

# A Guide to the Safe Use of Secondary Lithium Ion Batteries in Notebook-type Personal Computers

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Japan Electronics and Information Technology Industries Association  
and  
Battery Association of Japan

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## Introduction

Since secondary lithium ion batteries were commercialized as power supplies for portable electronic equipment in the early 1990s, much progress has been made in terms of technology and performance. Based on the importance of safety by these batteries, Battery Association of Japan (BAJ) issued "A Guide to the Safe Design, Manufacture, and Use of Portable-type Chargeable Lithium Ion Batteries" <sup>[1]</sup> (hereinafter, "the Guide") in 1999, in cooperation with National Electrical Manufacturers Association (NEMA) in the USA and European Portable Battery Association (EPBA).

Because of their high energy density, secondary lithium ion batteries are widely used in notebook-type personal computers (notebook PCs) and have become predominant in terms of secondary battery technology utilized in notebook PCs. However, in the summer of 2006, there were incidents of such batteries igniting, highlighting the need for guidelines on the safer use of secondary lithium ion batteries in notebook PCs, the Japan Electronics and Information Technology Industries Association (JEITA) and BAJ have therefore tackled the issue together.

This guide describes the design and evaluation for safe use of a secondary lithium ion battery cell system that is consisted of cells, batteries, and a PC system to ensure higher safety.

This guide is intended to help ensuring that secondary batteries are safely used for notebook PCs application, and JEITA and BAJ strongly recommend following the guide when the manufacturers are designing or manufacturing secondary lithium ion battery systems consisting of cells, batteries, and a PC system.

## **Scope**

This guide is applicable to secondary lithium ion battery cells and secondary lithium ion polymer battery cells of cylindrical and prismatic configurations used for notebook PCs with the battery cell capacity range is from 100 to 5,000 mAh.

## **Standards Referenced**

- [1] "A Guide to the Safe Design, Manufacture, and Use of Portable-type Chargeable Lithium Ion Battery Cells" issued and published by BAJ (Japan)/ NEMA (USA)/ EPBA (Europe) in November 1999
- [2] JIS C8712 "Safety requirements for portable sealed secondary cells, and batteries made from them, for use in portable applications"

## **Warning**

The tests described in this guide use procedures which may result in harm if adequate precautions are not taken. Tests should only be performed by qualified and experienced technicians using adequate protection.

## **Caution**

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The original copy of this document has been translated into languages other than Japanese. However, if there is any inconsistency between the Japanese version and the international version, the Japanese version shall have preference over the international version.

## **Definitions of Terms**

The main terms used in this guide are defined below.

Specific voltage and other values expressed by the defined terms shall be determined by the battery/cell manufacturer from the viewpoints of performance and safety. The basic terms conform to JIS C8712<sup>[2]</sup>.

### **Cell:**

A basic system component, consisting of electrodes, a separator, electrolyte, a container, and terminals, that converts chemical energy into electric energy as a source of electric energy when charged.

### **Battery:**

An assembly of single or multiple cells used as a source of electric energy that can be characterized by voltage, size, terminal arrangement, container, and discharging performance.

### **Cell block:**

A set of cells wired in parallel in a battery.

### **Upper limited charging voltage:**

The safe upper limit of voltage when charging each cell. If the charger has a problem in charging control and the protection circuit detects a voltage beyond the limit, charging shall be stopped immediately. However, resetting shall be permitted. A value shall be defined for each of: the standard charging temperature range, the low charging temperature range, and the high charging temperature range.

[Reference] The secondary protection voltage shall be as close to the upper limited charging voltage in each temperature range as possible because the voltage is charged in the overcharging range which should usually be inaccessible. A battery where the above secondary protection has been triggered in the past shall not be used. However, discharge shall be permitted.

### **Rated cell charge-start voltage:**

The fixed cell charging voltage applicable when measuring the rated cell capacity.

### **Rated cell discharge-end voltage:**

The discharge-end cell voltage applicable when measuring the rated cell capacity.

### **Lower limited discharging voltage:**

The safe lower limit of voltage when discharging each cell. If the cell voltage becomes lower, the cell should preferably not be charged.

### **Maximum charging current:**

The safe upper limit of current when charging each cell. During charging, the charging current shall not exceed this value. The value shall be defined for each of: the standard charging temperature range, the low charging temperature range, and the high charging temperature range.

### **Maximum discharging current:**

The safe upper limit of current when discharging each cell. During discharging, the discharging current shall not exceed this value.

