



IEEE Standard for Rechargeable Batteries for Mobile Phones

STANDARDS

IEEE Power and Energy Society

Developed by the
Energy Storage and Stationary Battery Committee

IEEE Std 1725™-2021
(Revision of IEEE Std 1725-2011)



IEEE Standard for Rechargeable Batteries for Mobile Phones

Developed by the

Energy Storage and Stationary Battery Committee
of the
IEEE Power and Energy Society

Approved 16 June 2021

IEEE SA Standards Board

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Abstract: Criteria for design analysis for qualification, quality, and reliability of rechargeable lithium ion batteries for host devices such as cellular telephone applications are established. Also included are: battery pack electrical and mechanical construction, packaging technologies, pack- and cell-level charge and discharge controls, and overall system considerations.

Keywords: cellular telephones, host device, IEEE 1725™, lithium ion batteries

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Introduction

This introduction is not part of IEEE Std 1725-2021, IEEE Standard for Rechargeable Batteries for Mobile Phones.

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 host devices such as mobile phones. This version of the standard is built on the foundational work of the 2006 and 2011 working groups. The focus of the standard is on design approaches for reliable operation of mobile phones, powerbanks, 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.

The [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 host device. This standard addresses questions such as: 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.

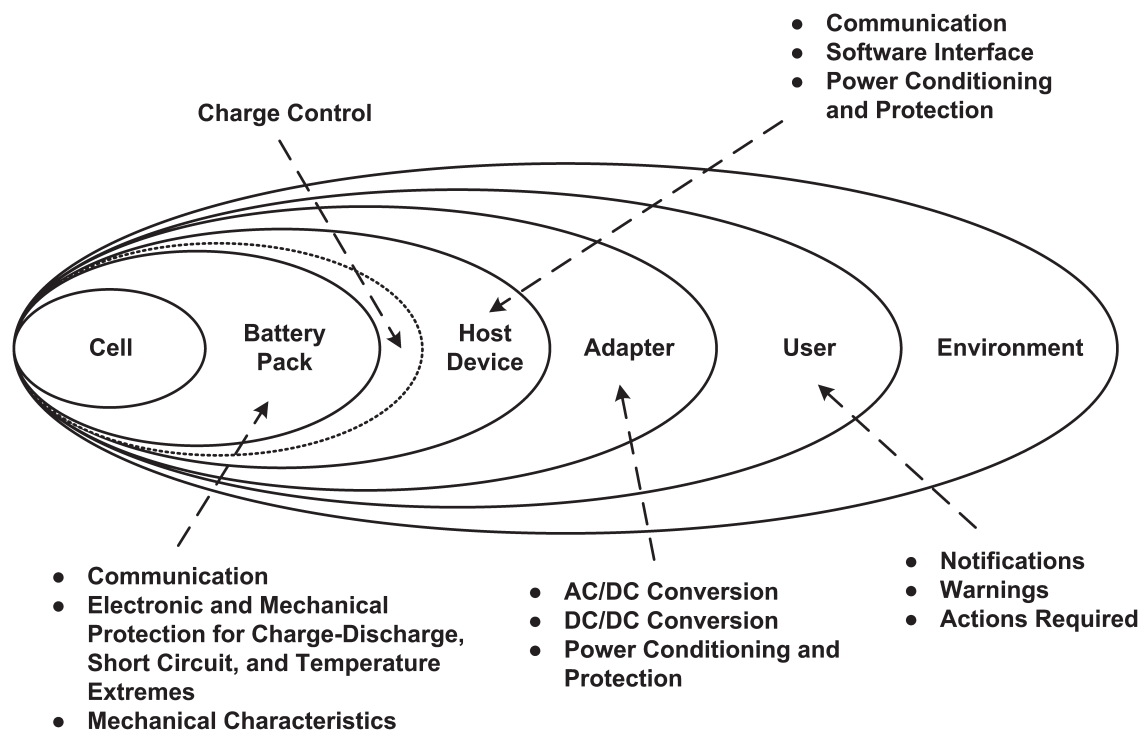


Figure 1—Conceptual diagram of a host device and its user (examples of functions for each subsystem component are shown)

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IEEE Standard for Rechargeable Batteries for Mobile Phones ~~Cellular~~ ~~Telephones~~

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1. Overview

1.1 Scope

This standard establishes criteria for design analysis for qualification, quality, and reliability of rechargeable lithium-ion (Li-ion) ~~and lithium-ion polymer (Li-Ion polymer)~~ batteries for host device ~~cellular telephone~~ applications. Also included in the standard are: battery pack electrical and mechanical construction, packaging technologies, and pack- and cell-level charge and discharge controls and overall system considerations.

1.2 Purpose

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

1.3 Word usage

The word *shall*: indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{1,2}

~~NOTE—Equivalent definition of IEC 61000-4-2 [B9]: *shall* = is to; is required to; it is required that; has to; only ... is permitted; it is necessary.~~

The word *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 (*should equals is recommended that*); or that (in a negative form) a certain course of action is depreciated but not prohibited.

~~NOTE—Equivalent definition of IEC 61000-4-2 [B9]: *should* = is recommended that; ought to.~~

The word *may*: is used to indicate ~~Indicates~~ a course of action permissible within the limits of the standard (*may equals is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can equals is able to*).

~~NOTE—Adapted from Annex G of IEC 61000-4-2 [B9].~~^{6,7}

¹The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

²The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

⁶~~The numbers in brackets correspond to those of the bibliography in Annex F.~~

⁷~~Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.~~

1.4 Prologue 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 host devices. This standard covers all forms of rechargeable Li-ion cells regardless of chemistry, assembly, and packaging ~~mobile phones~~.

The provisions of this standard work together to define approaches to design, test, and evaluate a cell, battery pack, adaptor ~~adapter~~, 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 adaptor ~~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, and ~~/~~suppliers of the subsystems and the end user. Compliance to this standard requires adherence to all provisions of the standard.

Overall compliance depends on conformity to each applicable subclause of the standard (cell, battery pack, host, adaptor, etc.). It is incumbent on the manufacturers/suppliers of the host device, battery pack, and cell, to review, thoroughly, their designs alone and together as part of a system.

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 document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC 62133, 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.^{3 1}

[IEC 62133-2, Secondary cells and batteries containing alkaline or other non-acid electrolytes—Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications—Part 2: Lithium systems.](#)

IEC/~~TRF~~ 60950-1, Information technology equipment—Safety—Part 1: General requirements.

