo representative.

5-9 Cautions to be Indicated on the Twicell

To ensure safe use of the Twicell, clearly indicate the cautions shown below on the battery. To make the cautions easier to understand, add the following marks.

⚠Danger! Use in cases where misuse of the battery creates a strong possibility of death or serious injury.

⚠Warning! Use in cases where misuse of the battery creates a possibility of death or serious injury.

⚠Caution! Use in cases where misuse of the battery creates a possibility of mild or serious injury to the user, or damage to equipment. Also use in cases where misuse may adversely affect product quality and reliability.

Before using Twicell batteries, be sure to read the operation manual and safety information. After reading the manual, be sure to keep it on hand and refer to it as necessary. If you do not fully understand the manual or safety information, please contact a Sanyo representative.

⚠ Danger!

- Failure to carefully observe the following procedures and precautions can result in leakage of battery fluid (electrolyte), heat generation, bursting, fire and serious personal injury!
- Never dispose of Twicell batteries in a fire or heat them.
  Doing so may melt the insulation, damage the gas release vents or protective devices, ignite hydrogen gas, cause leakage of battery fluid (electrolyte), heat generation, bursting and fire.
- Do not connect the (+) (positive) and (–) (negative) terminals of Twicell batteries together with electrically conductive materials, including lead wires. Do not transport or store Twicell batteries with their uncovered terminals or connected with a metal necklace or other conductive material. Doing so may short circuit a battery, which would result in excessive current flow and possibly cause leakage of battery fluid, heat generation, bursting and fire. When carrying or storing batteries, use a special case.
- Only charge Twicell batteries using those specific chargers that satisfy Sanyo's specifications. Only charge batteries under the conditions specified by Sanyo. Failure to follow proper charging procedures may cause excessive current flow, loss of control during charging, leakage of battery fluid, heat generation, bursting and fire.
- Never disassemble Twicell batteries. Doing so may cause an internal or external short circuit or result in exposed material of battery reacting chemically with the air. It may also cause heat generation, bursting and fire. Also, this is dangerous as it may cause splashing of alkaline fluid.
- Never modify or reconstruct Twicell batteries. Protective devices to prevent danger are built into batteries(single cell or packed cells). If these are damaged, excessive current flow may cause loss of control during charging or discharging of the battery, leakage of battery fluid, heat generation, bursting and fire.
- Never solder lead wires directly on to Twicell batteries.
  The heat of the soldering operation may melt the insulation, damage the gas release vents or protective devices, cause leakage of battery fluid, heat generation, bursting and fire.
- The (+) (positive) and (–) (negative) terminals of Twicell batteries are predetermined. Do not force the terminal connection to a charger or equipment. If the terminals can not be easily connected to the charger or equipment, check if the (+) and (–) terminals are correctly positioned. If the terminals are reversed, during charging the battery may be discharged rather than charged. Furthermore, reversed connections may cause abnormal chemical reaction in the battery, the flow of abnormal currents, leakage of battery fluid, heat generation, bursting and fire.
- The gas release vent which release internal gas is located in the (+) positive terminal of the Twicell battery. For this reason, never deform this section or cover or obstruct its gas release structure. If this section is deformed or covered or obstructed, the gas release vent will not function properly, possibly causing leakage of battery fluid, heat generation, bursting and fire.
- Do not directly connect Twicell batteries to a direct power source or the cigarette lighter socket in a car. High voltage may cause excessive current flow, leakage of battery fluid, heat generation, bursting and fire.
- Do not use Twicell batteries in any equipment other than those specified by Sanyo. Depending on the equipment being used, doing so may cause abnormal current flow, leakage of battery fluid, heat generation, bursting and fire.
- Twicell batteries contain a strong colorless alkaline solution(electrolyte). The alkaline solution is extremely corrosive and will cause skin damage. If any fluid from a Twicell battery comes in contact with a user's eyes, they should immediately flush their eyes and wash them thoroughly with clean water from the tap or another source and consult a doctor urgently. The strong alkaline solution can damage eyes and lead to permanent loss of eyesight.
- When Twicell batteries are to be incorporated in equipment or housed within a case, avoid air-tight structures as this may lead to the equipment or case being damaged or may be harmful to users.