**Standard charging temperature range (T2 – T3):**

The cell surface temperature range where the greatest values can be applied from the safe upper limits and maximum values defined for each of: the standard charging temperature range, the high charging temperature range, and the low charging temperature range.

**Low charging temperature range (T1 – T2):**

A temperature range lower than the standard charging temperature range or the cell surface temperature range during charging that can be permitted by changing either or both of the Maximum charging current and the maximum safe allowable charging voltage in the standard charging temperature range.

**High charging temperature range (T3 – T4):**

A temperature range higher than the standard charging temperature range or the cell surface temperature range during charging that can be permitted by changing either or both of the maximum charging current and the upper limited charging voltage in the standard charging temperature range.

**Recommended temperature range (T5 – T6):**

The cell surface temperature range recommended by the cell manufacturer in terms of performance.

**Lowest charging temperature:**

The safe lower limit of cell surface temperature when charging each cell. If the cell surface temperature becomes lower than this limit before or during charging, charging shall be prohibited by any type of current.

[Reference] Equivalent of T1

**Highest charging temperature:**

The safe upper limit of cell surface temperature when charging each cell. If the cell surface temperature becomes higher than this limit during charging, charging shall be prohibited by any type of current.

[Reference] Equivalent of T4

**Highest charge-start temperature:**

The safe upper limit of cell surface temperature where the charging of each cell may be started. If the cell surface temperature becomes higher than this value before charging, the charging conditions in the high charging temperature range shall apply.

[Reference] Equivalent of T3

**Highest discharging temperature:**

The safe upper limit of cell surface temperature when discharging each cell. Keep the cell surface temperature below this limit during discharging.

**Highest discharge-start temperature:**

The safe upper limit of cell surface temperature where the discharging of each cell may be started. If the cell surface temperature is higher than this limit before discharging, discharging shall not be initiated.

**Upper limited temperature:**

A safe cell surface temperature prescribed by the cell manufacturer. This value shall not be exceeded during either usage or storage.

## **Chapter 1 Design Considerations on Secondary Lithium Ion Cells**

### **1-1 Overview**

Secondary lithium ion cells contain lithium-containing metallic oxides (of the metal such as: Co, Mn, Ni, etc.) for positive electrodes, carbon materials (for example, graphite, hard carbon, etc.) for negative electrodes, and organic solvents for electrolytes. During charging and discharging operation, lithium ions move back and forth between a pair of positive and negative electrodes in an electrolyte. While the operation, the lithium atoms are always remained in the ionic state, and it is considered to be stable from the science theory point of view.

When researching this guide, the causes and mechanisms of explosion, fire, and other hazardous events that can occur to secondary lithium ion cells (including those used in applications other than notebook PCs) in the market were analyzed in detail. As a result of this research, the following causes of thermal uncontrolled state of cells, which are the primary initiator leading to hazardous events, were identified:

- Internal short circuit
- Overcharging
- External short circuit
- External heating

In particular, thermal uncontrolled state caused by an internal short circuit was conjectured to be due to a combination of several factors, such as foreign substance in a cell, an imbalance of voltage among cells in a battery, and a high charging voltage applied to a specific cell. This indicates that individual safety measures need to be taken for each element of the components of a secondary lithium ion cell system, like the cells, batteries, and PC system.

This chapter discusses several guidelines for the management of the manufacturing and the design processes of the cells. These guidelines are intended to improve safety and are based on the newly defined concept of safe use ranges. The design considerations for a battery in a PC system will be explained in Chapter 2.

### **1-2 Cell Manufacturing Process Management**

To prevent foreign substance in cells, cell manufacturers have been taking the following two measures in terms of manufacturing process management. Improved process management is the foundation for providing the market with high-quality cells, and continuous quality improvement activities are essential for raising the level of process management. These include the followings:

- Constructing a manufacturing environment where foreign substance does not contaminate in or around electrodes of the cells
- Constructing a inspection process to ensure that no foreign substance is contaminated in the cells

However in another view, it should be realized that the ideally high quality level may not be obtained only by improving the cell manufacturing and inspection processes to avoid cell contamination by foreign substance. It is imperative to introduce other approaches, such that developing cells in which thermal runaway may not likely to occur even if there is contamination by foreign substance. It may also be important to introduce new evaluation criteria to complement the existing criteria for the evaluation of more stringent conditional requirements and to develop new evaluation techniques in IEC and JIS standards.

