



IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices

IEEE Power & Energy Society

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Stationary Batteries Committee



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IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices

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of the
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Approved 26 September 2008

IEEE-SA Standards Board

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Abstract: Guidance for the designer/manufacturer/supplier in planning and implementing controls for the design and manufacture of lithium-ion and lithium-ion polymer rechargeable battery packs used for mobile computing devices is provided. The provisions of this standard work together, and they define approaches to design, test, and evaluate a cell, battery pack, and host device to mitigate battery system failure in end-user environments. Additionally, recommendations for end-user education and communication materials are provided in this standard. This approach suggests the interfaces between subsystems (for example, cell, battery pack, host device) and end users are as important to system reliability as is robust subsystem design and testing. Therefore, subsystem interface design responsibilities for each subsystem designer/manufacturer/supplier are provided, as well as messaging and communication provisions for end-user awareness. The influence of the end user in system reliability is also recognized in this standard.

Keywords: battery, battery pack, cell, host device, lithium-ion (Li-ion), lithium-ion polymer (Li-ion polymer), mobile computing device, pack, portable computing, rechargeable battery, rechargeable battery packs

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Introduction

This introduction is not part of IEEE Std 1625-2008, IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices.

The Portable Computer Battery Working Group was created to provide a platform based on the experience of industry leaders in cell, battery pack, and systems management leading to design approaches for mobile computing devices, such as notebook computers. This standard focuses on design approaches for the reliable operation of mobile computing devices and similar rechargeable battery-operated systems with multiple cells in series or series and parallel. Third-party certification is out of the scope of this standard. This standard may be relevant to other devices, but these devices were not expressly considered in the development of this standard.

Users of mobile computing devices with only one or more cells in parallel (but none in series) are directed to IEEE Std 1725™-2006 [B18]^a for possible applicability.

Figure a presents the need for an approach involving all subsystems of the system, including the end user and environment, to arrive at a satisfactory end-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 computing device. The standard addresses the following questions:

- What are the critical operational parameters?
- 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 end-user experience requires that design margins be maintained as end-user patterns, profiles, and duty cycles change.

This standard applies to all types of rechargeable lithium-ion (Li-ion) and lithium-ion polymer (Li-ion polymer) batteries and battery packs with multiple series cells or series and parallel for use in mobile computing devices. The intent of this standard is to consider the interaction of the technologies manufactured by cell manufacturers, battery pack assemblers, and systems integrators. Because of the nature of the interactions between the battery and the host device, a system approach shall 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. For devices that have multiple functions, manufacturers may choose the primary function of the device to determine which standard applies.

This standard is a system-level standard as depicted in Figure a. Overall compliance is dependent on conformity to each and every subclause of this standard. Compliance with the standard cannot be achieved by any particular multi-cell mobile computing device or subsystem alone without considering the conformity of all subsystems within the system as well as the end user. It is incumbent upon the manufacturers/suppliers of the host device, battery pack, and cell to thoroughly review 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 conform to all of their particular subclause requirements, the overall system compliance is not complete until the manufacturer/supplier completes a thorough design analysis, for example, design failure mode and effects analysis, to ensure their particular design minimizes the risk of hazards that may occur during intended use and reasonably foreseeable misuse. Additionally, the recommended end-user education and communication should be followed.

^a The numbers in brackets correspond to those of the bibliography in Annex G.

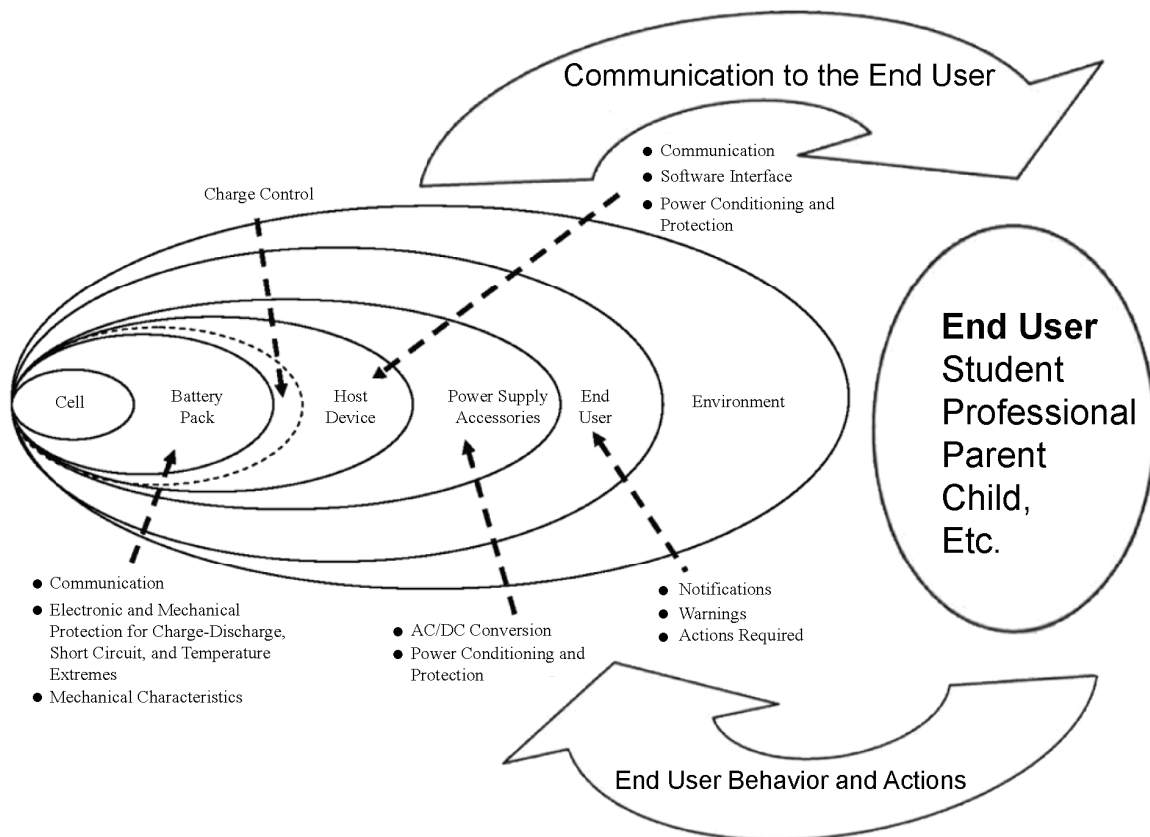


Figure a—Conceptual diagram of a mobile computing device and its end user. Examples of functions for each subsystem component are shown

This standard includes seven annexes—one normative annex, which is required for compliance with this standard, and six informative annexes, which are not required for compliance with this standard. Annex A (informative) briefly describes failure mode effects and analysis techniques. Annex B (informative) provides guidance about a two-fault tolerant system analysis. Annex C (informative) reports environmental considerations encountered in automobiles. Annex D (informative) provides information about test methodologies to evaluate a battery cell's ability to withstand internal shorts due to manufacturing, design, or external abuse. The only normative annex contained herein, Annex E, includes a template for describing battery cell characteristics. The template in Annex E identifies those characteristics that shall be communicated on a Cell specification sheet. Annex F (informative) is a glossary of definitions that this standard uses that are not unique to this standard; however, they are provided for better understanding of this standard. Annex G (informative) contains bibliographic references.