⚠ Warning!

- Do not apply water, seawater or other oxidizing reagents to Twicell batteries, as this can cause rust and heat generation. If a battery becomes rusted, the gas release vent may no longer operate, and can result in bursting.
- Do not connect more than 21 Twicell batteries in series, as this may cause electrical shocks, leakage of battery fluid and heat generation.
- Keep Twicell batteries and the equipment using them out of the reach of babies and small children, in order to avoid accidental swallowing of the batteries. In the event the batteries are swallowed, consult a doctor immediately.
- Do not charge or use Twicell batteries with the (+) and (–) terminals reversed. Charging batteries with the terminals reversed may drain rather than charge the batteries, or it may cause abnormal chemical reaction in the batteries. Using batteries with the terminals reversed may cause discharge with abnormal currents, leakage of battery fluid, heat generation, bursting and fire.
- Do not over-charge Twicell batteries by exceeding the predetermined charging period specified by the battery charger's instructions or indicator. If Twicell batteries are not fully charged after the battery charger's predetermined charging period has elapsed, stop the charging process. Prolonged charging may cause leakage of battery fluid, heat generation, and bursting. Be sure to handle recharged batteries carefully as they may be hot.
- Do not remove the outer tube from a battery or damage it. Doing so will expose the battery to the risk of a short circuit, and may cause leakage of battery fluid, heat generation, bursting and fire.
- If Twicell batteries leak fluid, change color, change shape, or change in any other way, do not use them, otherwise they may cause heat generation, bursting and fire.
- Twicell batteries contain a strong colorless alkaline solution (electrolyte). If the skin or clothing comes in contact with fluid from a Twicell battery, thoroughly wash the area immediately with clean water from the tap or another source. Battery fluid can irritate the skin.

⚠ Caution!

- Do not strike or drop Twicell batteries. Sharp impacts or concussions to Twicell batteries may cause leakage of battery fluid, heat generation, bursting and fire.
- Store Twicell batteries out of the reach of babies and small children. When charging or using a battery, do not let babies or small children remove the battery from the charger or the equipment being used.
- Children should not use Twicell batteries unless they have been carefully instructed on the contents of this instruction manual and their parents or guardians have confirmed that the children understand and appreciate the proper usage and safety hazards presented by the batteries.
- Be sure to charge Twicell batteries within a temperature range of 0 to 40°C (degrees Celsius). When used at temperatures outside this range (0 to 40°C) the batteries may cause leakage of battery fluid or heat generation. It could also impair performance or shorten service life of Twicell batteries.
- Do not charge Twicell battery when it has been cooled to 0°C or below. Doing so may cause leakage of battery fluid, impair performance or shorten operating life of Twicell batteries.
- Do not use or store battery at high temperature, such as in strong direct sunlight, in cars during hot weather, or directly in front of a heater. This may cause leakage of battery fluid. It could also impair performance and shorten operating life of Twicell batteries.
- Do not use old and new batteries mixed together, or batteries at different charge levels. Do not use the Twicell battery mixed together with a dry cell or other battery of different capacity, type, or brand name. This may cause leakage of battery fluid and heat generation.
- When more than two batteries are to be used together, charge them simultaneously prior to use. If they are not charged at the same time, it could cause leakage of battery fluid and heat generation.
- Do not connect Twicell batteries in parallel as this may cause leakage of battery fluid, heat generation, bursting and fire.
- For the recommended charging method for Twicell batteries, read the battery charger's instruction manual carefully.
- If Twicell batteries do not perform or function well with certain equipment, refer to the instruction manual or warnings of the subject equipment.
- Do not charge Twicell batteries beyond the recommended time described in the instruction manual for the charger or equipment. Over charging causes leakage of battery fluid, heat generation, bursting and fire. It could also impair performance and shorten service life of Twicell batteries.
- Be sure to turn off the equipment after use of Twicell batteries, as this may result in leakage of battery fluid.
- After they have been removed from equipment, store Twicell batteries in a dry place and within the recommended storage temperature range. This will help preserve the batteries' performance and durability and minimize the possibility of leakage of battery fluid or corrosion. (For the indicated storage temperature range, refer to the rating table of this catalog. Sanyo recommends a temperature range from -20 to +30°C for longer service life).
- Before using the Twicell, be sure to read the operation manual and all precautions carefully, then store the manual and precautions carefully to use as reference when the need arises. If you have specific questions about the operation manual or the precautions, contact Sanyo at the location listed on the last page of this manual.
- If corrosion, heat generation or other abnormalities with new Twicell batteries are detected, immediately stop using them and return them to the store that they were purchased from.
- If the Twicell battery terminals become dirty, clean them with a soft dry cloth prior to use. Dirt on the terminals can result in poor contact with the equipment, loss of power, or inability to charge.

