



IEEE Standard for Rechargeable Batteries for Cellular Telephones

IEEE Power Engineering Society

Sponsored by the
Stationary Batteries Committee

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IEEE Standard for Rechargeable Batteries for Cellular Telephones

Sponsor

**Stationary Batteries Committee
of the
IEEE Power Engineering Society**

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Abstract: This standard establishes criteria for design analysis for quality and establishes criteria for reliability of rechargeable Li-Ion and Li-Ion polymer batteries for mobile telephone applications. Also included in the standard are battery pack electrical and mechanical construction, packaging technologies, pack and cell level charge and discharge controls, and overall system considerations.

Keywords: ac/dc adapter, ac/dc charger, battery pack, cell, dc/dc adapter, dc/dc charger, failure mode and effects analysis (FMEA), host device, Li-Ion polymer battery, mobile telephone battery, rechargeable Li-Ion battery

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Introduction

This introduction is not part of IEEE Std 1725-2006, IEEE Standard for Rechargeable Batteries for Cellular Telephones.

The working group was formed to provide a platform based on the experience of industry leaders in cell, battery pack, and systems management leading to design approaches for mobile phones. The focus of the standard is on design approaches for reliable operation of mobile phones and similar rechargeable battery operated systems. This standard may be relevant to other devices, but these were not expressly considered in the development of this standard.

Figure 1 presents the need for an approach involving all subsystems of the system, including the user and environment, to arrive at a satisfactory user experience. It is necessary to examine all design margins in combination to understand the true effect of a multiple fault response on the mobile phone. This standard addresses such questions as follows: What are the critical operational parameters, and how do these parameters change with time and environment? What are the effects of extremes in temperature, pressure, and impact? A total system view is required to protect the design margins in the various components. The goal of reliability and positive user experience requires that design margins be maintained as user patterns, profiles, and duty cycles change.

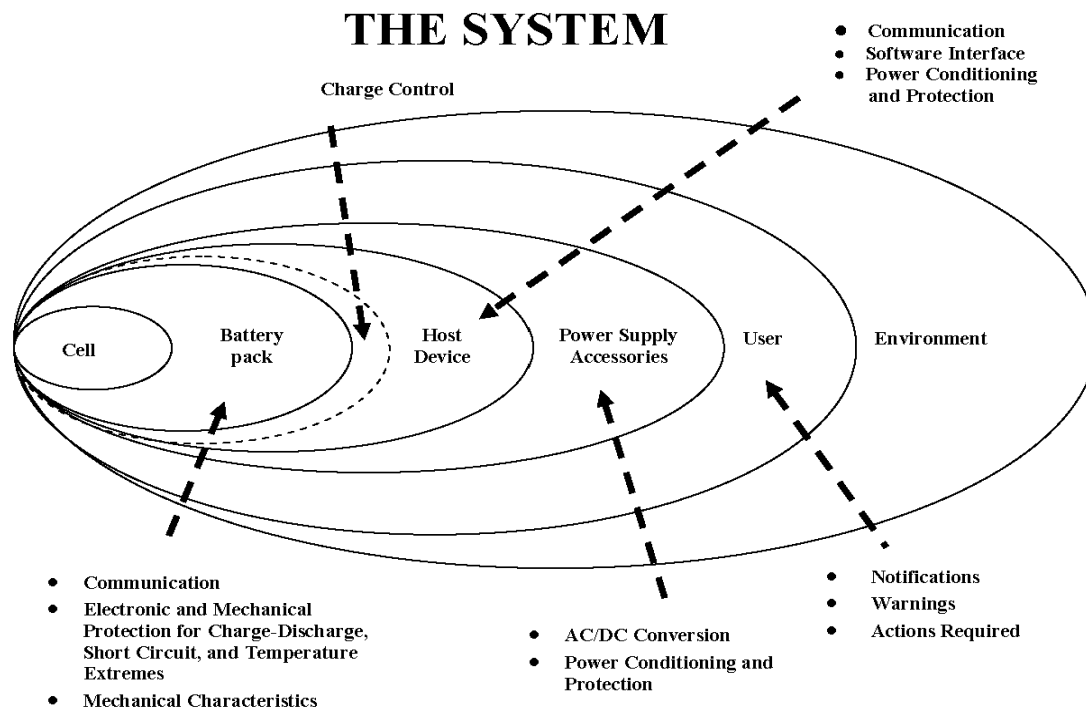


**Figure 1—Conceptual diagram of a mobile phone and its user
(Examples of functions for each subsystem component are shown)**

This standard applies to all types of rechargeable lithium ion (Li-Ion) and lithium-ion polymer (Li-Ion polymer) batteries and battery packs for use in mobile phones. This standard is limited to battery packs consisting of single Li-Ion cell or battery packs with multiple Li-Ion cells connected in parallel. Battery packs with cells connected in series are outside the scope of this standard. Because of the nature of the interactions between the battery and the host device, a system approach must be used in developing an appropriate operating envelope for the system. The provisions of this standard are intended to provide considerations for design analyses to minimize the occurrence of failures leading to hazards.