Disclaimer

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 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 this standard does not guarantee safety in all circumstances.

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1. Overview

This standard guides manufacturers/suppliers in planning and implementing the controls for the design and manufacture of lithium-ion (Li-ion) and lithium-ion polymer (Li-ion polymer) rechargeable battery packs used for multi-cell mobile computing devices.

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 end-user education and communication materials. This approach recommends the interfaces between subsystems (for example, cell, battery pack, host device, power adapter, etc.), 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 the provisions of the standard.

CAUTION

This standard, and its accompanying annexes, provides no guarantee of protection or safety for battery end users. This standard sets forth recommendations for design analyses and certain testing procedures. The level of 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 intended use and reasonably foreseeable misuse by the end user. However, compliance with this standard does not provide a complete guarantee against hazards to the end user, such as fire, explosion, and leakage.

1.1 Scope

This standard establishes criteria for design analysis for qualification, quality, and reliability of rechargeable battery systems for multi-cell mobile computing devices. It also provides methods for quantifying the operational performance of these batteries and their associated management and control systems including considerations for end-user notification.

This standard covers rechargeable battery systems for mobile computing. The battery technologies covered are limited to Li-ion and Li-ion polymer, but future versions of this standard may include technologies that are not in general use at present. Also included are: battery pack electrical and mechanical construction; system, pack, and cell level charge and discharge controls; and battery status communications. The following are addressed: qualification process; manufacturing process control; energy capacity and demand management; levels of management and control in the battery systems; current and planned lithium-based battery chemistries, packaging technologies, and considerations for end-user notification.

1.2 Purpose

~~The purpose of this standard is to ensure reliable user experience and operation of batteries in portable computing environments. The battery industries need standardized criteria for design and qualification of rechargeable battery systems and for verifying the quality and reliability of those batteries~~

~~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 (that is, 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.

~~This standard shall be used in conjunction with the following publications. When the following specifications are superseded by an approved revision, the revision shall apply.~~

~~Guidance for Safe Usage of Portable Lithium-Ion Rechargeable Battery Pack, First Edition, March 2003, Battery Association of Japan.1~~

WARNING

Some of the 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.

[AIAG SPC-3, Statistical Process Quality Control, Second Edition, 2005.1](#)

[ANSI/ASQ 9002, Quality Management Systems Requirements.2](#)

[IEC 60695-11-10, Fire hazard testing—Part 11-10: Test flames—50 W horizontal and vertical flame test methods.3](#)

~~IEC 60050-486:1991, International Electrotechnical Vocabulary—Chapter 486: Secondary Cells and Batteries.2~~

[IEC 60950-1:2005, Information technology equipment—Safety—Part 1: General requirements.](#)

~~IEC 61000-2-4:2002, Electromagnetic Compatibility (EMC) Part 2-4: Environment—Compatibility Levels in Industrial Plants for Low-Frequency Conducted Disturbances.~~

[IEC 62133:2002, 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.](#)

~~IEC 61960-1:2000, Secondary Lithium Cells and Batteries for Portable Applications—Part 1: Secondary Lithium Cells.~~

[IEC 62281, Safety of primary and secondary lithium cells and batteries during transport.](#)

~~IEC 61960-2:2001, Secondary Lithium Cells and Batteries for Portable Applications—Part 2: Secondary Lithium Batteries.~~

~~IEC 62133:2002, 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, Annexes A and B.~~

[IPC-A-610, Acceptability of Electronic Assemblies.4](#)

[IPC-2221, Generic Standard on Printed Board Design.](#)

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[4 IPC publications are available from the Institute for Interconnecting and Packaging Electronic Circuits \(IPC\), 2215 Sanders Road, Northbrook, IL 60062-6135, USA \(<http://www.ipc.org/>\).](#)

~~1 This publication is available from the Battery Association of Japan, Kikai Shinko Kaikan, Suite 509, 5-8, Shibakoen 3-chome, Minato-ku, Tokyo 105-0011, Japan (<http://www.baj.or.jp>)(bajapan@hi-ho.ne.jp).~~

~~2IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH 1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC 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. 3ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, 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/>).~~

~~4This publication available from United Nations Publications, Room DC2 853, 2 UN Plaza, New York, NY 10017, USA, or Publications des Nations Unies, Section des Ventes et Commercialisation, Bureau E 4, CH 1211 Geneva 10, Switzerland (<http://www.un.org/>).~~

ISO 9001, Quality management systems—Requirements.5

~~ISO 3864 1:2002, Graphical Symbols—Safety colors and safety signs—Part 1: Design principles for safety signs in workplaces and public areas.3~~

UL 94, Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.6

~~UL 1642-1995, Lithium Batteries, Third Edition.5~~

UL 1642-2005, Standard for Lithium Batteries.

UL 2054, Standard for Household and Commercial Batteries.

UL 60950-1, Information Technology Equipment—Safety—Part 1: General Requirements.

UN ST/SG/AC.10/11/Rev.4-2003, Recommendations on the Transport of Dangerous Goods—Manual of Tests and Criteria, Fourth Revised Edition.7

3. Definitions

For the purpose of this standard, the following terms and definitions apply. The glossary in Annex F and The Authoritative Dictionary of IEEE Standards Terms [B17] should be referenced for terms not defined in this clause.8

~~If not defined in this clause, English words are used in accordance with their definitions in the latest editions of Merriam Webster's Collegiate Dictionary [B10]. 6 Electrical and electronic terms not defined in this clause or in the Collegiate Dictionary are used in accordance with their definitions in The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition [B7].~~

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

~~electronic terms not defined in this clause or in the Collegiate Dictionary are used in accordance with their definitions in The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition [B7]~~

3.2 active authentication: A method of qualification of a battery and/or accessory where the system makes the compatibility decision independent from the end 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 computing device.

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 (for example, ac

wall outlet, airline, or automobile outlets, etc.) to the power used by the host.

3.5 aging of cells: Manufacturing process(es) from initial charge to final acceptance.

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

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

3.8 battery management circuit: An integrated circuit that manages battery operation to prevent overvoltage, overcurrent, and stops battery operation at set high and low temperatures as well as at a set low-voltage cutoff.

3.9 burr: A sharp metallic projection at the edge of an electrode foil may penetrate the separator cause an internal short in a Li-ion Li-ion polymer cell.

NOTE—See Figure 6.9

5 ISO 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/>).

6 UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (~~<http://global.ihs.com/>~~) 6(<http://global.ihs.com/>).7

UN publications are available from United Nations Publications, 2 United Nations Plaza, Room DC2-853, New York, NY 10017, or Sales Office and Bookshop, Bureau E4, CH-1211 Geneva 10, Switzerland USA (<http://www.un.org/Pubs/>).8 The numbers in brackets correspond to those of the bibliography in Annex G.

3.10 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.

3.11 cell block: One or more cells connected in parallel.

~~3.1.11 design failure mode effects analysis (DFMEA): A detailed engineering examination of the design before it is put into production to determine the effect(s) of failure(s) of a component and a subsystem on the host device~~

3.12 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.