### 1-3 Cell Design

It is required to strive for designing a cell that will not result in explosion or fire even if foreign substance are contaminated in the cells and cause an internal short circuit. This may be achieved by the following two points:

- Improving a cell structure to reduce the possibility of an internal short circuit even if the cell is contaminated with foreign substance
- Improving materials and structures of the cell to increase the robustness and prevent from explosion or fire even if an internal short circuit condition occurs in the cell

An internal short circuit that generates excessive heat can be caused by the contact being made between the collector metal and the active substance of the counter electrode through the contaminated foreign material. For the structure suggested by ①, it is effective to add protection measures at the corresponding positions to structurally prevent an internal short circuit.

The improvement as suggested by above ② is to take an additional step of designing a cell about the material and structure that prevent an internal short circuit from resulting in explosion or fire even if an internal short circuit happens to occur under unexpected circumstances as long as the conditions of use specified by the cell manufacturer are followed.

The effectiveness of the new cell design and construction discussed in this chapter can be verified by testing as described in Chapter 3.

### 1-4 Range of safe use for secondary lithium ion cell

#### 1-4-1 Overview

General safe use principles for secondary lithium ion cells are described in the Guide issued in the past by the battery associations of Japan, USA and EU. These principles should be strictly observed at all facilities where secondary lithium ion cell systems are designed and manufactured. In pursuing a higher level of safety, particularly for the cells used in notebook PCs, the concept of safe use ranges has been defined. The understanding of this concept and application of the following guidelines are fundamental to the safe use of batteries in notebook PCs.

#### 1-4-2 Voltage

A charging voltage is applied to promote the chemical reaction of charging. If this value is set greater than the specified value by cell manufacturer, however, ancillary reactions may cause a thermally unstable state (thermal runaway may occur in case there is an accident such as heat generation). Therefore, it is extremely important to prevent the charging voltage from exceeding the recommended value specified by the cell manufacturer. The cell manufacturer must verify the safety of cells that are charged at the specified voltage.

##### **Upper limited charging voltage**

Definition: The safe upper limit of voltage when charging each cell.

If a cell is charged beyond the upper limited charging voltage, lithium ions separate excessively from the positive electrode active material and the crystal structure may be broken, releasing oxygen easily. It is also possible that lithium deposits on the carbon material of the negative electrode. Compared with charging under the prescribed conditions, overcharging increases the possibility of thermal uncontrolled state in case of an internal short circuit. Therefore, charging beyond the upper limit must be avoided. A protection system shall also be prepared and implemented in case of faulty charging control by a

charger.

The secondary protection voltage shall be as close to the upper limited charging voltage in each temperature range as possible because the voltage is charged in the overcharging range which should usually be inaccessible. A battery where the above secondary protection has been triggered in the past must not be used. However, discharge shall be permitted.

The above shall not apply to alternate current components (ripples etc.) at 50 kHz or greater where lithium ions do not react inside of the cell.

#### **Lower limited discharging voltage**

Definition: The safe lower limit of voltage when discharging each cell.

If a cell is discharged beyond the lower limited discharging voltage, the collector metal may leach from the negative electrode and deposit locally during charging. This deposition may grow toward the positive electrode and cause an internal short circuit or liquid leakage. If the battery voltage becomes lower than the lower limited discharging voltage, continued charging the cell should be avoided.

#### **1-4-3 Temperature and current**

Charging proceeds with chemical reaction and it is greatly affected by temperature. Even when the upper limited charging voltage and charging current are the same, the likelihood of side reaction and the charging product depend greatly on the temperature. It is therefore preferable to reduce either or both the upper limited charging voltage and the maximum charging current in the low charging temperature range and the high charging temperature range where the conditions are considered to be severe for safety.

#### **Standard charging temperature range (T2 – T3)**

Definition: The cell surface temperature range where the greatest values can be applied from the safe upper limits and maximum values defined for each of: the standard charging temperature range, the high charging temperature range, and the low charging temperature range.

In the standard charging temperature range, a cell can be charged by optimal conditions of the upper limited charging voltage and the maximum charging current in terms of safety. If the cell surface temperature becomes higher than T3 during charging, the charging conditions in the high charging temperature range shall apply. If the cell surface temperature becomes lower than T2 during charging, the charging conditions in the low charging temperature range shall apply.

