



JOINT CANADA-UNITED STATES  
NATIONAL STANDARD

# STANDARD FOR SAFETY

## ANSI/CAN/UL-1973:2018, Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications



ANSI/UL 1973-2018



Standards Council of Canada  
Conseil canadien des normes

UL COPYRIGHTED MATERIAL –

NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL



Documents

Document Sharing Hub

## SCC FOREWORD

### National Standard of Canada

A National Standard of Canada is a standard developed by a Standards Council of Canada (SCC) accredited Standards Development Organization, in compliance with requirements and guidance set out by SCC. More information on National Standards of Canada can be found at [www.scc.ca](http://www.scc.ca).

SCC is a Crown corporation within the portfolio of Innovation, Science and Economic Development (ISED) Canada. With the goal of enhancing Canada's economic competitiveness and social well-being, SCC leads and facilitates the development and use of national and international standards. SCC also coordinates Canadian participation in standards development, and identifies strategies to advance Canadian standardization efforts.

Accreditation services are provided by SCC to various customers, including product certifiers, testing laboratories, and standards development organizations. A list of SCC programs and accredited bodies is publicly available at [www.scc.ca](http://www.scc.ca).

UL Standard for Safety for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications, UL 1973

Second Edition, Dated February 7, 2018

### **Summary of Topics**

***The Second Edition of UL 1973 has been issued to reflect the latest ANSI and SCC approval dates, and to incorporate the proposals dated June 30, 2017 and October 6, 2017. Please note that the standard title has changed from the Standard for Batteries for Use in Light Electric Vehicle (LER) Applications and Stationary Applications to the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications.***

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated June 30, 2017 and October 6, 2017.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form by any means, electronic, mechanical photocopying, recording, or otherwise without prior permission of UL.

UL provides this Standard "as is" without warranty of any kind, either expressed or implied, including but not limited to, the implied warranties of merchantability or fitness for any purpose.

In no event will UL be liable for any special, incidental, consequential, indirect or similar damages, including loss of profits, lost savings, loss of data, or any other damages arising out of the use of or the inability to use this Standard, even if UL or an authorized UL representative has been advised of the possibility of such damage. In no event shall UL's liability for any damage ever exceed the price paid for this Standard, regardless of the form of the claim.

Users of the electronic versions of UL's Standards for Safety agree to defend, indemnify, and hold UL harmless from and against any loss, expense, liability, damage, claim, or judgment (including reasonable attorney's fees) resulting from any error or deviation introduced while purchaser is storing an electronic Standard on the purchaser's computer system.

No Text on This Page

*UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL*



**Documents**

Document Sharing Hub



ANSI/UL 1973-2018



FEBRUARY 7, 2018

1

UL 1973

**Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and  
Light Electric Rail (LER) Applications**

The title of the First Edition of UL 1973 was the Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications.

First Edition February, 2013

**Second Edition**

**February 7, 2018**

This ANSI/CAN/UL Safety Standard consists of the Second Edition.

The most recent designation of ANSI/UL 1973 as an American National Standard (ANSI) occurred on February 7, 2018. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been approved as a National Standard of Canada (NSC) by the Standards Council of Canada (SCC).

**COPYRIGHT © 2018 UNDERWRITERS LABORATORIES INC.**

**UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL**



**Documents**

Document Sharing Hub

No Text on This Page

**UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL**



**Documents**

Document Sharing Hub

## CONTENTS

|                    |   |
|--------------------|---|
| Preface (UL) ..... | 7 |
|--------------------|---|

## INTRODUCTION

|                              |    |
|------------------------------|----|
| 1 Scope .....                | 10 |
| 2 Components .....           | 12 |
| 3 Units of Measurement ..... | 12 |
| 4 Undated References .....   | 12 |
| 5 Normative References ..... | 12 |
| 6 Glossary .....             | 16 |