[IEC 62368-1, Audio/video, information and communication technology equipment—Part 1: Safety requirements.](#)

[IEC 62368-3, Audio/video, information and communication technology equipment—Part 3: Safety aspects for DC power transfer through communication cables and ports.](#)

ISO ~~9001~~ ~~9000:2005~~, Quality management systems [requirements](#) —~~Fundamentals and vocabulary.~~^{4 2}

^{3 1} IEC publications are available from the ~~Central Office of the~~ International Electrotechnical Commission, ~~3, rue de Varembe, P.O. Box 131, CH 1211, Geneva 20, Switzerland~~ (~~[https](https://www.iec.ch/) <http://www.iec.ch/>~~) and the American National Standards Institute (<https://www.ansi.org/>). ~~IEC 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/>).~~

^{4 2} ISO publications are available from the [International Organization for Standardization \(<https://www.iso.org/>\)](https://www.iso.org/) and the American National Standards Institute ~~ISO Central Secretariat, 1, ch. de la Voie Creuse, Case Postale 56, CH 1211, Geneva 20, Switzerland~~ (~~[https](https://www.ansi.org/) <http://www.ansi.org/>~~).

UL 1642, Lithium Batteries.^{5 4}

UL 2054, Household and Commercial Batteries.

United Nations Recommendations on the Transport of Dangerous Goods—Manual of Tests and Criteria (UN Manual of Tests and Criteria).³

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online: Glossary of Terms & Definitions* should be consulted for terms not defined in this clause.^{6 5}

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.

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 original equipment manufacturer's (OEM's) host device ~~mobile phone~~.

⁵UL publications are available from Underwriters Laboratories (<https://www.ul.com/>).

⁶*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

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

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

⁵~~The IEEE Standards Dictionary: Glossary of Terms & Definitions is available at <http://shop.ieee.org/>.~~

active charger: A charger that has a communication channel and interacts with the host device. [Also called an adaptive charger.](#)

[adaptor](#) ~~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.

[ambient temperature:](#) $20\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$.

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

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

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.

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*.

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.

[cell block:](#) [One or more cells connected in parallel.](#)

cell core: Internal cell assembly consisting of positive and negative electrodes integrated with the separator. Electrodes and separator may be spirally wound (“jelly roll”) or stacked (~~“cut and stack”~~) in a planar arrangement [such as “cut and stack.”](#)

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.

charge control: A means of ensuring that a cell is charged in accordance with its manufacturer's specifications.

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.

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.

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 original equipment manufacturer (OEM).

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.

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

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.

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

embedded battery: A battery that is not intended to be replaced or serviced by the end user/consumer.

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.

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.

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.

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.

host (host device): The device that is powered by a battery and/or charges the battery. Mobile phones, [powerbanks, and similar rechargeable battery-operated systems](#) are examples of a host device.

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

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

manufacturer/supplier: An entity that designs, assembles, and/or markets finished [host devices](#) ~~mobile telephones~~ or cells, battery packs, and/or systems, as appropriate.

open circuit voltage (cell or battery pack) (VOC): The voltage at [cell or battery](#) ~~its~~ terminals when no appreciable current is flowing.

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

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.

overdischarge: The [depletion](#) ~~forcing~~ of [charge from a cell or](#) ~~current through a~~ battery pack after it has been fully discharged, [and may include active discharge or self-discharge](#). Overdischarge may damage the normal operation of the cell or battery and/or induce a hazard.

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.

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.

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

positive temperature coefficient (PTC) 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.

powerbank: [A portable device consisting of one or more cells with associated power management circuitry housed within an enclosure used for the primary purpose of charging another host device.](#)

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

~~**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.~~

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

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.

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

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.

swelling: An increase in the volume of the cell.

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

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.

3.2 Special terms

agreement: For purposes of this standard, an *agreement* between the various category manufacturers means that the relevant specifications are not in conflict for the parameters in question. It does not imply that a separate document is necessary to demonstrate compliance.

4. System integration considerations

4.1 Introduction

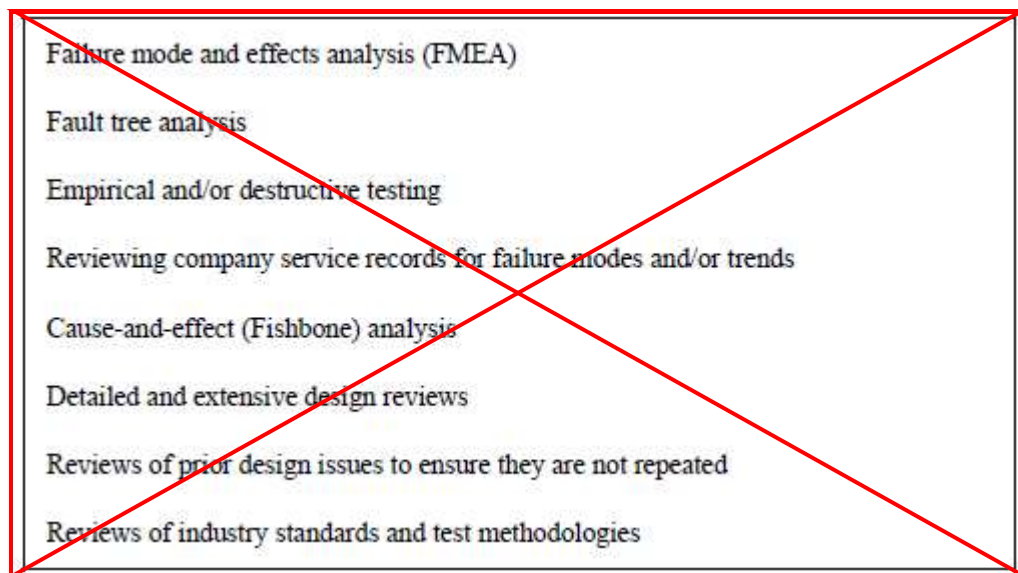
The scope of this clause sets forth provisions for conducting design analyses for cell, pack, host devices, and power adapters and an overall system-level design analysis of the combination of these, including the end user. The design analyses shall be conducted to reduce hazards (as defined in Clause 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 [reduce](#) ~~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