#### **High charging temperature range (T3 – T4)**

Definition: A temperature range higher than the standard charging temperature range or the cell surface temperature range during charging that can be permitted by changing either or both of the maximum charging current and the upper limited charging voltage in the standard charging temperature range.

In the high charging temperature range, if a cell is charged by the same upper limited charging voltage and maximum charging current as that in the standard charging temperature range, the instability of the positive electrode crystal structure is likely to lower safety. To avoid this it is therefore necessary for the charging conditions to be switched to those specified by the high charging temperature range. If the cell surface temperature is over T3 before charging, the specified charging conditions in the high charging temperature range shall apply. If the cell surface temperature exceeds T4 during charging, continued

charging the cell shall be avoided.

#### **Low charging temperature range (T1 – T2)**

Definition: A temperature range lower than the standard charging temperature range or the cell surface temperature range during charging that can be permitted by changing either or both of the maximum charging current and the upper limited charging voltage in the standard charging temperature range.

In the low charging temperature range, lithium is likely to deposit on the negative electrode carbon because the transfer rate decreases and the penetration of lithium ions into the negative electrode carbon slows down. In this state, heating easily leads to thermal runaway. In the low charging temperature range, the charging acceptance depends greatly on the temperature and a battery easily loses its balance. To avoid this it is therefore necessary for the charging conditions to be switched to those specified by the low charging temperature range. If the cell surface temperature is below or becomes lower than T1 before or during charging, continued charging the cell shall be avoided.

#### **Discharge current and temperature range**

During discharging, the highest discharging temperature shall not be exceeded. If the temperature is over the highest discharge-start temperature before discharging, discharging shall not be started. During discharging, the maximum discharging current shall not be exceeded.

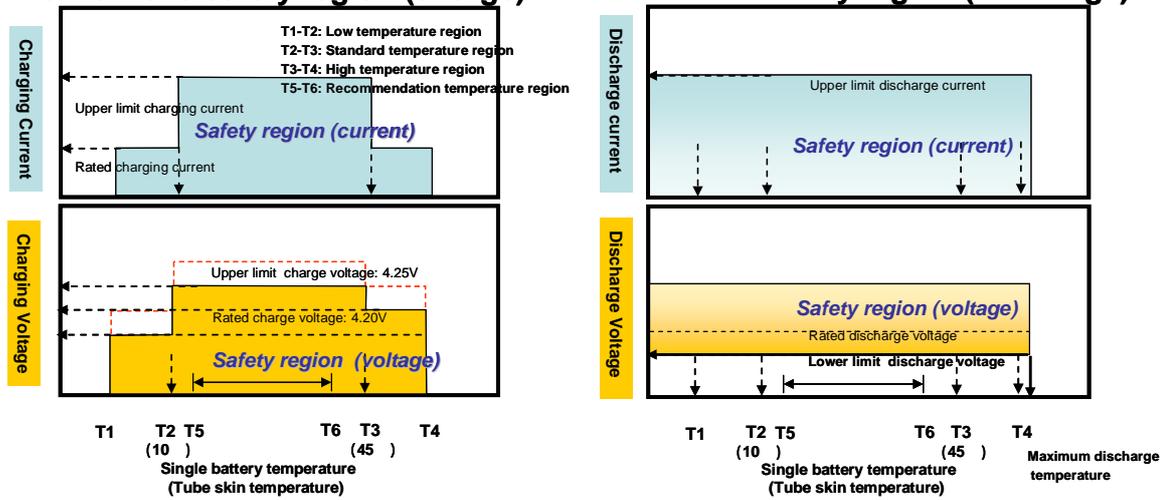
The above shall not apply to alternate current components (ripple etc.) at 50 kHz or greater where lithium ions do not react inside of the cell.

#### **1-4-4 Cell life**

In general, the capacity of a cell is decreased after the repeated charging and discharging are performed and if the cell is stored in high-temperature environment. If the capacity is decreased, the cell is still usable as long as leakage or other problems do not occur. However, a decrease in capacity increases the possibility of leakage because the gas generated by the decomposition of electrolyte increases internal pressure. Therefore, it is not recommended to continue the use of such cells after its capacity decreases below that specified by its manufacturer.