~~3.1.12 embedded controller: A programmable microprocessor that has a dedicated function to control specific components of the computer architecture independent of the main processor~~

3.13 cell production lot: A group of cells that have similar characteristics as a result of common materials, manufacturing timeframe, or other identifiable characteristics according to the manufacturer’s specifications.

3.14 charge and discharge test current (It): $ItA = CnAh / 1h$, where Cn is the rated capacity declared by the cell manufacturer in ampere hours (Ah) and ‘n’ is the time base in hours (h) for which the rated capacity is declared.

3.15 charge control: The specific mechanism that supervises/controls the charge of a battery.

~~3.1.15 failure mode effects analysis (FMEA): The identification of significant failures, irrespective of causes and consequences. This includes, but is not limited to, electrical and mechanical failures that could conceivably occur under specified service and use conditions and their effect, if any, on adjoining circuitry or mechanical interfaces displayed in a chart, table, fault tree, or other format~~

3.16 charger: A charger is 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 (SOC).

~~3.1.6 cell block: Unit cells connected in parallel.~~

3.17 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.

3.18 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.10

3.19 critical change: Any change that would increase the chance of a hazard.

3.20 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.

3.21 fault: A defect in the cell/host/pack that causes the device to fail to perform normally.

3.22 fresh cells: Cells as received from the vendor prior to any additional assembly or use of those cells.

3.23 host (host device): The device that is powered by a battery and/or charges the battery. Mobile computing devices and external chargers are examples of a host device.

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

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

~~3.1.24 over-discharge: The forcing of current through a battery pack after it had been fully discharged. Over discharge may damage the normal operation of the cell or battery and/or induce a hazard.~~

~~3.1.25 overvoltage: A situation where the voltage of a cell or battery pack exceeds rating or specifications. Overvoltage may damage the normal operation of the cell or battery and/or induce a hazard.~~

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

10 Critical limits, critical steps, traceability plans, etc., may be considered to be critical design factors. Such parameters are determined by the manufacturer/supplier

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

3.27 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.

3.28 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.

3.29 overdischarge: The draining of charge from a battery pack after it has been discharged to a normal discharge voltage specified by the cell manufacturer. Overdischarge may damage the normal operation of the cell or battery and/or induce a hazard.

3.30 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.

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

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

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

3.34 product life: The duration in which a consumer can use a product within manufacturers' recommended specifications. Within this product life, the battery provides energy.

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

3.36 qualified batteries: Batteries that have undergone analysis and evaluation required by this standard by the cell, battery pack, and host device manufacturer/supplier.

3.37 reasonably foreseeable misuse: Use of a product, process, or service in a way that is not intended by the supplier, but which may result from readily predictable human behavior.

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

3.39 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.

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

3.41 thermal runaway: The cell condition where the internal cell reactions generate more thermal heat than the cell can dissipate. The condition typically causes cell venting.

3.42 unqualified batteries: Batteries that do not meet the definition of qualified batteries.

3.43 vision system: Inspection technique using a camera or other device (x-ray) that creates and compares information, analyzed by a computing device programmed to evaluate conformance, to a mechanical template and/or dimension and/or color variations, and/or other visual attributes.

~~3.1.27 portable computer: A portable computing device consisting of a processor and various input and output devices, capable of executing software programs on direction, and powered by a battery or by a connection to an external power source.~~

~~3.1.28 portable computing device: A notebook, laptop, tablet computer with processor, memory storage and I/O devices that can be powered either by a battery or by a connection to the utility grid.~~

~~3.1.29 positive temperature coefficient (PTC): A PTC resistor is a component that has the characteristic of a sudden large increase in resistance when the device reaches a specified temperature and/or current.~~

~~3.1.31 reasonable and foreseeable misuse: Use of a product in a way that is not intended by the supplier but may result from reasonable and foreseeable human behavior.~~

~~3.1.32 risk priority number (RPN): A number calculated by multiplying severity, occurrence likelihood, and likelihood of not detecting the fault in an FMEA analysis. The scale is typically 1 through 5, with 5 being highest and 1 being lowest.~~

~~3.1.16 fault: A physical condition that causes a device, a component or an element to fail to perform in the required manner, for example, a short circuit, broken wire and an intermittent connection, or a software error~~

3.2 Other terms

~~3.2.1 may: The word may indicates a course of action permissible with in the limits of the standard. See ISO/IEC Directive Part 2 [B8], Annex G.~~

~~3.2.2 shall: The word shall is used to indicate mandatory requirements strictly to be followed in order to conform to the standard. (The equivalent definition of ISO/IEC Directive Part 2 [B8]: Shall = is to; is required to; it is required that; has to; only...is permitted; it is necessary.)~~

~~3.2.3 should: The word should is used to indicate that among several possibilities one is 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. (The equivalent definition of ISO/IEC Directive Part 2 [B8]: Should = is recommended that; ought to.)~~

4. System integration considerations

4.1 General

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 minimize hazards (as defined in Annex F) from occurring as a result of one ~~and or~~ two independent faults while in intended use, depending on 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 minimize hazards from occurring due to reasonably foreseeable misuse.

Table 1 lists several different design analysis techniques that can be used. Conditions beyond reasonably foreseeable misuse are outside the scope of this standard. While 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 system design safety, 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.

~~analyses methods include the following:~~

- ~~— FMEA~~
- ~~— Fault tree~~
- ~~— Empirical and/or destructive testing~~
- ~~— Reviewing company service records for failure modes and/or trends~~
- ~~— 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~~

Table 1 —Example design analysis tools

Failure mode and effects analysis (FMEA)
Fault tree analysis
Empirical and/or destructive testing
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 1).

~~The following four design analyses shall be developed: Analysis 1 (cell), Analysis 2 (battery pack), Analysis 3 (host device), and Analysis 4 (combined cell, battery pack, and host device working together as a system and including the end user). Analysis 4 shall include interactions between Analyses 1, 2, and 3, as noted in Annex B, Annex C, and Annex D.~~

4.2 Specifications and components

The subsystems shall meet the specifications in Table 2. Table 2 shows minimum subsystem analysis tools including system components and the related specifications.