Industry standards and test methodologies review
Company service record (for failure modes and/or trends) review
Lessons-learned (for prior design issues, to ensure avoidance) review
Failure mode and effects analysis (FMEA)
Fault tree analysis
Empirical and/or destructive testing
Cause-and-effect (fishbone) analysis
Detailed and extensive design reviews

(New)

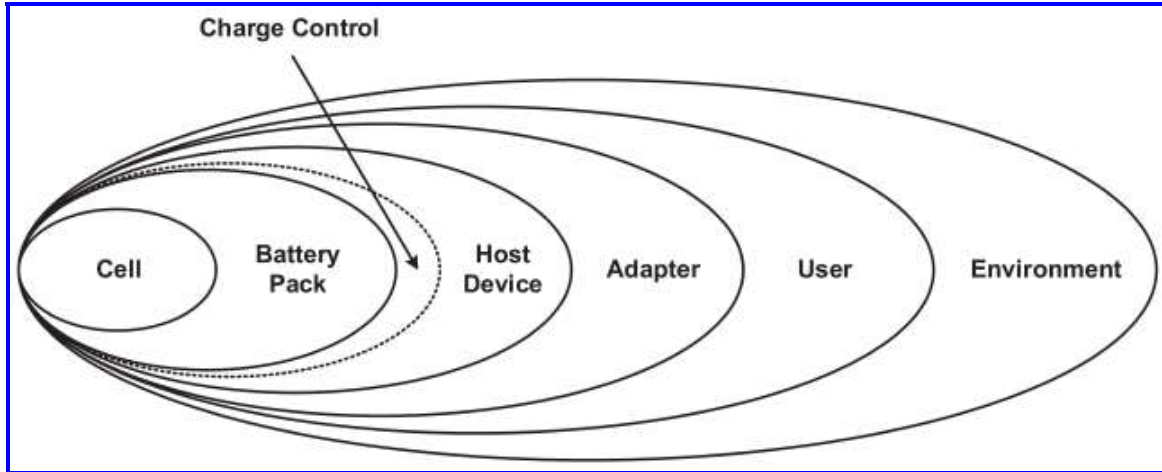


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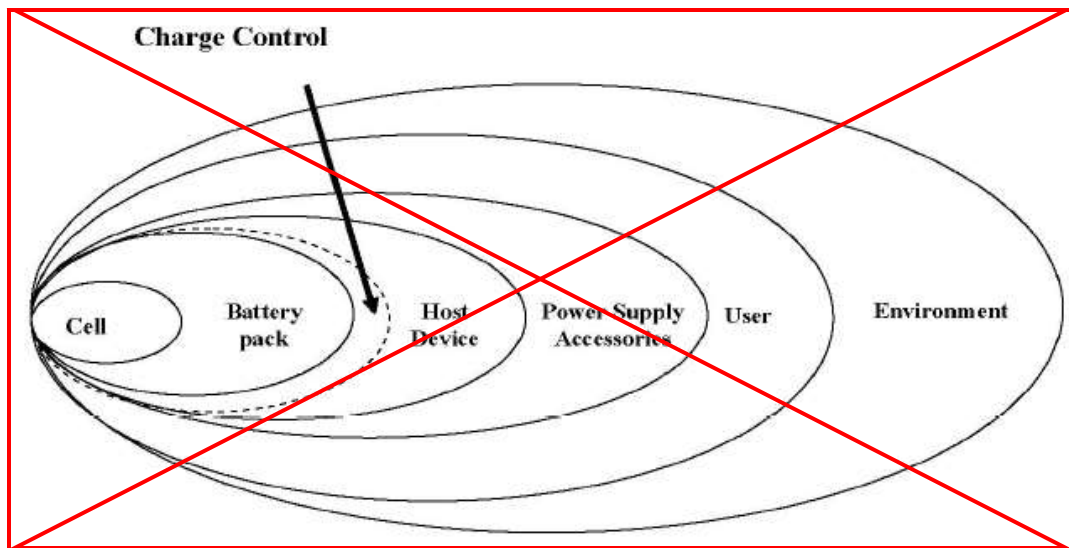
The design analyses shall identify the following:

- 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+).



(New)



(Deleted)

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

4.2 Operating specification requirements

The operating voltage, current, and temperature conditions for the cell, battery pack, and host device shall be set on the basis of an agreement made among the cell, battery pack, and host device manufacturers/suppliers and shall be based on the operating limits of the cell, as specified by the cell manufacturer/supplier.

4.3 Subsystem standard requirements

4.3.1 Minimum subsystem standard requirements

Subsystems shall meet the requirements of the latest [valid edition](#) ~~versions~~ of the standards listed in Table 2^{7,8}.

Table 2—Minimum subsystem requirements

System component	Standard
AC/DC adaptor or charger	IEC/UL 60950-1 or IEC/UL 62368-1 and IEC 62368-3 or appropriate safety standard of destination country
DC/DC adaptor or charger	IEC/UL 60950-1 or IEC/UL 62368-1 and IEC 62368-3 or appropriate safety standard of destination country
Battery pack	UN Manual of Tests and Criteria, Section 38.3 Lithium Batteries and appropriate safety standard of destination country
Cell	UN Manual of Tests and Criteria and appropriate safety standard of destination country, refer to 5.7.4

(New)

System component	Specification
AC/DC adapter or charger	IEC/TRF 60950-1; 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

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4.3.2 Additional subsystem standards

In addition to requirements identified in 4.3.1², subsystems may also be tested to the latest [valid edition](#) ~~version~~ of the standards shown in Table 3.

Table 3—Other subsystem standards

System component	Standard
AC/DC adaptor or charger	UL 1310 [B16]
DC/DC adaptor or charger	UL 2089 [B17]
Battery pack	UL 2054 IEC/UL 62133 IEC 62133-2

(New)

System component	Specification
AC/DC adapter or charger	UL 60950-1 [B21] UL 1310 [B19]
DC/DC adapter or charger	UL 2089 [B20]
Battery pack	UL 2054
Battery pack	IEC 62133
Cell	IEC 62133

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^{z.8} Information on references can be found in Clause 2.

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 reduce ~~minimize~~ latent problems and increase reliable user experience. Cell manufacturers shall define the Cell Operating Region for the pack and host manufacturers. At a minimum, the Cell Operating Region defines limits for ~~Manufacturers—should—make recommendations about temperature,~~ current and voltage at specific temperature ranges ~~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 2 depicts typical cell construction for cylindrical [Figure 3 2(a)], prismatic [Figure 3 2(b)], wound ~~pouch~~-Li-ion laminate ~~polymer~~ [Figure 3 2(c)], and stacked ~~pouch~~-Li-ion laminate ~~polymer~~ cells [Figure 3 2(d)].