### The view of a safety region (charge)

### The view of a safety region (discharge)



Temperature domain	- T1	T1 - T2	T2 - T5	T5 - T6	T6 - T3	T3 - T4	T4 -
Capacity	Small	Design center value			Almost similar		
Characteristic	x						x
Safety	x						x

**Figure: Safe use ranges**

In the above table, the values prescribing each area shall be determined after testing and verification of test results by each individual battery/cell manufacturer in accordance with the test procedures detailed in Chapter 3. For the current secondary lithium ion cells using cobalt acid lithium and carbon, BAJ proposes the upper limited charging voltage and maximum charging current to be 4.25 V and 0.7 I<sub>A</sub> simultaneously, and the upper and lower limit temperatures to be 45 and 10 simultaneously in the standard charging temperature range.

## Chapter 2 Design Considerations on Lithium Ion Batteries

### 2-1 Overview

A secondary battery utilized in a notebook PC is not consisted of single cells but actually consisted of multiple cells. To ensure higher-level safety of cells used in a notebook PC, therefore, it is necessary to pay more attention to the physical arrangement of the cells and circuit boards which together constitute a battery. It is necessary to incorporate appropriate electrical controls and protection systems. This chapter discusses the following design aspects for lithium ion batteries:

- Arrangement of cells and circuit boards
- Drop, vibration, and shock
- Temperature control
- Overcharge protection
- Over discharge protection
- Deterioration

### 2-2 Arrangement of cells and circuit boards

To prevent one cell faults (such as overheating) from affecting to other cells in a multiple cell battery composition, it is important to adhere to the following:

- Do not assemble cells in a battery in the condition that the top covers (i.e. the side of the vent) faced each other.
- Always allow sufficient clearances between cells. Alternatively, provide a heat-insulating configuration to prevent coincidental explosion.

To prevent hot electrolyte steam emitted from a gas-releasing vent to be staying in the battery enclosure and to catch fire, it is imperative that an electrolyte steam outlet is prepared. Such outlet should be positioned to allow the steam emitted to be directed away from the user.

To prevent hot electrolyte steam emitted from a gas -releasing vent to cause a secondary fault (e.g. short circuit, etc.) of the circuit boards in the battery, it is important to add a protective coating to critical part of the circuit board preventing short circuits or to install partitions preventing any leakage from a cell coming into contact with the circuit boards.

If the circuit board is provided with a storage device storing the operating status of the battery, arrange the board so that the storage device is located away from the cell. This is to ensure that the stored data is protected from the influence by the heat generated in the event of a battery fault.

To localize and minimize the damage in the event of a fault, the battery and the PC should be made of incombustible materials having a self-extinguishing function as follows:

- About the flammability grade of the battery housing, the flammability class of fire enclosure requirements of IEC 60950-1 or better should be applied. For the flame-resistant enclosure and the battery housing, select materials of flammability class V0 or greater or VTM0.
- In the part of the PC enclosure adjacent to the battery, apply the above flammability class requirements to the part of the PC housing when no battery is inserted.
- Note that IEC 60950-1 requires V1 or greater flammability class to the materials of fire enclosures, while this guide requires V0 or higher flammability class.

### **2-3 Drop, Vibration, and Shock**

The battery and PC should be designed and configured in a manner to reduce the likely of a drop, vibration, or shock causing an internal short circuit in cells of the battery.

When installed into a notebook PC, the battery may be totally covered by the PC housing (built-in) or partially exposed depending on the particular PC designs. To evaluate the possibility of a drop, vibration, or shock causing an internal short circuit in a cell of the battery, the performance of evaluation testing for each individual battery model is essential.

Warnings should be provided visible on the PC, in the instruction manual or on the battery label (or both), instructing the user to stop using the battery in the event of a drop, vibration, or shock occurring.

### **2-4 Temperature Management**

To ensure safe and appropriate charge /discharge control, it is necessary to manage the temperature internal to the battery with the use of thermistors or equivalent. The following should be noted when designing the battery and the charge/discharge control system:

Temperature monitoring and charge/discharge control

- For temperature monitoring, measure the cell surface temperature in the battery. When using a single thermistor, its position should be determined with consideration of the temperature distribution in the battery under the condition when it is inserted in a PC system.
- For charge/discharge control, refer to Section 1-4-3, "Temperature and current" in Chapter 1.

Temperature dispersion among cells in a battery

Temperature dispersion among cells in a battery greatly affects the safety during charging as well as causing degradation of battery capacity because the fluctuation in temperature causes fluctuation in voltage. The following should therefore be noted:

- Carefully consider the arrangement of the cells in the battery and the installation location in of the battery in the PC to attain equal temperature among cells.
- Determine the battery design with the objective of maintaining a variance in cell surface temperature to be not greater than 5°C.