Glossary

Active material	The chemically reactive material in an electrode which generates electricity in a battery.
Alkali	A general name for chemicals showing the properties of a base when dissolved in water. Generally refers to a solution in water of a hydroxide of an alkali metal element or an alkali soil-type metal element.
Assembled battery	A battery composed of two or more cells.
Breaker	When the battery temperature or the current reaches a certain level, the breaker opens the circuit and stops the current. It recovers after operating, and is built into the battery.
C	C is a value which expresses the rated capacity of a battery. Charging and discharging current are generally expressed as a multiple of C. For example, if the rated capacity is 1200mAh, a current of 0.1C is equal to $1200 \times 0.1 = 120$mA.
Cadnica	The brand name of Sanyo's nickel-cadmium batteries.
Cell	The minimum unit of a battery.
Charge efficiency	Charge efficiency indicates the ease with which a battery can be charged. It is obtained by dividing the discharge capacity by the product of the charging current and the time.
Charge retention	The amount of capacity remaining after a charged battery is stored for a period of time.
Depth of discharge	Capacity removed from a battery as compared to its actual capacity. It is expressed as a percentage.
Discharge capacity	The amount of charge taken from the battery when discharged at the rated current and ambient temperature until the discharge end voltage is reached. Generally expressed in units of mAh (milliampere-hours).
Discharge rate	Expresses the amount of current during discharging. If an amount of time "h" is required to reach the discharge end voltage when the battery is discharged at a current level "I" the discharge is called an "h"-hour discharge rate, and "I" is called the "h"-hour discharge rate current. In practice the rated capacity is used as a standard for the discharge rate.
Electrochemical polarization voltage	The voltage between the battery terminals and the potential between the electrodes differ when current is flowing and when it is not flowing. This is called polarization. The difference in potential and in voltage is called the electrochemical polarization voltage.
Electrolyte	The medium which transmits ions (charged particles) during the electrochemical reaction in a battery. Solutions in water of potassium hydroxide (KOH) and sodium hydroxide (NaOH) are used as electrolytes in Twicell batteries.
End voltage	This is a limit voltage which indicates the point at which discharging must end. It is roughly equivalent to the usage limit in actual use.
Energy density	The amount of energy stored in a battery. It is expressed as the amount of energy stored per unit volume or per unit weight (Wh/L, or Wh/Kg).
Gas release vent	This is a vent which opens when gas pressure within a battery exceeds a certain value. There are two types : automatically resealable and non-resealable
High-rate discharge	Discharge at a current of 2 It or more.
Hydrogen absorbing alloy	Among metal hydrides, hydrogen absorbing alloy is the common name for those possessing a special property. It is often used to indicate metal-combining hydrides, which are an alloy of a metal with a strong affinity to hydrogen and a metal with a weak affinity to hydrogen. A large quantity of hydrogen can be absorbed in this alloy. The hydrogen can be released by heating or depressurizing the alloy, and can be absorbed by cooling or pressurizing the alloy. Releasing and absorbing are reversible, and the reaction speed is fast. Among metal hydrides, those alloys which exhibit a fast hydrogen release/absorb reaction and have high reversibility are called hydrogen absorbing alloys. Metal hydrides are sometimes designated by MH.
Ion	An atom or group of atoms carrying a positive or negative charge.
IR-drop	A drop in battery voltage due to the internal impedance of a battery or a drop in voltage of a conductor which connects batteries.
It	{It} is a standard shall be expressed as; $It(A) = C_5(Ah) / 1(h)$ C_5 is the rated capacity of the cell or battery, in ampere-hours.
Leakage	The leakage of electrolyte to the outer surface of the battery.
Metal hydride	A general name for chemical compounds consisting of metal elements and hydrogen.