This standard is a System Level Standard as depicted in Figure 1. Overall compliance is dependent on conformity to each and every subclause of the standard. Compliance with the standard cannot be achieved by any particular mobile phone or subsystem alone without considering the conformity of all subsystems within the system as well as the user. It is incumbent on the manufacturers/suppliers of the host device, battery pack, and cell to review, thoroughly, their designs alone and in conjunction with other subsystems to identify faults that could propagate hazards. Once it has been ascertained that the cell, battery pack, and host device all conform to all their particular subclause requirements, the overall system compliance is not complete until the manufacturer/supplier completes a thorough design analysis, for example, DFMEA, to ensure their particular design prevents hazards from occurring during intended use and reasonable and foreseeable misuse.

At the end of this standard, there are five informative annexes. Annex A summarizes tests that may be used in conjunction with design verification for reliable performance of cells, battery packs, and host devices. Annex B briefly describes the FMEA process through a series of examples. Annex C provides guidance and background information related to two-fault tolerant system analysis. Annex D provides an option to implement validation of the requirement contained within this standard to include both product testing and process/system auditing to qualify or certify components and products for use in mobile phones. Annex E reports thermal environmental considerations encountered in automobiles. Annex F is a bibliography of references useful for understanding and implementing this standard.

The Working Group suggests that this standard be updated in two years, in view of the rapidity that new technology is introduced to the market.

CAUTION

Compliance with the provisions of this standard does not imply compliance to the regulatory requirements that are applicable to cell, battery packs, and systems. Care must be used to observe and refer to the applicable regulatory requirements, as part of the intended design analyses, for this standard does not assure protection or safety. This standard sets forth recommendations for design analyses and certain testing procedures. The level of assurance for protection and safety resulting from applying this standard depends on the implementation by the manufacturer/supplier and the actions of the end user. Compliance with the standard does not guarantee safety in all circumstances.

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IEEE Standard for Rechargeable Batteries for Cellular Telephones

1. Overview

1.1 Introduction

This standard guides manufacturers/suppliers in planning and implementing the controls for the design and manufacture of Li-Ion and Li-Ion polymer rechargeable battery packs used for mobile phones.

The provisions of this standard work together to define approaches to design, test, and evaluate a cell, battery pack, and host device to mitigate battery system failure. Additionally, this standard provides recommendations for user education and communication materials. This approach suggests the interfaces between subsystems (e.g., cell, battery pack, host device, and power adapter) and end users are as important to system reliability as is robust subsystem design and testing. This standard, therefore, includes subsystem interface design responsibilities for each subsystem manufacturer/supplier, and it provides messaging and communication provisions for end-user awareness. Therefore, the responsibility for total system reliability is shared between the designers/manufacturers/suppliers of the subsystems and the end user. Compliance to this standard requires adherence to all provisions of the standard.

1.2 Scope

This standard establishes criteria for design analysis for quality and establishes criteria for reliability of rechargeable Li-Ion and Li-Ion polymer batteries for mobile telephone applications. Also included in the standard are battery pack electrical and mechanical construction, packaging technologies, pack and cell level charge and discharge controls, and overall system considerations.

1.3 Purpose

The purpose of this standard is to ensure reliable user experience and operation of mobile phone batteries. The battery and mobile telephone industries need standardized criteria for design and qualification of rechargeable battery systems and for verifying the quality and reliability of those batteries.

CAUTION

This standard, and its accompanying annexes, provides no guarantee of protection or safety for battery users. This standard sets forth recommendations for design analyses and certain testing procedures. The level of assurance for protection and safety resulting from applying this standard depends on the implementation by the manufacturer/supplier and the actions of the end user. In the recommendations for design analyses contained herein, this standard contemplates reasonable intended use by the end user, but it does not provide a complete guarantee against hazards to the end user such as fire, explosion, and leakage.