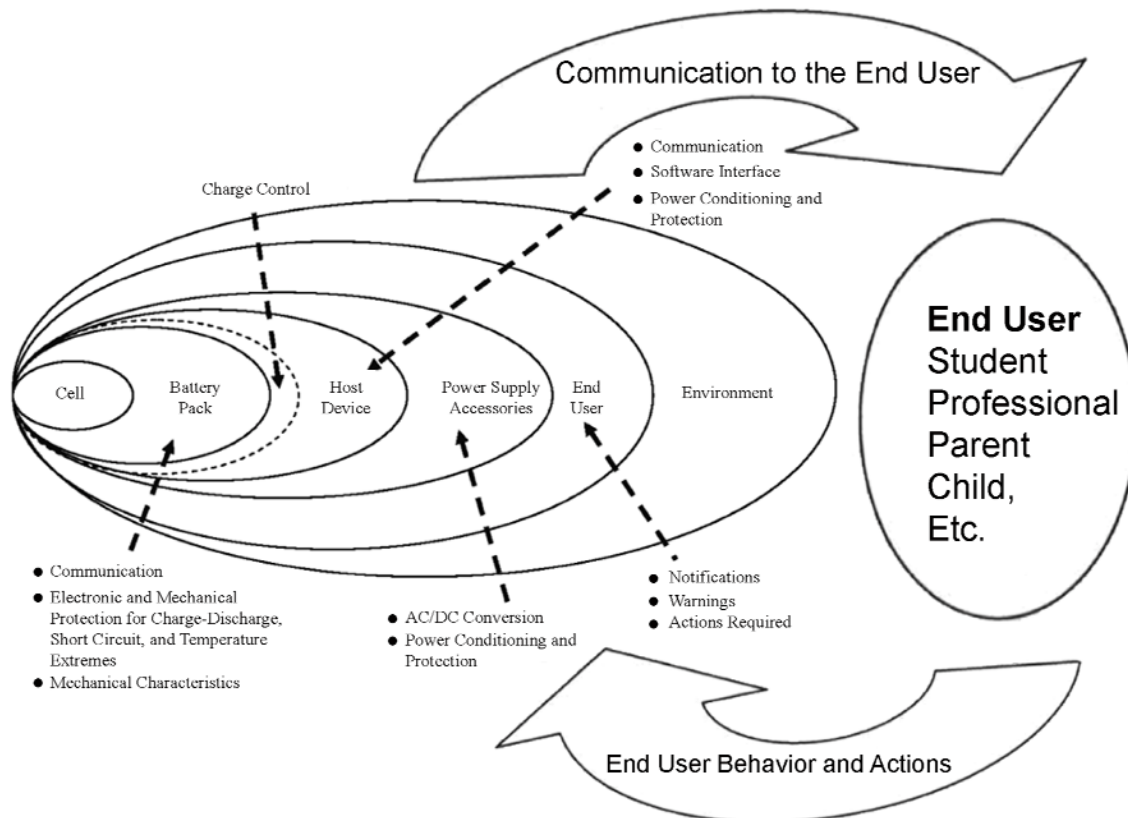


Figure 1 —Conceptual diagram of a mobile computing device and its end user.

Examples of functions for each subsystem component are shown

Table 2 —Minimum subsystem analysis tools11

System component	Specification(s)
AC/DC adaptor or AC/DC charger	IEC 60950-1:2005; or Appropriate safety standard of destination country
DC/DC adaptor or DC/DC charger	Appropriate safety standard of destination country
Battery pack	UN Manual of Tests and Criteria, Part III, Subsection 38.3, Lithium batteries (ST/SG/AC.10/11/Rev.4-2003) UL 2054

Cell	UN Manual of Tests and Criteria, Part III, Subsection 38.3, Lithium batteries (ST/SG/AC.10/11/Rev.4-2003); and Appropriate safety standard of destination country; and Pass all tests defined by UL 1642-2005 for “User replaceable batteries”
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[11 Information on references can be found in Clause 2.](#)

[4.3 Additional specifications](#)

[In addition to the requirements identified in 4.2, subsystems may also be tested to standards shown in Table 3. Table 3 shows example design analysis tools including system components and the related specifications.](#)

[Table 3 —Example design analysis tools](#)

System component	Specification(s)
AC/DC adaptor or AC/DC charger	UL 60950-1 UL 1310 [B30]
DC/DC adaptor or DC/DC charger	UL 2089 [B31]
Battery pack	IEC 62133:2002 IEC 61960 [B16]
Cell	IEC 62133:2002 IEC 61960 [B16]

5. Cell considerations

[5.1 General](#)

[Cell manufacturers/suppliers shall provide cell specifications, incorporating a definition of an Operating region. See Annex E for a template for a Cell specification sheet with minimum content. Cell manufacturers shall define the Operating region of their Li-ion batteries to the pack and system manufacturers. The following describes limits for the Li-ion battery system design; since each chemistry is different, they require varying charging profiles, per specifications. For an example, see Figure 2for an explanation of Operating region \(charging\) in which the upper limit for the charging voltage is 4.250 V for common lithium cobalt oxide/graphite in the Operating region for the following temperatures: 10 °C to45 °C.](#)

[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. Design parameters shall be of the format: limit + tolerance 1/ tolerance 2, or max](#)

limit and min limit, as defined by the cell manufacturer/supplier. For example, if a cell manufacturer/supplier specifies that the voltage of a cell is $4.250\text{ V} + 0.000\text{ V} / - 0.100\text{ V}$, the circuit design shall ensure that this maximum is not exceeded. If the measuring device has a tolerance of $\pm 0.005\text{ V}$, then the circuit shall be designed to operate to $4.245\text{ V} \pm 0.005\text{ V}$, in order not to exceed the maximum. The measurement tolerance should have a 4-sigma confidence.

Figure 3 depicts typical cell construction for cylindrical [part (a) of Figure 3], prismatic [part (b) of Figure 3], pouch prismatic [part (c) of Figure 3], and stacked pouch polymer cells [part (d) of Figure 3].

~~This clause describes the precautions and considerations to include in the analysis of designing, manufacturing, and testing of rechargeable Li-ion and Li-ion polymer cells over their useful life. The objective is to identify the precautions for the cell design to reduce latent problems to a minimum and to increase reliable user experience.~~

~~5.1 Design process~~

~~Critical design factors that require careful attention include aspects of the manufacturing process from mixing of the active materials to the final evaluation for product release.~~

~~5.1.1~~

~~The thickness and choice of material quality of the separator shall prevent electrically conductive material from penetrating separator and causing an internal short.~~

~~5.1.3~~

~~Separator material should ensure internal resistance increases within separator pores (electrical conductivity shutdown) when cell temperature rises above its shutdown point. The shutdown point of the separator should be lower than the temperature where thermal runaway initiates.~~

~~5.1.4~~

~~The width of the separator shall be designed to be wider than either positive or negative electrodes.~~

~~5.1.5~~

~~The electrode and lead wire whose polarity is opposite to that of the cell case should be insulated from the cell case to prevent shorting in the event the cell is subjected to shock and/or vibration.~~

~~5.1.6~~

~~Vent design or mechanism and specifications should be designed to operate within a very close tolerance.~~