The following describes limits for the Li-ion battery system design; since each chemistry is different, they require varying charging profiles, per specifications. For example, see Figure 4 3 for an explanation of operating region (charging) in which the upper limit for the charging voltage, current, and temperature are shown.

5.2 Design considerations ~~process~~

5.2.1 Introduction

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

NOTE—Cells may be designed with tabs emerging from opposite sides of the cell core assembly. See Figure 6(b).

5.2.2 Selection and characteristics of a separator material

5.2.2.1 [Introduction](#)

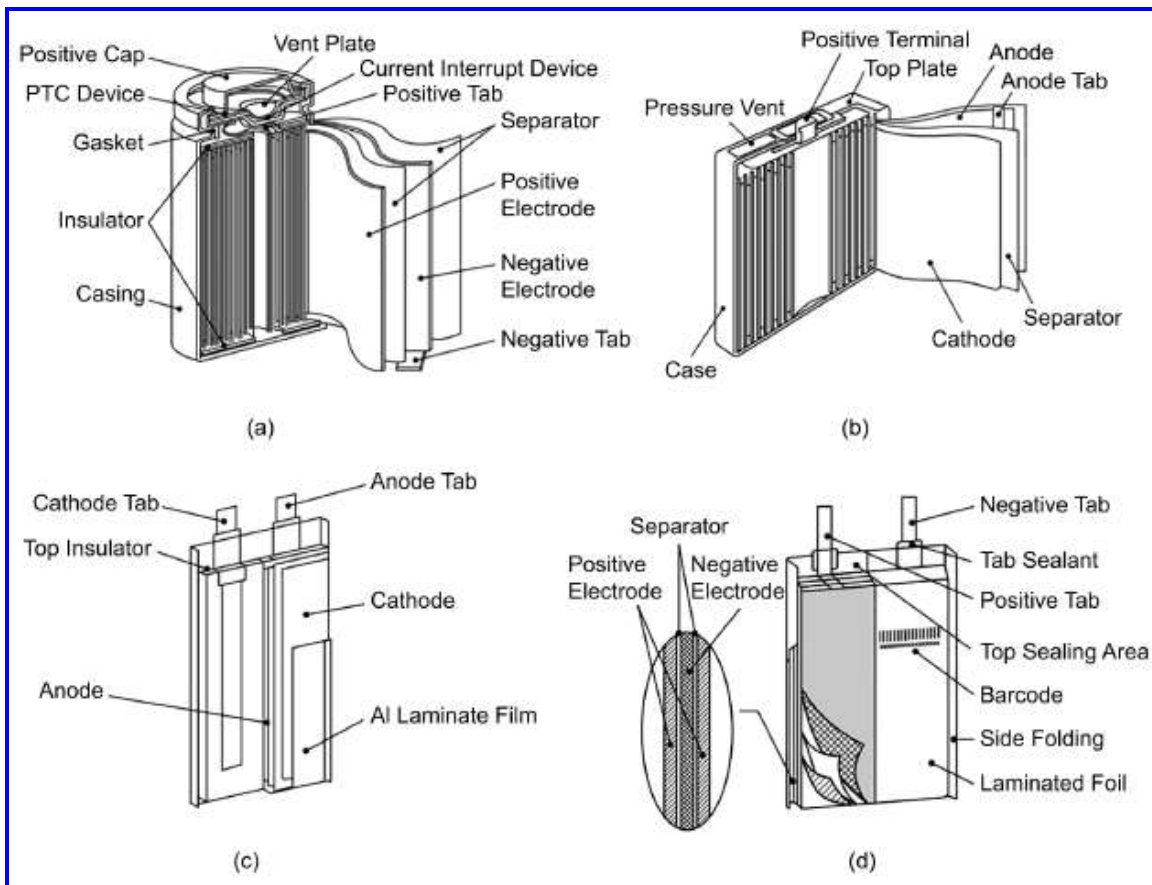
The separator is a critical element in cell construction. It physically prevents internal short circuits inside the cell by separating the anode from the cathode and provides a path for ionic current flow inside the cell. It also has a safety function that shuts down ionic conductivity inside the cell if the cell temperature increases to abuse conditions. Examples of these functions are depicted in Figure [5 4\(a\)](#) and Figure [5 4\(b\)](#).