2. Normative references

The following referenced documents are indispensable for the application of this Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

WARNING

Some tests specified herein can be dangerous to the persons carrying them out. All appropriate measures to protect personnel against possible chemical, thermal, and/or explosion hazards should be taken.

Battery Association of Japan, Guidance for Safe Usage of Portable Lithium-Ion Rechargeable Battery Pack, First Edition, March 2003.

IEC/TRF 60950-1, Edition 1.0, Information technology equipment—Safety—Part 1: General requirements (2002-01).¹

IEC 61000-4-2, Electromagnetic Compatibility (EMC) Part 2-4 Environment—Compatibility Levels in Industrial Plants for Low Frequency Conducted Disturbances.

IEC 61960, Edition 1.0, Secondary cells and batteries containing alkaline or other non-acid electrolytes—Secondary lithium cells and batteries for portable applications.

IEC 62133, Edition 1.0, Secondary cells and batteries containing alkaline or other non-acid electrolytes—Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications.

ISO 3864-1:2002 Graphical Symbols-Safety colors and safety Signs—Part 1: Design principles for safety signs in workplaces and public places, Revision 02.²

Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Third revised edition, United Nations, New York and Geneva, 2002.³

Underwriters Laboratory Inc., UL 1310, Standard for Class 2 Power Units, May 3, 2005.⁴

¹IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

²ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/ Suisse (<http://www.iso.ch/>). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³United Nations publications are available on the World Wide Web at <http://www.unece.org/>.

Underwriters Laboratories Inc., UL 1642, Lithium Batteries, 1995.

Underwriters Laboratory Inc. UL 2054, Household and Commercial Batteries, 2003.

Underwriters Laboratory Inc., UL 2089, Standard for Vehicle Battery Adapters, December 12, 2003.

Underwriters Laboratory Inc., UL 60950, Safety of Information Technology Equipment, December 11, 2000.

3. Definitions

For the purposes of this Standard, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms* [B9]⁵ should be referenced for terms not defined in this clause.

3.1 abuse: Use of product in a way that is not intended by the manufacturer/supplier but that may result from unreasonable or malicious human behavior or unreasonably extreme conditions or environments.

3.2 active authentication: A method of validation of a battery and/or accessory where the system makes the compatibility decision independent from the user. For example, the use of a secure memory device within the battery pack that communicates to the host that the pack is suitable for use with a specific OEM's mobile phone.

3.3 active charger: A charger that has a communication channel and interacts with the host device

3.4 adapter: A device that transforms the available power from an external source (e.g., ac wall outlet, airline, or automobile outlets.) to the power used by the host.

3.5 authentication: Any method of validation of a battery and/or accessory designed to ensure compatibility with a specific host device.

3.6 battery/battery pack: An assembly of any number of Li-Ion or Li-Ion polymer cells, associated electronics, battery packaging, and connector(s).

3.7 burr: A sharp metallic projection at the edge of an electrode foil that may penetrate the separator and cause an internal short in a Li-Ion or Li-Ion polymer cell.

3.8 cause-and-effect (Fishbone) diagram: A branching, skeletal diagram used to illustrate cause and effect. Main branches are typically labeled "manpower, methods, materials, and machinery." This diagram is also known as an Ishikawa diagram.

3.9 cell: Basic manufactured Li-Ion or Li-Ion polymer unit providing a source of electrical energy by direct conversion of chemical energy that consists of electrodes, separators, electrolyte, container, and terminals, and that is designed to be charged electrically.

3.10 cell core: Internal cell assembly consisting of positive and negative electrodes integrated with separator. Electrodes and separator may be spirally wound ("jelly roll") or stacked ("cut and stack") in a planar arrangement.

⁴UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

⁵The numbers in brackets correspond to those in the bibliography in Annex F.

3.11 cell leakage: The appearance of the cell electrolyte outside the contained components. Leakage is evidenced by liquid or condensed electrolyte composition external to the cell on the cell surface.

3.12 charger: A device that imposes a voltage and current in the proper polarity on a cell or battery to return the battery to a higher state of charge.

3.13 charging algorithm: The set of rules and decisions used to determine the voltages and currents applied to the cell, cells, and/or battery pack as a function of time, temperature, or other parameters.

3.14 counterfeit batteries: Products that are intentionally labeled to mislead the purchaser of a battery. For example, the battery may be marked as being “genuine” or “approved for use” by a specific OEM.