Dealing with an abnormal temperature

- If the temperature of a charge/discharge control element (such as FET, field effect transistor) in a battery becomes abnormal, the charging and discharging path should be discontinued with a current blocking element (thermal fuse, etc.).
- If the temperature monitored in the battery exceeds the upper limited temperature, the charging and discharging path should be discontinued with a current blocking element (such as thermal fuse, etc.).

### **2-5 Overcharge Protection**

Multiple cells are connected together in a battery. For the example of a battery consisting of six cells whose rated charging voltage is 4.2 V, they are composed of three cell blocks. Each cell block is consisted of two cells wired in parallel and those are then wired in series. In this case, although the total rated charging voltage is 12.6V, it is not promised that the charging voltage of each cell block is exactly 4.2V. As such voltage dispersion among the cell blocks may cause overcharging condition. The following charging control should therefore be considered.

- Design the charging voltage control circuit so that not only the total battery voltage is controlled but also the voltages of every cell blocks are controlled.

- Maintain the voltage of each cell blocks in the battery in the range of the upper limited charging voltage parameters.
- Upon detection of an overcharge status, the charging operation should be immediately halted (as the primary protection). Even in this halted condition, the discharge operation may be possible.

#### Voltage dispersion among cells

If a Current Interrupt Device (CID) is triggered in a battery consisting of cells wired in parallel, or if deterioration of a particular cell progresses at a faster rate than the others, it is possible to be the abnormal unbalance of charging voltage or currents among cells resulting in potential unsafe condition. Therefore variances in the voltage level between the cell blocks should be therefore be monitored and the battery use should be stopped or limited if the voltage of any cell block exceeds the upper limited charging voltage.

#### Multiple protections (from overcharging )

The entire charging and discharging system should be verified for the risk by failures through the investigation using Failure Mode and Effects Analysis (FMEA) or other techniques. The system should be protected at multiple levels are required for optimal operational safety.

#### Charging completion

To prevent overcharging, charging shall be completed under the conditions specified by the cell manufacturer.

### **2-6 Overdischarge Protection**

If a secondary lithium ion battery is overdischarged, the collector metal may leach from the negative electrode and deposit locally during the following charging operation. It is possible that this deposition may grow toward the positive electrode and result in an internal short circuit or liquid leakage. If the voltage of an individual cell block is driven to the level below the lower limited discharging voltage, the charging of the battery should be avoided.

### **2-7 Deterioration**

Even after extended usage, batteries may not be in a hazardous condition, but there is increased risk potentially connected to hazardous condition. In case of batteries which experienced repeated charging and discharging and reached to more than 50% decrease in its rated capacity, it is possible that some of its cells are deteriorated in excess of usual level. In such condition, there may be unbalanced condition among the cells in the battery liquid leakage from deteriorated cells may occur, and there may be the increased risk.

In order to avoid this situation from occurring, the following precautions are recommended:

- To draw the user's attention of the deterioration level of the battery the users are using, the information should be provided to the user with the capacity retention rate (from the initial capacity) and other information,
- To notify to the users with a warning message, when the capacity retention rate of the battery has become 50% or less, and with a prohibition or warning message from the continued use when it has become 30% or less.

## Chapter 3 Tests and Criteria

Warning:

THE TESTS DESCRIBED IN THIS GUIDE USE PROCEDURES WHICH MAY RESULT IN HARM IF ADEQUATE PRECAUTIONS ARE NOT TAKEN. TESTS SHOULD ONLY BE PERFORMED BY QUALIFIED AND EXPERIENCED TECHNICIANS USING ADEQUATE PROTECTION.

### 3-1 Overview

The safe design (Chapter 1) and safe use (Chapter 2) of a cell must be confirmed by safety testing (Chapter 3). In other words, it must be clearly understood and confirmed through testing that a secondary lithium ion batteries system consisting of cells manufactured on the basis of safe design remains safe only when used in a safe and appropriate manner. Specifically, the cells and batteries need to be evaluated using the tests described in this chapter, as well as the conventional test standards of IEC 62133 and JIS C8712.

### 3-2 Additional Tests for Cells

This section gives the test conditions as follows.

a) Charging procedure for testing

The tests described here are performed with cells and batteries charged by applying the upper limited charging voltage and the maximum charging current at the upper and lower limits of the standard charging temperature range prescribed by the cell manufacturer <sup>Note</sup>. Before charging, the cells and batteries are discharged to the discharge-end voltage by a constant current of 0.2 I<sub>t</sub>A at 20±5 °C.

b) Unless stated otherwise, "completely charged" in each test item means "charged to the upper limited charging voltage by the charging procedure of a)." The capacity in this state is equal to or greater than the rated capacity.