## CONSTRUCTION

|                                                                        |    |
|------------------------------------------------------------------------|----|
| 7 General .....                                                        | 22 |
| 7.1 Non-metallic materials .....                                       | 22 |
| 7.2 Metallic parts resistance to corrosion .....                       | 23 |
| 7.3 Enclosures .....                                                   | 23 |
| 7.4 Wiring and terminals .....                                         | 24 |
| 7.5 Spacings and separation of circuits .....                          | 26 |
| 7.6 Insulation levels and protective grounding and bonding .....       | 27 |
| 7.7 System safety analysis .....                                       | 29 |
| 7.8 Protective circuit and controls .....                              | 30 |
| 7.9 Cooling/thermal management system .....                            | 31 |
| 7.10 Electrolyte containment parts and parts subject to pressure ..... | 32 |
| 7.11 Cells (battery and electrochemical capacitor) .....               | 33 |

## PERFORMANCE

|                                                    |    |
|----------------------------------------------------|----|
| 8 General .....                                    | 34 |
| 9 Determination of Potential for Fire Hazard ..... | 36 |
| 10 Important Test Considerations .....             | 36 |
| 11 Single Fault Conditions .....                   | 37 |
| 12 Test Results .....                              | 37 |
| 13 Determination of Toxic Emissions .....          | 39 |
| 14 Measurement Equipment Accuracy .....            | 39 |

## ELECTRICAL TESTS

|                                                                                   |    |
|-----------------------------------------------------------------------------------|----|
| 15 Overcharge Test .....                                                          | 40 |
| 16 Short Circuit Test .....                                                       | 41 |
| 17 Overdischarge Protection Test .....                                            | 43 |
| 18 Temperature and Operating Limits Check Test .....                              | 44 |
| 19 Imbalanced Charging Test .....                                                 | 46 |
| 20 Dielectric Voltage Withstand Test .....                                        | 47 |
| 21 Continuity Test .....                                                          | 48 |
| 22 Failure of Cooling/Thermal Stability System .....                              | 49 |
| 23 Working Voltage Measurements .....                                             | 50 |
| 24 Tests on Electrical Components .....                                           | 50 |
| 24.1 Locked-rotor test for low voltage dc fans/motors in secondary circuits ..... | 50 |
| 24.2 Input .....                                                                  | 51 |

|                                  |    |
|----------------------------------|----|
| 24.3 Leakage current .....       | 51 |
| 24.4 Strain relief test .....    | 51 |
| 24.5 Push-back relief test ..... | 52 |

## MECHANICAL TESTS

|                                                   |    |
|---------------------------------------------------|----|
| 25 Vibration Test (LER Motive Applications) ..... | 52 |
| 26 Shock Test (LER Motive Applications) .....     | 53 |
| 27 Crush Test (LER Motive Applications) .....     | 55 |
| 28 Static Force Test .....                        | 56 |
| 29 Impact Test .....                              | 57 |
| 30 Drop Impact Test .....                         | 59 |
| 31 Wall Mount Fixture/Handle Test .....           | 60 |
| 32 Mold Stress Test .....                         | 61 |
| 33 Pressure Release Test .....                    | 61 |
| 34 Start-To-Discharge Test .....                  | 61 |

## ENVIRONMENTAL TESTS

|                                                         |    |
|---------------------------------------------------------|----|
| 35 Thermal Cycling Test (LER Motive Applications) ..... | 62 |
| 36 Resistance to Moisture Test .....                    | 63 |
| 37 Salt Fog Test .....                                  | 64 |
| 38 External Fire Exposure Test .....                    | 65 |

## TOLERANCE TO INTERNAL CELL FAILURE TESTS

|                                                                      |    |
|----------------------------------------------------------------------|----|
| 39 Single Cell Failure Design Tolerance .....                        | 67 |
| 39.1 General .....                                                   | 67 |
| 39.2 Single cell failure design tolerance (lithium ion) .....        | 67 |
| 39.3 Single cell failure design tolerance (other technologies) ..... | 69 |