~~5.1.6.1~~

~~Vent activation should perform within design specification.~~

~~5.1.6.2~~

~~The vent should operate immediately when pressure increases to design level.~~

~~5.1.6.3~~

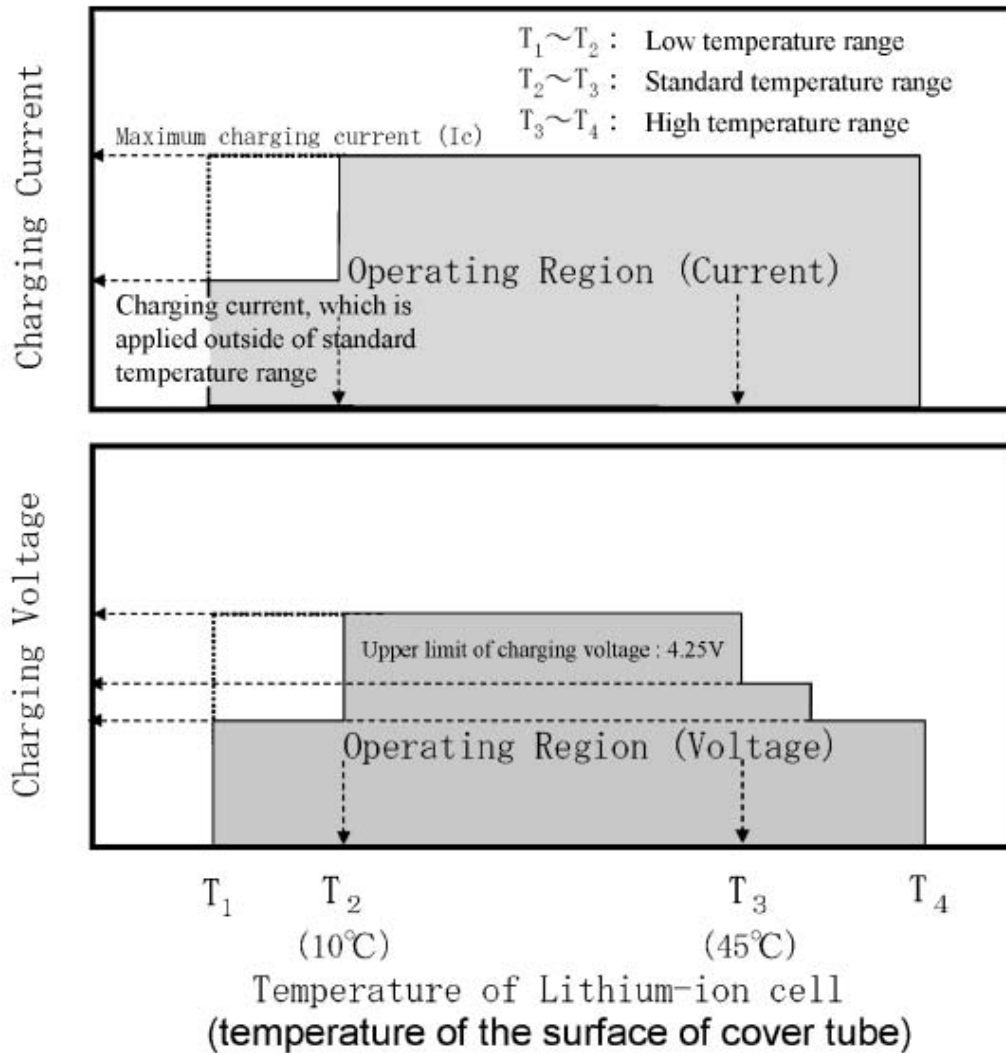
~~The vent should be designed to activate when the cell is exposed to excessive overcharge and other internal pressure stress conditions.~~

~~5.1.7~~

~~The manufacturer/supplier should incorporate an overcurrent protector such as a PTC resistor or other protective device with each cell in the event of external short and overcharge.~~

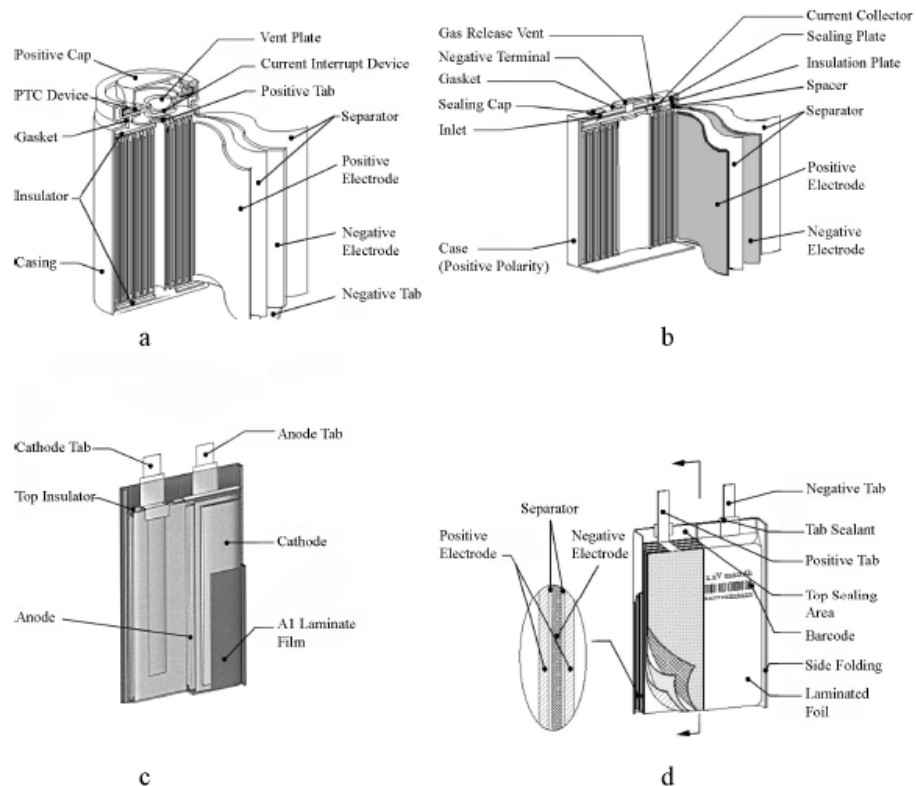
~~5.1.8~~

~~There shall be no damage to the cell container, and critical cell design elements, during welding and other operations. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure control.~~



Reprinted with permission from the Battery Association of Japan, "Guidance for Safe Usage of Portable Lithium-Ion Rechargeable Battery Pack" [B6]. Copyright © 2003.

Figure 2—Example of Operating region (charging)



Part (a) and part (b) are reprinted with permission from the Mobile Energy Company, Sanyo Electric Co., Ltd., *Engineering Handbook of Sanyo's Li-Ion Batteries*.

Part (c) is reprinted with permission from the Sony Corporation. Copyright © 2006.

Part (d) is courtesy of ATL (Amperex Technology Limited).

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

5.2 Design requirements

5.2.1 General

The design process includes definition of nominal cell performance, physical and chemical design parameters, analysis of and mitigation of known and potential faults, characterization of the manufacturing process capability (or specification of processes requirements for the manufacture of a cell), and the initial confirmation of cell performance. The final cell design shall be confirmed. The cell produced shall meet the requirements of the design.