3.15 critical: (A) Of, relating to, or being a turning point or an especially important juncture. (B) Relating to or being a state in which, or a measurement or point at which, some quality, property, or phenomenon suffers a definite change.⁶

3.16 design analysis: The evaluation of a design to determine correctness with respect to stated requirements, conformance to design standards, system efficiency, and other criteria, including consideration of system aging and usage over the life of the product.

3.17 electrostatic discharge (ESD): Electrical discharges of static electricity that build up on personnel or equipment generated by interaction of dissimilar materials. The discharge may damage sensitive components and render them inoperative.

3.18 failure mode: The manner in which failure occurs, generally categorized as electrical, mechanical, thermal, or contamination. It can be associated with a defect or use outside of specification.

3.19 failure mode and effects analysis (FMEA): A systematic group of cross-functional team activities whose purpose is to identify and evaluate the potential failure of a product (Design FMEA; DFMEA) or process (Process FMEA; PFMEA), and to ensure that such failure modes have been properly understood and prioritized for action. It includes evaluation of the severity of such failures, relative frequency of occurrence, and probability of detection and thus containment. The results of these activities are documented and updated as required.

3.20 fault: A physical condition that causes a device, a component, or an element to fail to perform in the required manner. Examples include short circuits, broken wires, and intermittent connections and software errors.

3.21 hazard: An undesirable result of one or more faults that includes a forceful rupture of the battery pack and/or projectile emission, fire, or flame outside of the battery enclosure; noticeable quantity of smoke; release of toxic, corrosive, or dangerous materials in excess of recognized health and safety standards; electric shock that exceeds accepted standards; systems or components generating untouchable surfaces; and leakage of liquid outside of the system enclosure.

3.22 host (host device): The device that is powered by a battery and/or charges the battery. Mobile phones are examples of a host device.

3.23 incompatible batteries: Battery products that do not meet the proper mechanical and/or electrical requirements for safe and reliable operation of the host device.

⁶Critical limits, critical steps, traceability plans, and so on may be considered to be critical design factors. Such parameters are determined by the manufacturer/supplier.

3.24 intended use: Use of a product in accordance with specifications, instructions, and information provided by the manufacturer/supplier.

3.25 manufacturer/supplier: An entity that designs, assembles, and/or markets finished mobile telephones or cells, battery packs, and/or systems, as appropriate.

3.26 may: Indicates a course of action permissible within the limits of the standard. (adapted from Annex G of IEC 61000-4-2⁷)

3.27 open circuit voltage (cell or battery pack) (V_{OC}): The voltage at its terminals when no appreciable current is flowing.

3.28 overcharge: The forcing of a current through a battery pack after it has been fully recharged. Overcharge may damage the normal operation of the cell or battery and/or induce a hazard.

3.29 overcurrent: The situation where the current to or from a cell or battery pack exceeds the manufacturer/supplier rating or specifications. Overcurrent may damage the normal operation of the cell or battery and/or induce a hazard.

3.30 overdischarge: The forcing of current through a battery pack after it has been fully discharged. Overdischarge may damage the normal operation of the cell or battery and/or induce a hazard.

3.31 overvoltage: The situation where the voltage of a cell or battery pack exceeds the manufacturer/supplier rating or specifications. Overvoltage may damage the normal operation of the cell or battery and/or induce a hazard.

3.32 passive authentication: A method of validation of a battery and/or accessory wherein the user makes the decision on the compatibility with the host device.

3.33 passive charger: A charger that does not have a communication channel with the host device

3.34 product lifetime: The actual period from initial operation to retirement of a system, structure, or component.

3.35 process control: The engineering discipline that deals with architectures, mechanisms, and algorithms for controlling the output of a specific process.

3.36 product life: The duration in which a consumer can use a product under normal user conditions. Within this product life, the battery shall provide a recoverable capacity as indicated in the battery information provided by the manufacturer/supplier.

3.37 positive temperature coefficient resistor (PTC): A component that has the characteristic of a sudden large increase in resistance when the device reaches a specified temperature and/or current.

3.38 reasonable and foreseeable misuse: Use of a product in a way that is not intended by the manufacturer/supplier but may result from reasonable and foreseeable human behavior.

3.39 shall: Indicates mandatory requirements strictly to be followed in order to conform to the standard.

NOTE—Equivalent definition of IEC Directive 61000-4-2: Shall = is to; is required to; it is required that; has to; only....is permitted; it is necessary.⁸

⁷Information on references can be found in Clause 2.

⁸Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the guide.