## MANUFACTURING AND PRODUCTION LINE TESTS

|                  |    |
|------------------|----|
| 40 General ..... | 70 |
|------------------|----|

## MARKINGS

|                  |    |
|------------------|----|
| 41 General ..... | 71 |
|------------------|----|

## INSTRUCTIONS

|                  |    |
|------------------|----|
| 42 General ..... | 72 |
|------------------|----|

## APPENDIX A (Normative)

|                                   |    |
|-----------------------------------|----|
| A1 Standards for Components ..... | A1 |
|-----------------------------------|----|

## APPENDIX B (Normative)

### Test program for sodium-beta battery cells

UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM  **Documents**  
Document Sharing Hub

|                          |    |
|--------------------------|----|
| B1 General .....         | B1 |
| B2 Cell Tests .....      | B1 |
| B2.1 Electrical .....    | B1 |
| B2.2 Mechanical .....    | B2 |
| B2.3 Environmental ..... | B3 |

## APPENDIX C (Normative)

### Test program for flowing electrolyte batteries

|                                                                                     |    |
|-------------------------------------------------------------------------------------|----|
| C1 General .....                                                                    | C1 |
| C2 Materials Containing Electrolyte – Resistance to Deterioration from Fluids ..... | C1 |
| C3 Materials Containing Electrolyte – Temperature Exposure .....                    | C2 |
| C4 Flowing Electrolyte Cell Stack Tests .....                                       | C2 |
| C4.1 Vibration of cell stack .....                                                  | C2 |
| C4.2 Shock test on cell stack .....                                                 | C3 |
| C4.3 High temperature test on cell stack .....                                      | C3 |
| C4.4 Short circuit test on cell stack .....                                         | C3 |
| C5 Flowing Electrolyte Battery System Tests .....                                   | C4 |
| C5.1 Hydraulic pressure test .....                                                  | C4 |
| C5.2 Leakage test .....                                                             | C4 |
| C5.3 Electrolyte blockage tests .....                                               | C5 |
| C5.4 Short circuit test .....                                                       | C5 |
| C5.5 Shunt current determination .....                                              | C5 |
| C5.6 Failure of the cooling/thermal stability system test .....                     | C6 |
| C6 Spill Containment Systems .....                                                  | C6 |

## APPENDIX D (Normative)

### Metal compatibility table

## APPENDIX E (Normative)

### Alternative Cell Test Program

|                           |    |
|---------------------------|----|
| E1 General .....          | E1 |
| E2 Short Circuit .....    | E1 |
| E3 Cell Impact .....      | E2 |
| E4 Drop Impact .....      | E2 |
| E5 Heating .....          | E2 |
| E6 Overcharge .....       | E2 |
| E7 Forced Discharge ..... | E3 |
| E8 Projectile .....       | E3 |

UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL



**Documents**

Document Sharing Hub

APPENDIX F (Informative)

Cell Failure Methods

F1 General .....F1

F2 Replicating Internal Cell Failures through Internal Defects .....F2

    F2.1 Single cell conductive contamination .....F2

    F2.2 Single cell separator defect .....F2

    F2.3 Internal heater application .....F2

F3 Replicating Internal Cell Failures Through Application of External Stress .....F2

    F3.1 External heater application .....F2

    F3.2 External indentation without casing/surface penetration .....F3

    F3.3 Nail penetration through cell casing .....F4

    F3.4 Single cell short circuit .....F5

    F3.5 Single cell overcharge .....F5

APPENDIX G (Informative)

Safety Marking Translations

## Preface (UL)

This is the Second Edition of the ANSI/CAN/UL 1973 Standard for Safety for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications.

UL is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL 1973 Standard for Safety is under continuous maintenance, whereby each revision is ANSI/CAN approved upon publication. If no revisions occur, the initiation of the review of this Standard will commence within 5 years of the date of publication.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at <http://csds.ul.com>.