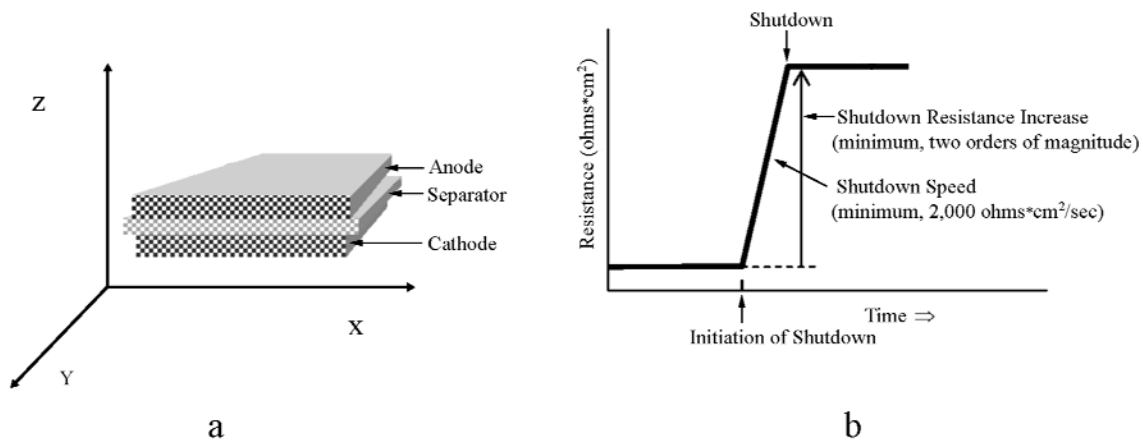
5.2.2.2 Stability

The separator material shall have sufficient chemical, electrochemical, thermal, and mechanical stability to meet every requirement of the cell manufacturer/supplier on safety performance for the product lifetime of the cell, under all normal operating conditions. To ensure that separator materials have the appropriate properties to meet expectations of safety performance, the engineering report and separator selections should be reviewed.

5.2.2.3 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 part (b) of Figure 4. Shutdown performance should be maintained for the life of the cell.



Part (a) has been contributed by John ZHANG of Celgard LLC.

Part (b) is courtesy of Asahi KASEI Chemicals Corporation, Yoshino, et al., The 34th Battery Symposium, Japan, 1993, p. 187. Copyright © 1993.

Figure 4—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

5.2.2.4 Strength and physical integrity

The selection of the thickness of the separator shall be through the design and qualification. The separator material shall provide adequate strength in all directions with the “Z” direction (normal to the electrode plane) being the most important for cell safety performance. For example, see part (a) of Figure 4. The separator shall have sufficient physical integrity to withstand handling during the cell manufacturing process.

An engineering analysis shall be conducted to determine if the separator’s physical strength provides adequate robustness for handling during cell production and adequate cell safety. The cell manufacturer/supplier shall conduct a design analysis that includes one or more of the following: a FMEA, a fault tree analysis, empirical or destructive testing, or a cause-and-effect (fishbone) analysis to mitigate hazards developing from small faults. For example, in the event of an internal cell short puncturing the separator, the separator or cell structure should prevent the separator melting from increasing the conduction area around the fault. As another example, in the separator selection, an analysis or test should be performed to ensure plastic flow and/or thinning will not compromise the reliability of the cell through the life of the product and under extreme conditions.

5.2.2.5 Shrinkage allowance

The area and width of the separator shall take into consideration allowances for certain separator shrinkage characteristics. The separator/cell design shall maintain adequate coverage of electrodes to meet cell safety requirements. The cell manufacturer/supplier shall conduct a design analysis that includes one or more of the following: a FMEA, a fault tree analysis, empirical or destructive

testing, or a cause-and-effect (fishbone) analysis for the separator to consider the allowances to reflect and compensate for a worst case tolerance analysis. This worst case tolerance analysis should prohibit hazards related to shrinkage. Such considerations shall include, but are not limited to, width, alignment, temperature, and any age-related changes in size. For example, the separator should extend beyond the positive electrode and the negative electrode, in all cases.

5.2.3 Electrode design criteria

Electrode design constituents for both the negative electrode (anode) and positive electrode (cathode) shall be designed for performance, safety, and durability in the designated application. The cell manufacturer/supplier shall conduct a design analysis that includes one or more of the following: a FMEA, a fault tree analysis, empirical or destructive testing, or a cause-and-effect (fishbone) analysis for the electrode design criteria that considers allowances to reflect and compensate for a worst case tolerance analysis. Design criteria shall specify material content, purity, and environmental factors, which will enable the electrode material to support the manufacturing process and usage in the end application.

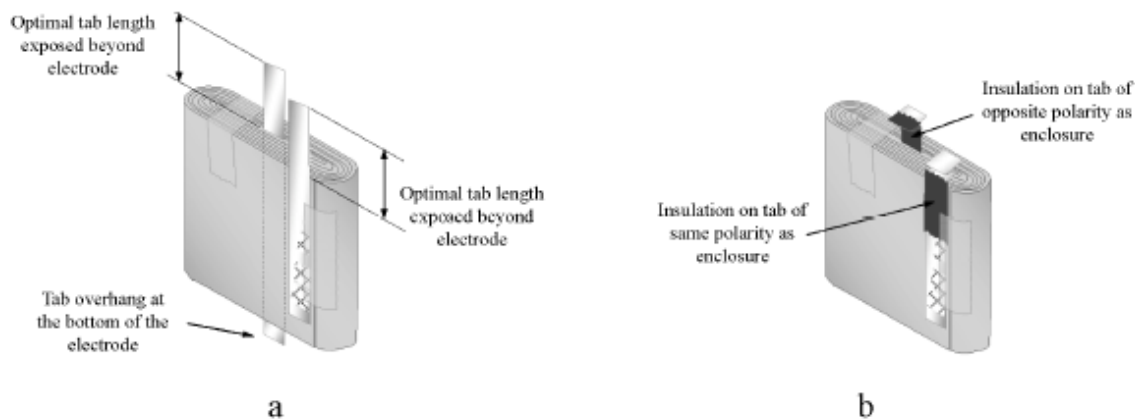
5.2.4 Electrode capacity balance and electrode geometry

The cell design shall ensure that after formation the reversible charge capacity of the negative electrode [Q-reversible (N)] is greater than the reversible charge capacity of the positive electrode [Q-reversible (P)]. Allowance shall be made in the design to maintain the cell balance during the useful life of the cell, regardless of cell geometry and cell charge conditions (temperature, current density, etc.).

The active area of the negative electrode shall completely cover the active areas of the positive electrode. The electrode design shall maintain adequate coverage to meet cell reliability requirements. The cell manufacturer/supplier shall conduct a design analysis that includes one or more of the following: a FMEA, a fault tree analysis, empirical or destructive testing, or a cause-and-effect (fishbone) analysis for the electrode capacity balance and electrode geometry that considers allowances to reflect and compensate for a worst case tolerance analysis. This worst case tolerance analysis should prohibit hazards related to overlap. Such considerations shall include, but are not limited to, width, alignment, temperature, and any age-related changes in size.

5.2.5 Electrode tabs (connection to cell terminals)

The manufacturer/supplier shall establish optimal tab length exposed beyond the electrode for each cell and control to specific tolerance. Tabs shall not overhang the opposite end of the electrodes, except by design. Part (a) of Figure 5 illustrates this principle.



Source: IEEE Std 1725™-2006 [B18].

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

[5.2.6 Tab insulation](#)

[5.2.6.1 Application of insulation](#)

The tab that has the opposite polarity of 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 part (b) of Figure 5. 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.

[5.2.6.2 Insulation adherence](#)

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

[5.2.6.3 Insulation characteristics](#)

Insulation material shall have electrochemical, chemical, mechanical, electrical, and thermal stability over the temperature range of use, storage, and transportation as specified by the cell manufacturer.

[5.2.7 Cell vent mechanism](#)

[5.2.7.1 General](#)

Cell designs shall include a reliable vent mechanism, such as a seam, a score, etc. Appropriate engineering analysis and qualification shall be conducted during the design and prototype phases of cell development. The vent should open at a pressure that is significantly lower than that at which the cell case fails. Pouch cells do not have a physical vent; therefore, this subclause does not apply to pouch cells.