5.2.2.2 [Separator](#) stability

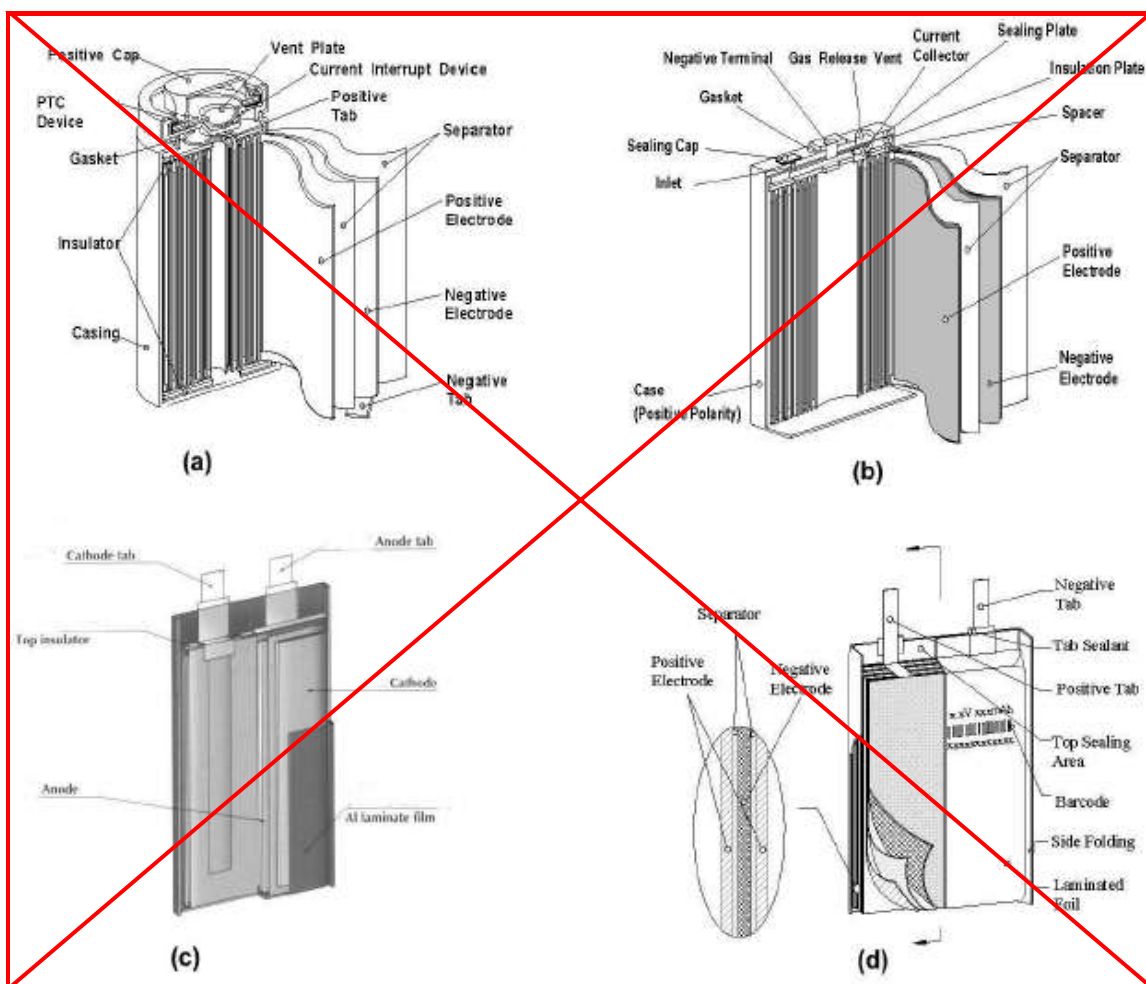
The separator material shall have sufficient chemical, electrochemical, thermal, and mechanical stability to meet all safety performance requirements.

5.2.2.3 [Separator](#) 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 [5 4\(b\)](#)]. Shutdown resistance should be maintained for an adequate time period.



[\(New\)](#)



(Deleted)

Parts (a) and (b) courtesy of Sanyo Electric Co., Ltd. Part (c) courtesy of Sony Corporation. Part (d) courtesy of Amperex Technology Limited.

Figure 3— Examples of schematic construction of Li-ion ~~and Li-Ion~~ polymer cells showing the important components: (a) cylindrical, (b) prismatic, (c) wound laminete polymer, and (d) stacked laminete polymer cell

5.2.2.4 Separator isolation properties

The separator/cell design shall maintain isolation properties up to 150 °C during a temperature excursion of at least 10 min in the cell to maintain safety of the cell (at 80% ± 5% state of charge).

5.2.2.5 Separator strength and physical integrity

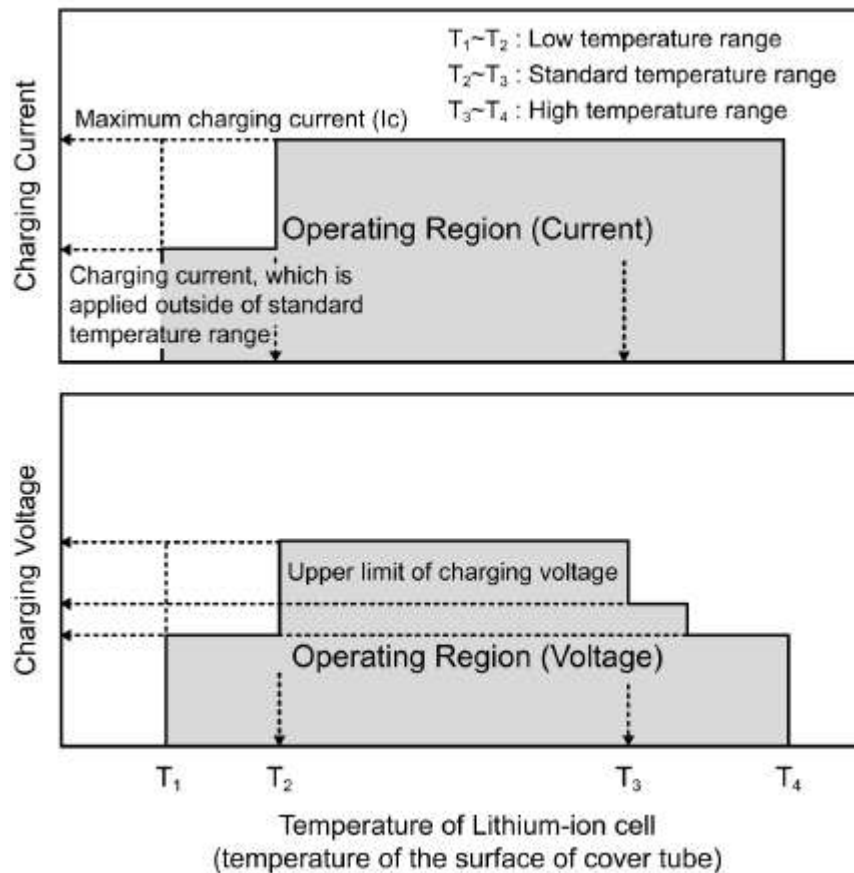
Selection of the thickness of the separator shall be made through design and validation. The separator material shall provide adequate strength in the z direction (normal to the electrode plane) to ensure cell safety performance [for example, see Figure 5 4(a)]. The separator shall have sufficient physical integrity to withstand handling during the cell manufacturing process.

5.2.2.6 Separator 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 ambient ~~room~~ temperature and elevated temperature of 110 °C ± 2 °C (for 1 h), 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.