UL's Standards for Safety are copyrighted by UL. Neither a printed nor electronic copy of a Standard should be altered in any way. All of UL's Standards and all copyrights, ownerships, and rights regarding those Standards shall remain the sole and exclusive property of UL.

To purchase UL Standards, visit the UL Standards Sales Site at <http://www.shopulstandards.com/HowToOrder.aspx> or call tollfree 1-888-853-3503.

This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Batteries Used in Stationary and in Light Electric Rail Applications, STP 1973.

This list represents the STP 1973 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

### STP 1973 Membership

| Name                 | Representing                                       | Interest Category                | Region                   |
|----------------------|----------------------------------------------------|----------------------------------|--------------------------|
| Abbassi, Mathher     | NYC Department of Buildings                        | AHJ                              | USA                      |
| Barnable, Brian      | BMO Financial Group                                | Commercial/Industrial User       | Ontario, Canada          |
| Byczek, Rich         | Intertek                                           | Testing and Standards            | USA                      |
| Chatwin, Troy        | General Electric                                   | Producer                         | USA                      |
| De Lucia, Thomas     | NEC Energy Solutions                               | Producer                         | USA                      |
| Dong, Jiaqi          | Shanghai Truron Testing Technology                 | Testing and Standards            | China                    |
| Florence, Laurie     | UL LLC                                             | Testing and Standards            | USA                      |
| Ginder, David        | Saft Batteries                                     | Producer                         | USA                      |
| Greiner, Michael     | MGA Research                                       | Testing and Standards            | USA                      |
| Haer, Jason          | Tesla Motors, Inc.                                 | Producer                         | USA                      |
| Hoemsen, Ray         | Red River College                                  | General                          | Manitoba, Canada         |
| Jackson, Pete        | City of Bakersfield                                | AHJ                              | USA                      |
| Jordan, Diana Pappas | Underwriters Laboratories Inc.                     | STP Chair – Non-voting           | USA                      |
| Lechner, Larry       | E-One Moli Energy (Canada) Ltd                     | Producer                         | British Columbia, Canada |
| McKean, Colin        | Candian Battery Association                        | General                          | Ontario, Canada          |
| Mutyala, Neilesh     | Seeo, Inc.                                         | Producer                         | USA                      |
| Okafor, Chukwuemeka  | American Electric Power                            | Commercial/Industrial User       | USA                      |
| Rogers, James        | Bay State Inspectional Agency                      | AHJ                              | USA                      |
| Ryu, ShinHwan        | TUV Rheinland Korea                                | Testing and Standards            | Korea                    |
| Saakian, Tamara      | FDNY                                               | Non-voting                       | USA                      |
| Savage, Michael      | City of Rio Rancho                                 | AHJ                              | USA                      |
| Savinell, Robert     | Case Western Reserve University                    | General                          | USA                      |
| Szymczyk, Rick       | eCamion                                            | Producer                         | Ontario, Canada          |
| Thompson, Gary       | Toronto Hydro                                      | Commercial/Industrial User       | Ontario, Canada          |
| VanHeirsele, Megan   | Underwriters Laboratories Inc.                     | STP Project Manager – Non-voting | USA                      |
| Wages, Joseph        | International Association of Electrical Inspectors | AHJ                              | USA                      |
| Wang, Jordano        | Extech Electronics Co., Ltd.                       | Testing and Standards            | Taiwan                   |
| Warner, Nick         | DNV GL                                             | Testing and Standards            | USA                      |
| Wills, Robert        | Integrid, LLC                                      | General                          | USA                      |

International Classification for Standards (ICS): 29.220

For further information on UL standards, please contact:

Underwriters Laboratories Inc.  
171 Nepean Street, Suite 400  
Ottawa, Ontario K2P 0B4  
Phone: 1-613.755.2729  
E-mail: customerservice@ulc.ca  
Web site: ul.com

This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE.

*UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL*



**Documents**

Document Sharing Hub

## INTRODUCTION

### 1 Scope

1.1 These requirements cover battery systems as defined by this standard for use as energy storage for stationary applications such as for PV, wind turbine storage or for UPS, etc. applications. These systems shall be installed in accordance with NFPA 70, C22.1, or other applicable installation codes.