[5.2.7.2 Retention of cell contents](#)

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

5.2.7.3 Projectile testing

The cells shall pass the projectile test of UL 1642-2005.

5.2.8 Overcurrent protection device

The manufacturer/supplier may employ an overcurrent protector [such as a positive temperature coefficient (PTC) 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 are qualified per this standard using a PTC resistor or other protective measure, it shall be included in the cells used in the battery pack design and the manufacturer's qualification of the PTC devices or other protective measure(s) will be done to ensure that the device will operate as intended.

5.2.9 Overvoltage protection

The cell manufacturer shall provide the recommended current to the cell and the upper-limit voltage to the cell, for the appropriate cell overvoltage protection function, at specified temperatures during charge.

~~5.2 General manufacturing considerations~~

~~5.2.1~~

~~Critical material for cell production shall have detailed specifications and shall have an incoming material quality control plan to ensure conformance to specification. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure control.~~

~~5.2.2~~

~~All known and possible undesirable impurities in materials should be identified, specified, minimized, and controlled.~~

~~5.2.3~~

~~The appropriate electrode substrate material for the positive electrode and negative electrode shall be specified and verified by analysis. Use manufacturer/supplier's specifications or documentation to ensure control this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure control.~~

~~5.2.4~~

~~Coating and thickness electrodes for the positive electrode and negative electrode shall be controlled to provide uniform thickness within tolerance set by cell specification. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure~~

~~5.2.5~~

~~Burrs on any cut (slit) side of the electrodes or tab materials shall not exceed limits specified by manufacturer/supplier. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure control.~~

~~5.2.6~~

~~Wrinkling, tearing, and/or deformation of the electrodes should be prevented and eliminated.~~

5.3 General manufacturing considerations

5.3.1 General

Verification of the proper operation of each critical machine used in the manufacturing process shall be performed at least once per shift. If a change is detected, a root cause analysis shall be conducted to identify the cause for the change and corrective action shall be taken to prevent future occurrences.

5.3.2 Materials specifications

Materials specifications shall be developed to identify and limit impurities to levels below critical limits, as specified by the cell manufacturer.

~~New cell designs shall pass specified tests which the manufacturer/supplier decided according to the contents of design change before qualification as production cells. Use manufacturer /supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure control~~

5.3.3 Impurity avoidance

All known and likely undesirable impurities in materials should be identified, specified, minimized, and controlled throughout the manufacturing process.

5.3.4 Cleanliness of manufacturing operations

The temperature range, humidity, and dust levels shall be specified, controlled, and monitored in the manufacturing environment. 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.

5.3.5 Manufacturing traceability

The cell manufacturing process shall implement a cell traceability plan. This plan should include a traceability mark that is likely to survive an exothermic reaction during product lifetime and after production to determine lot designation and performance data related to the cell. Use manufacturer/supplier specifications or documentation to ensure control of this criterion or process. The traceability plan should enable identification of all materials and machinery used in cell assembly. It should enable tracking of all items, including equipment maintenance, which could potentially affect the behavior of the cell produced. Follow documentation requirements consistent with 11.2.

5.3.6 Electrode production process

5.3.6.1 Uniform coating of active materials

Coating density, thickness, and surface roughness (that is, peaks, bumps, and irregularities) of the positive and negative electrodes shall be controlled within the tolerance documented in the manufacturer's specification. The criterion defined in 5.2.4 shall be met in the worst case tolerance. Follow documentation requirements consistent with 11.2.

5.3.6.2 Burr control

The manufacturer shall have an effective method to prevent internal short circuit by burr. Figure 6 shows the schematic cross section of Li-ion cell element to demonstrate the possible occurrences of burr near the electrode edges. Burrs shall not contact any conductive portion of the opposite

polarity electrode. In case there is no appropriate burr penetration prevention method in the design (such as the insulation taping at the uncoated foil), each cutting point shall be examined and burr height measured at each shift or lot. Burr height shall be measured and shall not exceed 50% of the lower tolerance limits of the thickness of the separator thickness. In the case of a burr height greater than 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. Burr on electrodes shall be measured once per day at a minimum. Follow documentation requirements consistent with 11.2.

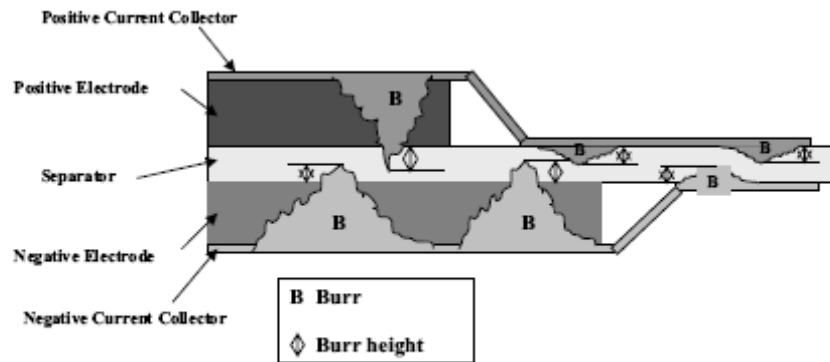


Figure 6—Li-ion cell element cross section showing burr height

5.3.7 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.

5.3.8 Characteristics of manufacturing equipment

The manufacturing equipment should be designed to prevent any damage or modifications to the cell during manufacturing operations. In-process quality controls shall be implemented to ensure consistent operation of the manufacturing equipment. Follow documentation requirements consistent with 11.2.

5.3.9 Defective electrodes

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

5.3.10 Preventive maintenance plan

Manufacturers shall maintain an effective preventive maintenance plan (including, for example, replacement of cutting knife for slitting electrodes) for all equipment used in the manufacturing processes. Follow documentation requirements consistent with 11.2.

5.3.11 Periodic cell teardown analysis

Cell teardown analysis shall be conducted at least once per machine per shift.

~~5.3 Spiral winding process~~

~~5.3.1~~

~~The position of negative and positive tabs shall be staggered so they do not overlap each other. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure control.~~

~~5.3.2~~

~~The external dimensions of the electrode core, which was spirally wound with the separator, shall be adjusted to maintain appropriate value. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO 9001) to ensure control.~~

~~5.3.3~~

~~The winding tension of the electrode and separator during the winding process shall be properly adjusted to keep in design range and optimized to fit into the cell container. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process. Establish a verification process (e.g., ISO9001) to ensure control.~~

~~5.3.4~~

~~To prevent damage to or telescoping of the wound electrodes, the winding spindle removal mechanism should be controlled, or a means to verify winding deviation has not occurred during removal of winding stick shall be incorporated.~~

5.4 Spiral winding and stacking process

5.4.1 General

All processes referenced in this subclause apply to assembly of the cell core by spirally wound jelly roll and/or other electrode separator combinations.

5.4.2 Care during winding and stacking

5.4.2.1 Tension and damage

The manufacturer/supplier shall use care during winding and/or stacking to avoid excessive tension and damage (twisting, bending, etc.) to the electrodes and the generation of loose particles.