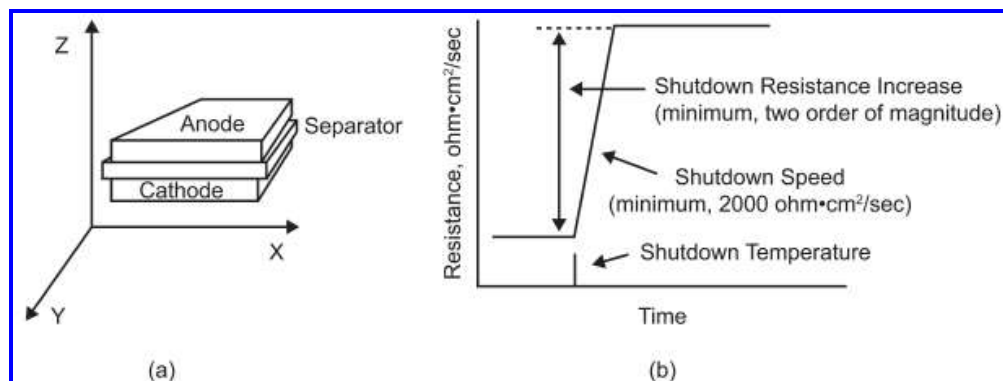
5.2.3 Electrode design criteria

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, dimensions, structure, and environmental factors that will enable the electrode material to support the manufacturing process and ~~usage~~-designated application.

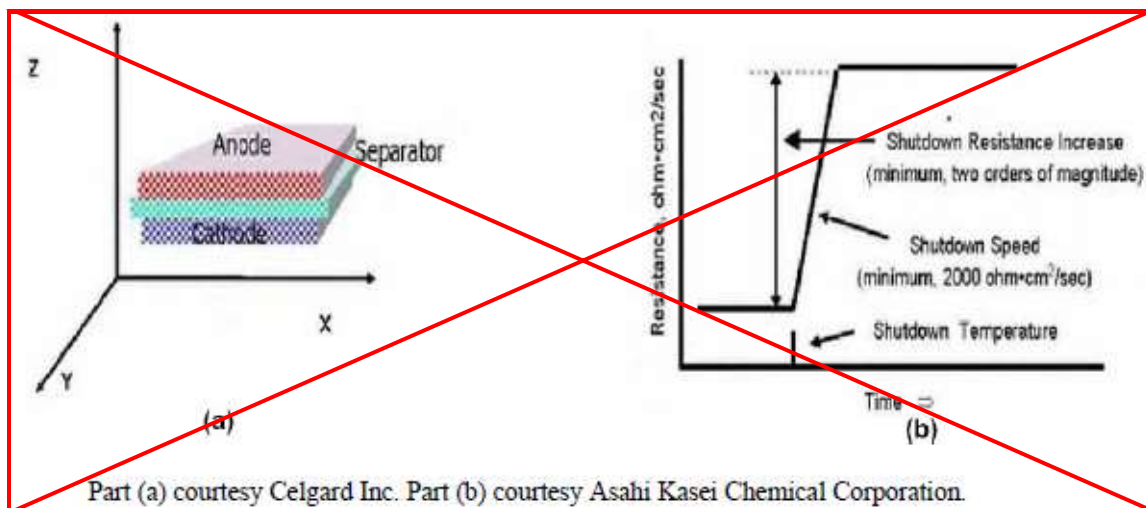


Reprinted with permission from the Battery Association of Japan, Guidance for Safe Usage of Portable Lithium-Ion Rechargeable Battery Pack [B2 B4]. Copyright © 2003.

Figure 4—Example of operating region (charging)



(New)



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Figure 5—Depiction of the separator (a) positioning, between the anode and cathode, and (b) the speed and magnitude of change in resistance (shutdown function) on reaching a critical temperature

5.2.4 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. By design, the negative electrode active area shall extend ~~be~~ at least 0.1 mm ~~wider~~ (plus process margin) beyond all ~~than the~~ positive electrode active area edges ~~on top and bottom of the cell~~ unless process capability/stability is demonstrated to be less than 0.1 mm.

5.2.5 Electrode tabs (connection to cell terminals)

The manufacturer/supplier shall establish optimal exposed tab length and tab overhang. A single tab shall not overhang both sides of the electrodes. Figure ~~6~~ 5(a) and Figure ~~6~~ 5(b) illustrate this principal.

5.2.6 Tab insulation

5.2.6.1 Introduction

This subclause includes requirements for tab insulation.

5.2.6.2 Application of insulation

For cells with metal enclosures, if one of the tabs ~~tab that~~ has the opposite polarity as the enclosure, it 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 6 5(c). 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. Insulation shall prevent tab edges or burrs from contacting the opposite electrode. For cells with laminate packaging, there shall be adequate insulation to prevent tabs from shorting through the laminate foil packaging where the tabs emerge through the packaging seal(s).

5.2.6.3 Insulation characteristics

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

5.2.7 Cell vent mechanism

5.2.7.1 Introduction

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

5.2.7.2 Retention of cell contents

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

5.2.8 Overcurrent protection device

The manufacturer/supplier may employ an overcurrent protector [such as a positive temperature coefficient ~~resistor~~ (PTC) resistor, [resistor](#), or other protective measure] integrated or built into each cell to protect from hazards in the event of external short circuit and/or overcharge. If the cells ~~require~~ [are qualified per this standard using](#) a PTC resistor, [resistor](#), or other protective measure [to comply with this standard, the same measure](#), ~~it~~ shall be included in the cells used in the battery pack design ~~and manufacture~~.

5.2.9 Maximum recommended voltage

The cell manufacturer shall provide a recommended maximum voltage for the appropriate pack overvoltage protection function ([see 6.15.4.2](#)).