1.2 These requirements also cover battery systems as defined by this standard for use in light electric rail (LER) applications and stationary rail applications such as rail substations. These systems are intended for installation within either the rail car or within a sheltered stationary location such as a rail substation. These battery systems may utilize regenerative braking from the trains as a source of energy for recharging and are intended for direct or indirect connection to the rail power lines. These battery systems are intended for balancing loads during peak hours, serving as an energy storage device during regenerative braking of the trains, and as a source of emergency power to move trains to the nearest station during power outages.

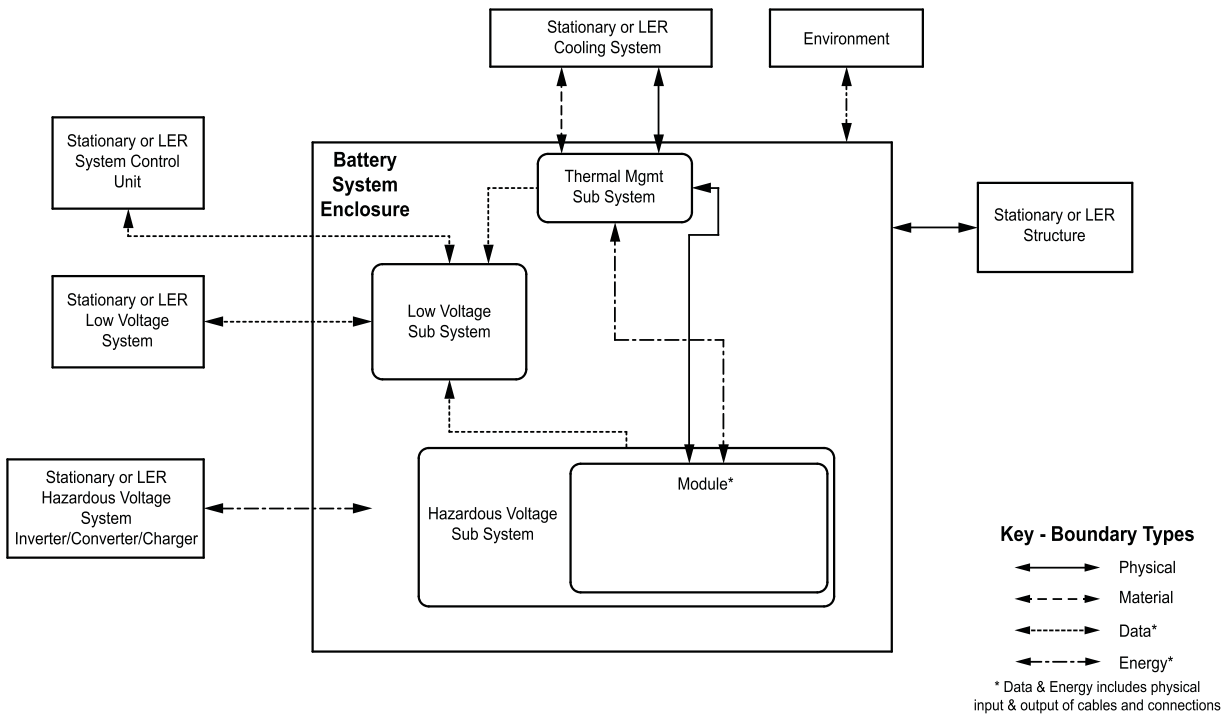
1.3 Appendix B of this standard includes requirements specific to sodium-beta type technologies. Appendix C of this standard includes requirements specific to flowing electrolyte technologies.

1.4 This standard evaluates the battery system's ability to safely withstand simulated abuse conditions. This standard evaluates the system based upon the manufacturer's specified charge and discharge parameters.