Misch metal	A mixture of rare earth elements. Sometimes indicated as "Mm". Includes such elements as Ce (40 to 50%), La (20 to 40%), Pr, and Nd. It is used as a rare earth mixture (without refining or extraction to produce a single element) in La-Ni-type batteries as a substitute for La.
Negative electrode	The electrode which has a negative potential. During battery discharge, current flows from the external circuit into this electrode.
Nickel hydroxide	The active material in the positive electrode of Ni-MH and Ni-Cd batteries.
Nickel oxyhydroxide	The chemical name of NiOOH. Indicates that the oxidization of $Ni(OH)_2$ has progressed, and that the active material of the positive electrode of an Ni-Cd or Ni-MH battery is charged.
Nickel-Cadmium battery	This is a secondary battery which uses nickel hydroxide as the active material in the positive electrode, and a cadmium compound as the active material in the negative electrode.
Nominal capacity	Used to indicate the average capacity of a battery. It is the average capacity when batteries are discharged at 0.2It within one hour of being charged for 16 hours at 0.1 It and 20± 5˚C.
Nominal voltage	Used to indicate the voltage of a battery. In general a value is taken which is close to the voltage during actual use. In the case of Twicell batteries, it is 1.2 V per cell.
Open circuit voltage	The voltage between the two terminals of a battery with no load.
Operating voltage	The voltage between the two terminals of a battery when a load is connected. Normally the voltage when 50% of capacity has been discharged is indicated..
Over-discharge	Discharging a battery to the point that the voltage is lower than the end voltage set for the battery.
Over-voltage	The difference between the actual potential at which an electrochemical reaction occurs, and its theoretical equilibrium potential.
Over-charge	Charging a battery when it is already fully charged.
Polarity reversal	Reversal of the polarity of a battery due to forced over-discharge.
Positive electrode	The electrode which has a positive potential. During battery discharge, current flows from this electrode into the circuit.
Positive temperature coefficient	A resistor with a positive temperature coefficient. When a large current flows, its resistance increases and restricts current.
Pulse current	A current which lasts only short time.
Quantity of charge	The amount of charge used to charge a battery. In the case of constant current charging , it is obtained by multiplying the current by the charging time, and expressed in units of Ah (ampere-hours).
Quick charging	A method of charging at a large current in a short period of time.
Rare earth alloys	Alloys which have as their main constituents rare earth elements with a strong affinity to hydrogen such as La and Ce, as well as other transition metals. Alloys of a hexagonal crystal structure such as $LaNi_5$ and $MmNi_5$ are well known.
Rated capacity	The minimum capacity of a battery. The battery must attain the rated capacity at least once during 5 cycles, with one cycle defined as charging a battery for 16 hours at 0.1 It, 20±5˚C and then discharging it within 1 to 4 hours at 0.2 It, 20±5˚C.
Residual capacity	Normally indicates the capacity remaining in a battery after partial discharge or prolonged storage.
Reversal charge	Reversing the "(+)" and "(-)" polarity of the battery and forcing current to flows from the negative electrode to the positive electrode.
Secondary battery	A battery which can be recharged and used repeatedly.
Self discharge	A decrease in battery capacity which occurs without any current flow to an external circuit.
Separator	The component within a battery, which separates the electrodes, prevents short-circuiting, and holds the electrolyte.
Short circuit	Directly connecting the positive electrode (terminal) to the negative electrode (terminal) of the battery.
Thermal fuse	This is a fuse which melts when the temperature reaches a certain point and breaks the current. Once it melts, it can no longer be used. It is built into assembled batteries.
Thermistor	A circuit element with a negative temperature coefficient. It is built into batteries and used to detect ambient temperature or battery temperature.
Trickle charging	Charging a battery to compensate for loss of capacity due to self-discharge.