3.40 shelf life: Duration of storage under specified conditions at the end of which a battery maintains its ability to give specified performance.

3.41 should: Indicates that among several possibilities, one is recommended as particularly suitable without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in a negative form) a certain course of action is depreciated but not prohibited.

NOTE—Equivalent definition of IEC: Should = is recommended that; ought to.

3.42 subsystem: A major portion or module that comprises the overall system. Examples of subsystems include, but are not limited to, cell, battery pack, host, interface electronics, and end user.

3.43 system: The combined cell, battery pack, host device, power supply or adapter, user, and environment.

3.44 vision system: Real-time inspection technique using a camera or other device (x-ray) that creates digitized information that is analyzed by a computer programmed to evaluate conformance to a mechanical template or dimension and/or color variations.

4. System integration considerations

4.1 Introduction

The scope of this clause sets forth provisions for conducting design analyses for cell, pack, host devices, and power adapters and an overall system-level design analysis of the combination of these, including the end user. The design analyses shall be conducted to reduce hazards (as defined in Clause 3) from occurring as a result of one or two independent faults while in intended use, depending on the scenario. The analysis shall consider two independent faults for charge and one fault for discharge and storage situations. The design analysis shall also be conducted to reduce hazards from occurring due to reasonable and foreseeable misuse.

Table 1 lists several different design analysis techniques that can be used. Conditions beyond reasonable and foreseeable misuse are outside the scope of this standard. Although design analyses should be thorough, it is not practical to address every conceivable scenario. Such an approach would prove onerous and unrealistic. Furthermore, cell design and manufacturing quality is fundamental to safe system design, as cell faults that create a hazard cannot be mitigated by external subsystems. To minimize hazards, there is no substitute for the use of high-quality cells manufactured in accordance with Clause 5.

Table 1—Examples of design analysis tools

Failure Mode Effects Analysis (FMEA)
Fault tree analysis
Empirical and/or destructive testing
Reviewing company service records for failure modes and/or trends
Cause-and-effect (Fishbone) analysis
Detailed and extensive design reviews
Reviews of prior design issues to ensure they are not repeated
Reviews of industry standards and test methodologies

The design analyses shall identify the following:

- a) End-user responsibilities for reliable total system operation. See Clause 9 for information on the reliable total system operation.
- b) Manufacturer/supplier responsibilities for independent and/or distributed control schemes for reliable total system operation.

In system design analysis, it is necessary to consider all system usage scenarios (charge, discharge, and storage) and the associated affected subsystems. An analysis shall be developed for cell, pack, host, charger, and accompanying accessories that are a part of the system, followed by an analysis that includes the interactions between the subsystems (see Figure 2).

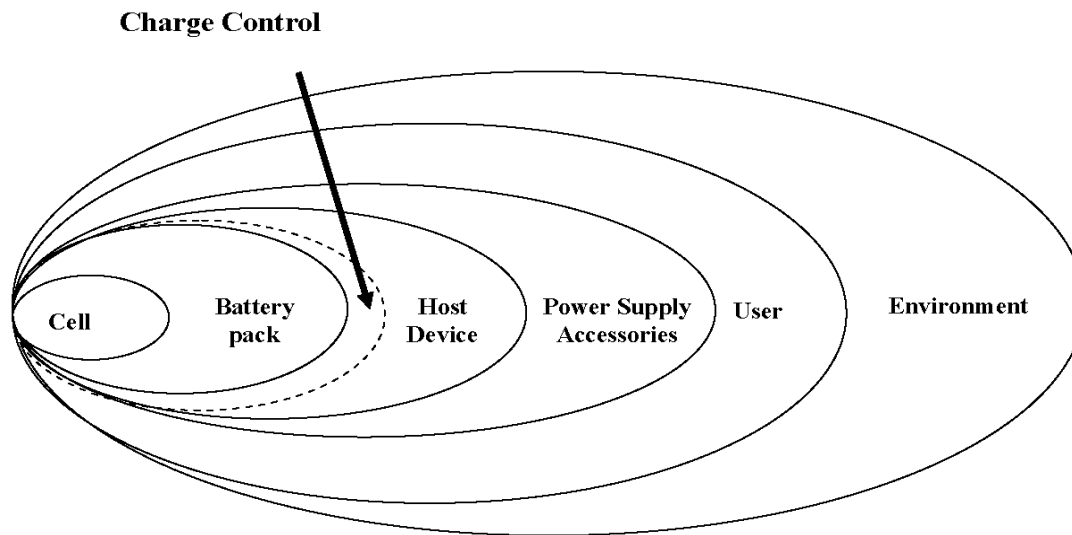


Figure 2—Schematic diagram of phone/battery/power supply system

4.2 Subsystem requirements

Subsystems shall meet the requirements of Table 2.