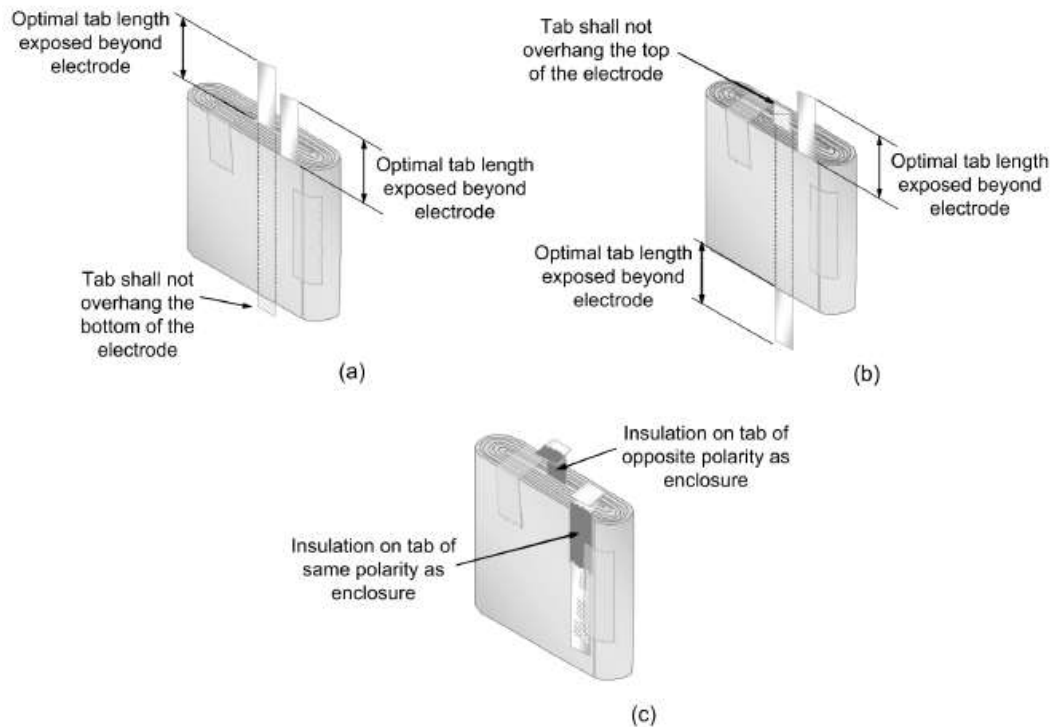


Figure 6—Cell core showing the tab positioning: (a) to demonstrate the optimum length for a particular cell design with positive and negative tabs emerging from the same side of the cell core assembly; (b) with tabs emerging from opposite sides of the cell core assembly; and (c) to demonstrate an example of positioning the tab insulation to prevent internal shorting of the electrodes

5.3 General manufacturing considerations

5.3.1 Materials specifications

Materials specifications shall be developed to identify and limit impurities to levels below critical limits.

5.3.2 Impurity avoidance

All undesirable impurities in materials should be identified, specified, reduced to acceptable levels, and controlled throughout the manufacturing process.

5.3.3 Cleanliness of manufacturing operations

In the manufacturing environment, management of temperature, humidity, and impurity levels shall be specified, controlled, and monitored. Also, environmental management of materials, before and after the manufacturing process, shall be specified and monitored. The introduction of metal contamination from equipment or process shall be prevented.

5.3.4 Manufacturing traceability

The cell manufacturing process shall have a cell traceability plan. This plan should include methods by which traceability can be implemented at any date during product lifetime and after production to determine lot designation and performance data related to the cell. Use manufacturer's/supplier's specifications or documentation to [verify](#) ~~ensure~~ control of this criteria or process.

[5.3.5 Uniform coating of active materials \(see 5.4.1\)](#)

[5.3.6 Burr control \(see 5.4.2\)](#)

[5.3.7 Prevention of damage to electrodes \(see 5.4.3\)](#)

5.3.8 Characteristics of manufacturing equipment

The manufacturing equipment should be designed to prevent any damage or [unintentional](#) modifications to the cell during manufacturing operations. In-process quality controls shall be implemented to [verify](#) ~~ensure~~ consistent operation of the manufacturing equipment.

5.3.9 Defective electrodes (see 5.4.4)

5.3.10 Preventive maintenance plan

Manufacturers shall maintain an effective preventive maintenance plan for all equipment used in the manufacturing processes.

5.4 Electrode processing

5.4.1 Uniform coating of active materials

Coating weight, thickness, and uniformity of electrodes for the positive electrode and negative electrode shall be controlled within the tolerance set by [the cell manufacturer's](#) specification. Use manufacturer's/supplier's specifications or documentation to [verify](#) ~~ensure~~ control of this criteria or process.

5.4.2 Burr control

The manufacturer shall have a method to prevent internal short circuit caused by burrs, either by design or manufacturing control. Design prevention may include insulation taping or coating at uncoated foil, or documented engineering analysis (such as FMEA) that shows that burr heights cannot cause internal shorts. In case there is no appropriate design prevention (such as taping, coating, or FMEA analysis), each cutting point shall be examined and burr height measured at least once per shift or once per manufacturing lot. The measured burr height shall be less than 50% of the lower tolerance limit of the separator thickness. In the case of a burr height greater than or equal to 50% of the lower tolerance of the separator, documented engineering analysis (such as FMEA) shall show that burr heights with greater limits cannot cause internal shorts. Considerations may include, but are not limited to, coating thickness, separator thickness, coated versus uncoated electrode areas, insulators, and electrode overlap.

See Figure [Z 6](#) for definition of burr height.

Burrs shall not exceed 50% of the lower tolerance limit of the thickness of the separator unless documented engineering analysis (such as FMEA) shows that burr lengths with greater limits cannot cause internal shorts. Considerations may include, but are not limited to, coating thickness, separator thickness, coated versus uncoated electrode areas, insulators, and electrode overlap.