Note: For the current secondary lithium ion batteries using cobalt acid lithium and carbon, the test conditions are the upper limited charging voltage and maximum charging current of 4.25 V and 0.7 I<sub>t</sub>A and the upper and lower limit temperatures of 45°C and 10°C in the standard charging temperature range. The test conditions could be charged by prescript of the cell manufacturer.

#### 3-2-1 Safety tests at Upper limited charging voltage

Requirements and tests:

The items listed in Table 1 shall be tested as prescribed in Chapter 4 of JIS C8712.

Table 1 Test items and quantities

Test Item	Corresponding Test of JIS C8712	Cell	Battery
Internal short circuit (Crushing)	4.3.6	5 sets per test temperature	-
External short circuit	4.3.2	5 sets per test temperature	5 sets per test temperature
External heating	4.3.5	5	-

Criteria:

The criteria of the corresponding test prescribed in Chapter 4 of JIS C8712 shall be satisfied.

### **3-2-2 Forced internal short circuit test**

Requirements: When foreign substance is intentionally mixed into a cell, an internal short circuit due to the presence of the foreign substance shall not cause fire or explosion of the cell.

Test: Remove the electrodes from a completely charged cell from the battery housing and insert conductive foreign substance ① between the active substances of the positive electrode and negative electrode and ② between the collector foil and the active substance. After stabilizing the test temperature at the upper limit of the standard charging temperature range, apply pressure until a voltage drop due to an internal short circuit is observed.

Criteria: No fire shall occur in ① or ②.

### **3-3 Additional Tests for Battery and PC System**

In addition to the items prescribed in Chapter 4 of JIS C8712, the following items shall be tested.

#### **3-3-1 Free fall**

Requirements: When a battery charged to 100% of the capacity or the rated capacity according to the specified charging method by the cell manufacturer is dropped or given a shock while it is installed in the PC, cells in the battery shall have no deformation or changing external shape that may cause an internal or external short circuit. The test shall be performed in the standard charging temperature range.

Test: Drop a PC containing the battery from a height of 1000 ±10 mm onto an iron plate or a concrete floor. The test shall be done with three sets of batteries which are charged to 100%. For dropping, adjust the orientation of battery so that free fall is likely to have the greatest impact to the battery. Instead of dropping a PC, the battery may be subjected to the shock equivalent to the condition of dropping contained in the PC.

Criteria: The cells shall have no internal short circuit condition, nor have any evidence of internal short condition, such as voltage drop or temperature rise. There shall be no cell-external short circuit inside the battery.

#### **3-3-2 Overcharge protection of each cell block**

Requirements: The voltage of each cell block in a battery shall be maintained below the upper limited charging voltage of a cell even if there is a difference in voltage potentials between the cells.

Test: Increase the voltage of a cell block beyond the upper limited charging voltage. This test shall be performed in the standard charging temperature range.

Criteria: The overcharge state of each cell block shall be detected correctly and charging operation stops on or below the upper limited charging voltage.

#### **3-3-3 Evaluation of overcharge protection circuit performance for a fault condition**

Requirements: Overcharge condition shall not be occurred in normal condition and single fault condition.

Test: Apply single fault conditions in the circuits in the PC system and the battery charging and discharging circuits to ensure not overcharged condition is

observed. All or a part of this test can be skipped if there is the test data available of the charging and discharging system with the same configuration. The test shall be performed in the standard charging temperature range.

Criteria: The overcharge protection circuit is effective for every possible fault condition.

### **3-3-4 Charge protection outside the temperature range of safe use**

Requirements: If the cell surface temperature in the battery is higher than the highest charging temperature or lower than the lowest charging temperature, the charging of each cell shall be stopped.

Test: Start charging operation to the battery in the standard charging temperature range. While battery is continued to be charged, control the cell surface temperature to increase above the highest charging temperature, and then decrease the temperature below the lowest charging temperature.

Criteria: Battery charging operation shall be stopped if the temperature becomes higher than the highest charging temperature or lower than the lowest charging temperature.

A Guide to the Safe Use of Secondary Lithium Ion Batteries in Notebook-type Personal  
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