Table 2—Minimum subsystem requirements

System component	Specification
AC/DC adapter or charger	IEC/TRF 60950; or Appropriate safety standard of destination country
DC/DC adapter or charger	Appropriate safety standard of destination country
Battery pack	UN Manual of Tests and Criteria, Section 38.3 Lithium Batteries
Cell	UN Manual of Tests and Criteria Appropriate safety standard of destination country Pass all tests defined by UL 1642 for “User replaceable batteries”

4.3 Additional subsystem standards

In addition to requirements identified in 4.2, subsystems may also be tested to standards shown in Table 3.

Table 3—Other subsystem standards

System component	Specification
AC/DC adapter or charger	UL 60950
	UL 1310
DC/DC adapter or charger	UL 2089
Battery pack	UL 2054
Battery pack	IEC 62133
	IEC 61960-2
Cell	IEC 62133

5. Cell considerations

5.1 Introduction

The scope of this clause includes the precautions and considerations required for design, manufacturing, and testing of rechargeable Li-Ion and Li-Ion polymer cells over their product lifetime to minimize latent problems and increase reliable user experience. Manufacturers should make recommendations about temperature, current and voltage limits, and proper storage conditions and should establish shelf-life specifications to the pack manufacturer to ensure proper design of battery packs and host operation. Figure 3 depicts typical cell construction for cylindrical (Figure 3a), prismatic (Figure 3b), wound pouch Li-Ion polymer (Figure 3c), and stacked pouch Li-Ion polymer cells (Figure 3d).

5.2 Design process

The Li-Ion cell is the basic element that powers mobile phone operation. It is essential to pay close attention to the critical cell design factors to ensure reliable cell performance and avoid generation of a potential hazard.

5.2.1 Selection and characteristics of a separator material

The separator is a critical element in cell construction. It physically prevents internal short circuits inside the cell by separating the anode from the cathode and provides a path for ionic current flow inside the cell. It also has a safety function that shuts down ionic conductivity inside the cell if the cell temperature increases to abuse conditions. Examples of these functions are depicted in Figure 4a and Figure 4b.

5.2.1.1 Stability

The separator material shall have sufficient chemical, electrochemical, thermal, and mechanical stability to meet all safety performance requirements.