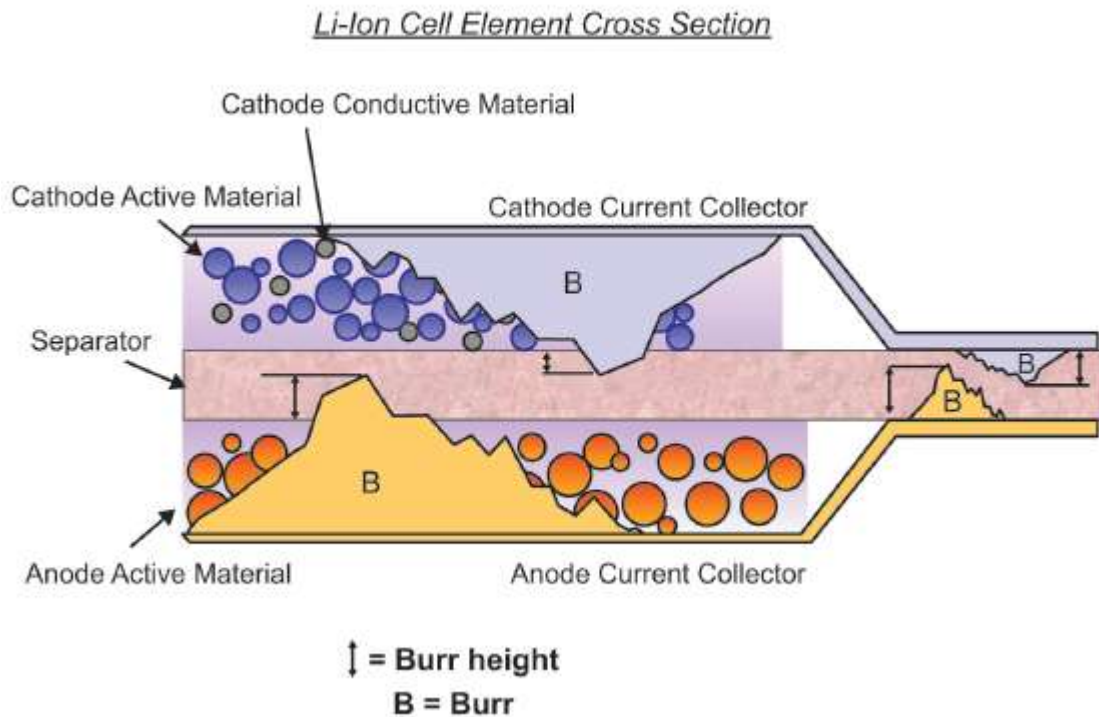


Figure 7—Li-ion cell element cross section showing definition of burr height

5.4.3 Prevention of damage to electrodes

Wrinkling, tearing, and/or deformation of the electrodes should be ~~prevented and~~ eliminated. [The](#) manufacturer shall have an effective method for detecting wrinkling, tearing, and/or deformation of all electrode material. An automated vision system may be used for this purpose.

[All electrodes that fail to meet the cell manufacturer's specification shall be scrapped, rejected, and shall not be used in the production of cells.](#)

5.4.4 Defective electrodes

All electrodes that fail to meet the specification shall be scrapped and shall not be used in the production of cells.

5.5 Cell core assembly

5.5.1 Introduction

All processes referenced in this subclause apply to assembly of the cell core. For example, the cell core is the structure formed by the spiral winding or stacking of electrodes and separator.

5.5.2 Care during cell core assembly process

5.5.2.1 Introduction

This subclause includes precautions to be followed during the cell core assembly process.

5.5.2.2 Tension and damage

The manufacturer/supplier shall use care during the cell core assembly process to avoid excessive tension ~~and~~ damage (twisting, bending, etc.) to the electrodes, and to reduce the generation of loose particles.

~~5.4.1.2 Collection of loose material~~

~~Manufacturer shall have an effective method to collect all loose material produced. Methods may include vacuum, magnetic, or other effective method.~~

5.5.2.3 Detection of damaged cores

The manufacturer shall have a method to detect and reject nonconforming cell cores. Methods may include high-voltage dielectric test (high-pot), voltage test, resistance/impedance test, and/or aging.

5.5.3 Control of electrode spacing

The dimensions of the cell core shall be adjusted to maintain uniform compression ~~and~~ dimensional characteristics, and ~~have~~ no interference that can induce a burr or damage the cell core. The winding spindle removal process shall not damage the jelly roll. Use manufacturer's/supplier's specifications or documentation to ~~verify~~ ~~ensure~~ control of this criteria or process.

5.5.4 Process controls ~~Uniformity of internal electrode pressure~~

The cell core assembly process shall be properly adjusted to remain in the specified range to maintain uniform tension, compression, and dimensional characteristics, and to prevent interference that can induce a burr or damage the cell core or stack. Excessive tension shall be avoided to prevent deformation. Use manufacturer's/supplier's specifications or documentation to ~~verify~~ ~~ensure~~ control of this criteria or process.

5.5.5 Avoidance of contaminants and collection of loose material

The cell core assembly process shall prevent ~~the~~ introduction of contaminants (such as dust, flakes) into the cell core. The manufacturer shall have an effective method to collect all loose material. Methods may include vacuum, magnetic, or other effective method.

5.6 Assembly precautions

5.6.1 Introduction

This subclause includes precautions to be followed during cell assembly.

5.6.2 Internal short avoidance

The ~~method of~~-assembly ~~method~~ for ~~applying insulation to electrodes~~ ~~insulating material, whether~~ ~~for electrode~~, current collectors, or ~~other~~ internal insulation~~7~~ shall provide reliable protection against latent shorts for the ~~product~~-lifetime of the cell, as defined by the cell manufacturer.

5.6.3 Tab positioning

Assembly process shall prevent deforming tab shapes in a manner that can create cell core assembly damage or tab/can short circuits. For example, the insulated tab should be formed into a reproducible shape in such a way that the bent (S-bend typically) sides of the tab are isolated from the walls of the can. Alternatively, an insulator gasket may be included to isolate the tab from the cell core assembly and can walls. Tabs positioning to the electrode stack specification should be confirmed by vision system inspection.

5.6.4 Integrity of cell core assembly

The integrity of cell core assembly shall be verified through resistance or a continuity check or equivalent means.

5.6.5 Positioning of insulating material

An insulating method or design shall be used in order to prevent electrical shorting of the cell core to the cell casing. An example of a bottom plate insulating scheme is demonstrated in Figure 87. Insulating material shall be readily visible and should be checked to specification with resistive measurement or other technological means or methods. Use manufacturer's/supplier's specifications or documentation to ~~verify~~ ~~ensure~~ control of this criteria or process.

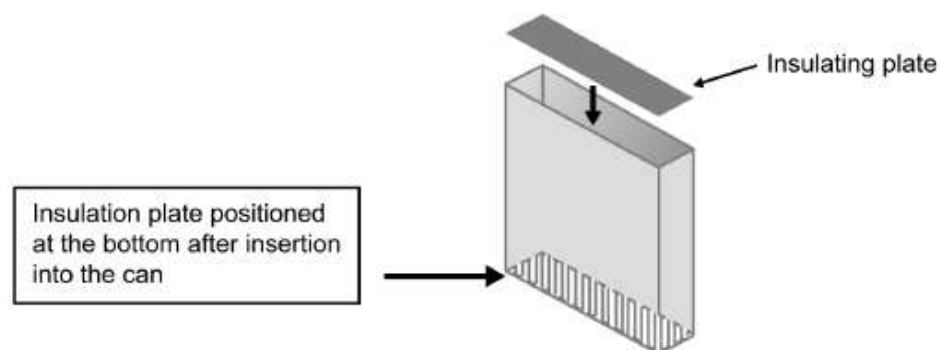


Figure 8—Positioning of the insulating plate in the bottom of the can to prevent internal shorting to the can