5.4.2.2 Collection of loose material

The manufacturer shall have an effective method to collect all loose material produced in various manufacturing processes or steps. Methods may include vacuum, magnetic, sticky tapes, etc.

5.4.2.3 Detection of damaged cores

The manufacturer shall have a method to detect nonconforming cell cores. Methods may include high-voltage dielectric test (high-pot), voltage test, resistance/impedance test, and/or aging. A vision system, such as x-ray check, shall be used to ensure electrode integrity at an appropriate point in the assembly process.

5.4.3 Control of electrode spacing

The external dimensions of the cell core shall be adjusted to maintain uniform compression, dimensional characteristics, and 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/supplier

specifications or documentation to ensure control of this criterion or process. Follow documentation requirements consistent with 11.2.

5.4.4 Uniformity of winding pressure (to core) or stacking pressure (to stack)

The cell core assembly process shall be properly adjusted to remain in the specified range to maintain uniform tension, compression, 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/supplier specifications or documentation to ensure control of this criterion or process. Follow documentation requirements consistent with 11.2.

5.4.5 Avoidance of contaminants

The winding process shall prevent introduction of contaminants from the winding process (dust, flakes from electrodes) into the cell. The manufacturer shall prevent introduction of contaminants from the preparation of materials for core or stack including electrode and separator and can or case, as well as through all processes including winding/stacking process to sealing of the cell cap.

~~5.4.1~~

~~The introduction of metal contamination from equipment or process should be prevented.~~

~~5.4.2~~

~~The method of assembly for insulating material, whether for electrode, current collectors, or internal insulation, should provide reliable protection against latent shorts for the functional life of the product.~~

~~5.4.3~~

~~The positions of lead tabs in the cell should be verified and not be overlapping.~~

~~5.4.4~~

~~The integrity of wound electrodes should be verified through resistance or a continuity check or equivalent means~~

~~5.4.5~~

~~If the cell has insulating plates, the insulating plates shall be securely positioned. Use manufacturer/supplier's specifications or documentation to ensure control of this criteria or process.~~

~~5.4.6~~

~~A permeable X-ray may be used to inspect the cell structure for correct assembly, especially during the preliminary production setup.~~

~~5.4.7~~

~~OCV and/or impedance or other appropriate testing should be taken after critical steps in the manufacturing process where contamination could be introduced.~~

~~5.4.8~~

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

~~process. Establish a verification process (e.g., ISO 9001) to ensure control.~~

~~5.4.9~~

~~Manufacturer/supplier should develop and apply appropriate cell aging, grading, and/or sorting criteria for post assembly screening of cells.~~

5.5 Assembly precautions

5.5.1 Internal short avoidance

The method of assembly for insulating material, whether for electrode, current collectors, or internal insulation, shall provide reliable protection against latent shorts for the product lifetime of the cell. The manufacturer shall provide a method to avoid a short where the bare aluminum foil interfaces with the negative electrode, if it could cause a hazard.

5.5.2 Tab positioning

5.5.2.1 General

The position of negative and positive tabs shall be staggered so that they do not overlap each other. Follow documentation requirements consistent with 11.2.

The assembly process shall prevent deforming tab shapes in a manner that can create jelly roll 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 jelly roll and can walls. Tabs positioning to the electrode stack specification should be confirmed by vision system inspection.

5.5.2.2 Integrity of cell core/stack

The integrity of wound or stacked electrodes shall be verified through resistance or a continuity check or equivalent means.

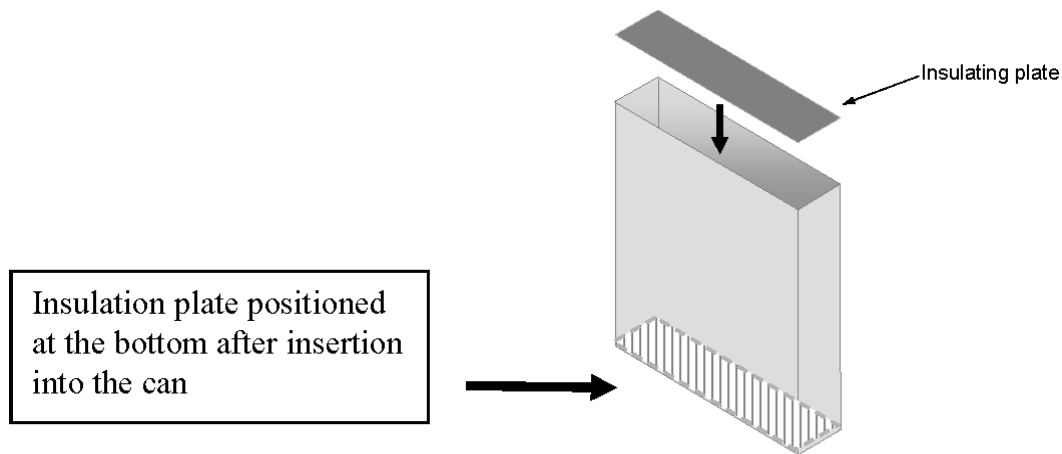
5.5.3 Positioning of insulating plate

If the cell has insulating plates, the insulating plates shall be properly positioned as shown in Figure 7. Insulating material shall be readily visible and should be checked to specification with resistive measurement or other technological means or methods. Use manufacturer/supplier specifications or documentation to ensure control of this criterion or process.

5.5.4 Electrode alignment

The proper alignment of positive and negative electrodes is critical to prevent hazards. The manufacturer/supplier shall ensure the accuracy of electrode placement through in-cell design and in-machine operation to prevent electrode misalignment. The manufacture/supplier shall ensure that the active material of the positive electrode is aligned and covered by the active material of the negative electrode.

The manufacture/supplier shall conduct 100% inspection by a vision system to ensure alignment. Follow documentation requirements consistent with 11.2.



Source: IEEE Std 1725-2006 [B18].

Figure 7 —Positioning of the insulating plate in the bottom of the can to prevent internal shorting to the can

5.5.5 Cell aging and screening

The manufacturer/supplier shall develop and apply appropriate cell aging and screening process. The formation of the cell is one of the most important functions of aging. The other function is the sorting. The sorting criterion shall identify and eliminate early failures.

5.5.6 Qualification of aging process by supplier

5.5.6.1 General

The purpose of this subclause is to provide a method to qualify the effectiveness of the aging test for a cell design. The method is intended to be independent of details of the specifics of a manufacturer's aging test defined in 5.5.5.

5.5.6.2 Aging qualification test

The manufacturer shall have an aging qualification process and test.

The manufacturer shall subject a statistically significant number of cells of a given type to the manufacturer's normal aging process. Those cells that pass shall then be subjected to a sequential series of the manufacturer's aging process to evaluate the effectiveness of the aging process to identify and eliminate early failures.

5.5.6.2.1 Aging qualification testing by the cell manufacturer

The following method is an example that may be used to qualify the aging process:

- a) The cells shall be subjected to the initial defined aging process of 5.5.5.
- b) The manufacturer's method to identify rejected cells shall be used. The rejected cells shall be identified and tracked through the remainder of the qualification process. At the manufacturer's discretion, the rejected cells may be removed from further testing.
- c) The cells shall be subjected to the defined aging process of 5.5.5.