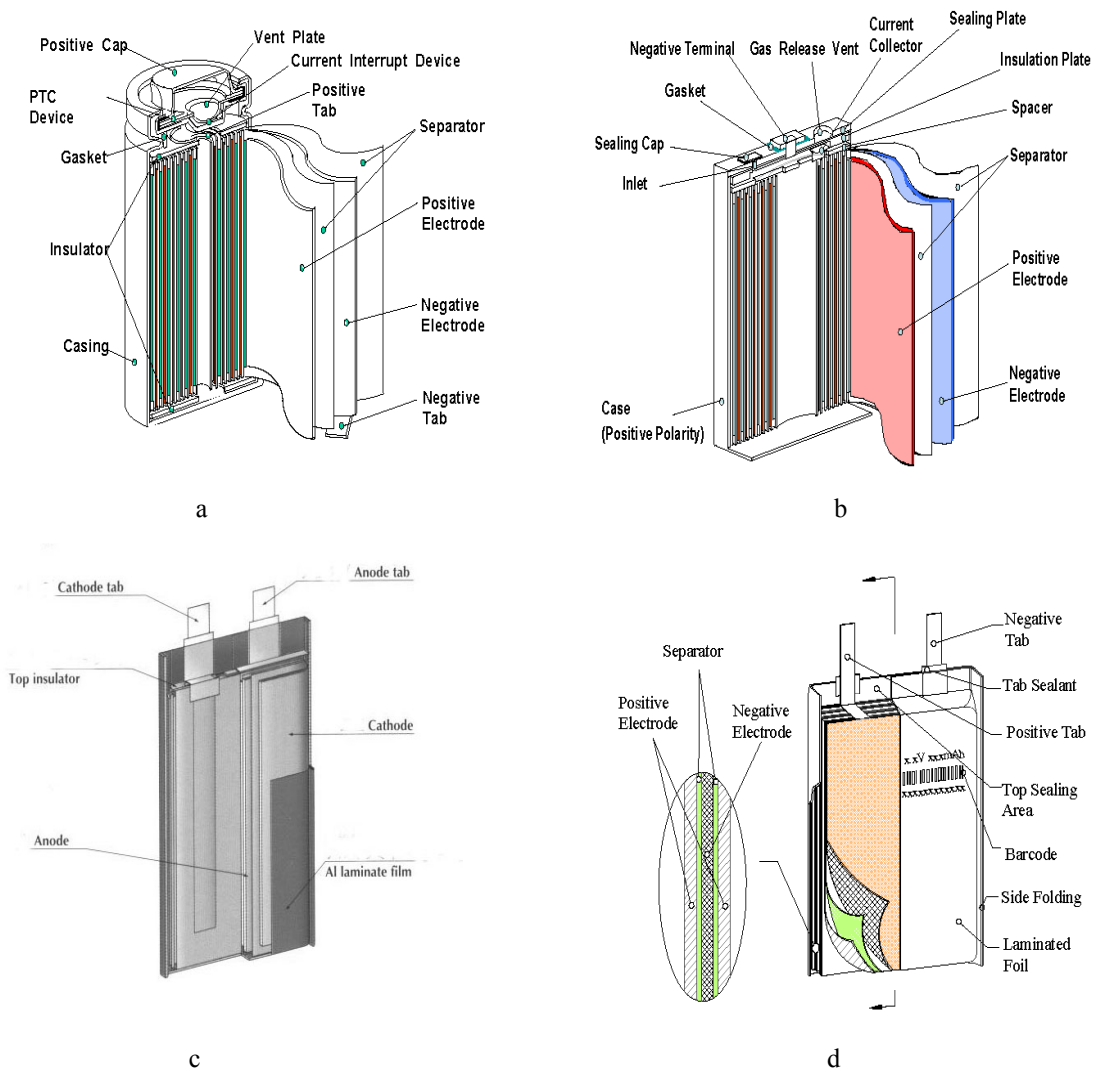


Figure 3—Examples of schematic construction of Li-Ion and Li-Ion polymer cells showing the important components: (a) cylindrical (Courtesy of Sanyo Electric Co., Ltd.), (b) prismatic (Courtesy of Sanyo Electric Co., Ltd.), (c) wound polymer (Courtesy of Sony Corporation), and (d) stacked polymer cell (Courtesy of Amperex Technology Limited)

5.2.1.2 Shutdown performance

The separator material should exhibit a rapid internal resistance increase (ionic conductivity shutdown) when cell temperature rises above its shutdown point. The separator should have a shutdown resistance increase of a minimum of two orders of magnitude at a minimum speed of $2000 \Omega \cdot \text{cm}^2/\text{s}$ (for example, see Figure 4b). Shutdown resistance should be maintained for an adequate time period.

5.2.1.3 Isolation properties

The separator/cell design shall maintain adequate isolation properties up to 150°C during a temperature excursion of at least 10 min in the cell to maintain safety of the cell.

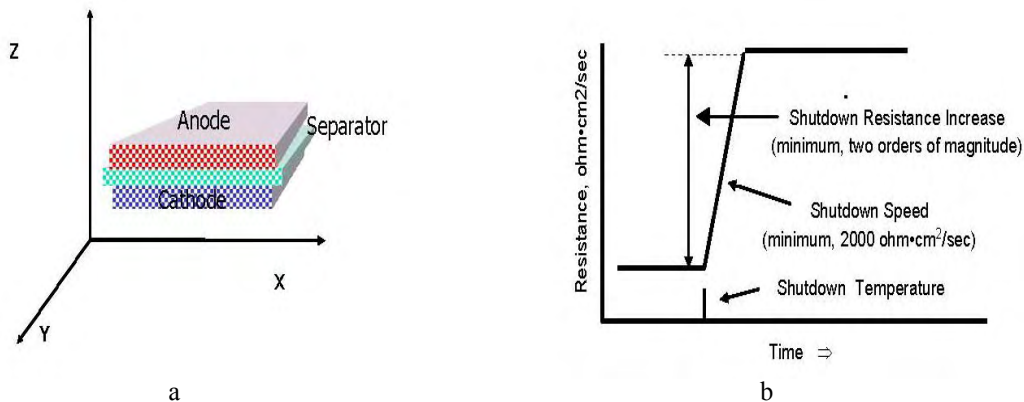


Figure 4—Depiction of the separator (a) positioning, between the anode and cathode (Courtesy of Celgard Inc.) and (b) the speed and magnitude of change in resistance (shutdown function) on reaching a critical temperature (Courtesy of ASAHI KASEI CHEMICAL CORPORATION)

5.2.1.4 Strength and physical integrity

Selection of the thickness of the separator shall be made through design and validation. The separator material shall provide adequate strength in the z direction (normal to the electrode plane) to ensure cell safety performance (for example, see Figure 4a). The separator shall have sufficient physical integrity to withstand handling during the cell manufacturing process.

5.2.1.5 Shrinkage allowance

The area and width of the separator shall take into consideration allowances for separator shrinkage characteristics. The separator/cell design shall maintain adequate coverage of electrodes to meet cell safety requirements. At room temperature, the separator shall be designed to extend beyond the positive electrode and should extend beyond the negative electrode. Separator shall extend at least 0.1 mm beyond the positive electrode (plus process margin) unless process capability/stability is demonstrated to be less than 0.1 mm.

5.2.2 Electrode design criteria

Electrode design constituents for both the anode and the cathode shall be designed to assure performance, safety, and durability in the designated application. Design criteria shall specify material content, purity, and environmental factors that will enable the electrode material to support the manufacturing process and usage in the end application.

5.2.3 Electrode capacity balance and electrode geometry

The charge capacity of the negative electrode shall be greater than the positive electrode. The reversible capacity of the negative electrode shall be greater by at least 0.1% plus process tolerance.

The active area of the negative electrode shall completely cover the active areas of the positive electrode. The negative electrode shall be at least 0.1 mm wider (plus process margin) than the positive electrode on top and bottom of the cell unless process capability/stability is demonstrated to be less than 0.1 mm.

5.2.4 Electrode tabs (connection to cell terminals)

The manufacturer/supplier shall establish optimal tab length exposed beyond the top of the electrode for each cell and control to specific tolerance. Tabs shall not overhang the bottom of the electrodes. Figure 5a illustrates this principal.

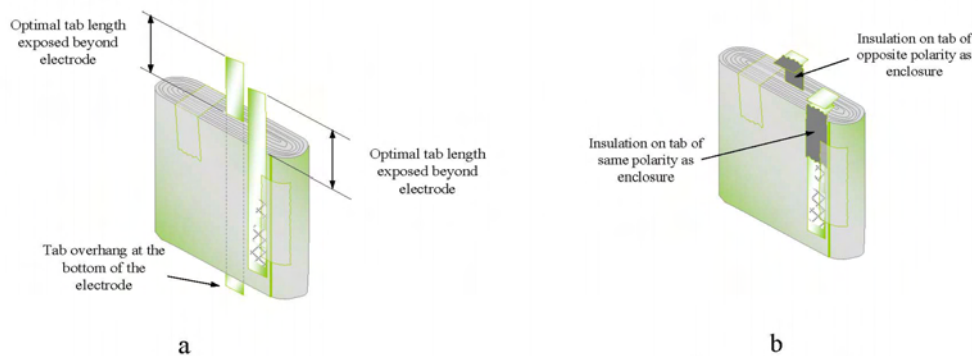


Figure 5—Cell core showing the tab positioning: (a) to demonstrate the optimum length for a particular cell design and (b) to demonstrate an example of positioning the tab insulation to prevent internal shorting of the electrodes

5.2.5 Tab insulation

This subclause includes requirements for tab insulation.

5.2.5.1 Application of insulation

The tab that has the opposite polarity as the enclosure shall be insulated where it exits the electrode assembly. Insulation shall continue until it reaches the point of attachment to the cell terminal. One embodiment of this principal is illustrated in Figure 5b. Insulation may be accomplished through one or more insulating schemes. If a tab is located where there is only a one-layer separator to isolate the opposite electrode, additional insulation shall be used, which may be additional layers of separator material or tape.

5.2.5.2 Insulation adherence

Insulation shall be permanently adhered and have good puncture resistance and may be opaque. Use of opaque insulators may be used to facilitate in-process inspection.

5.2.5.3 Insulation characteristics

Insulation material shall have electrochemical, chemical, mechanical, and thermal stability over the temperature range, -40°C to 150°C .

5.2.6 Cell vent mechanism

Cells shall be designed to include a consistent vent design or mechanism, for example, foil, edge, seam, or score.

5.2.6.1 Retention of cell contents

The vent mechanism shall be designed to minimize projectiles and maximize retention of cell contents.