1.5 This standard does not evaluate the performance (i.e. capacity measurements under various discharge conditions) or reliability (i.e. capacity measurements under various environmental conditions) of these devices.

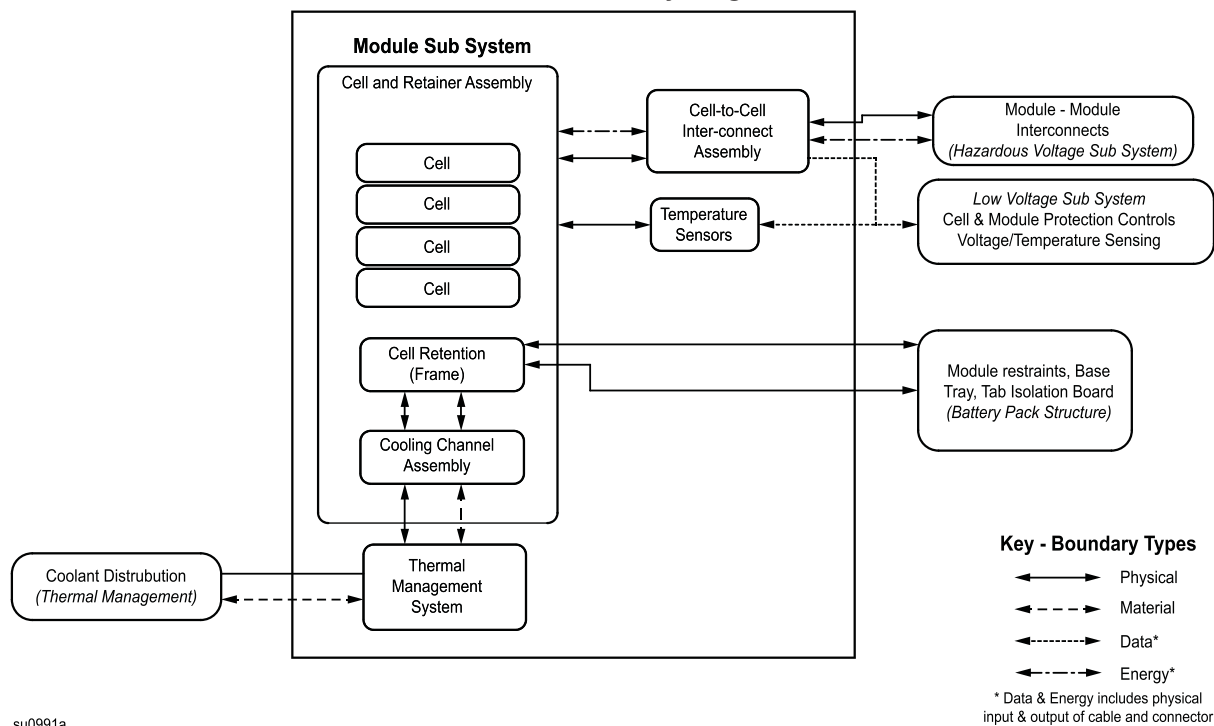
1.6 Figure 1.1 is a boundary diagram example for a battery system for this application. Figure 1.2 is a boundary diagram example for a module for this application.

**Figure 1.1**  
**Components of a battery system**



su0992e

**Figure 1.2**  
**Module – boundary diagram**



su0991a

UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM



**Documents**  
Document Sharing Hub

## 2 Components

2.1 A component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard. A component shall comply with the CSA, UL, and/or ULC standards as appropriate for the country where the product is to be used.

## 3 Units of Measurement

3.1 Values and their respective units of measurement that are stated without parentheses constitute the requirement of the standard and those in parentheses constitute explanatory or approximate information.

## 4 Undated References

4.1 Any undated reference appearing in the requirements of this standard shall be interpreted as referring to the latest edition of the reference, including all revisions and amendments.

## 5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance. Battery systems covered by this standard shall comply with the referenced installation codes and standards as appropriate for the country where the battery system is to be used. When the battery system is intended for use in more than one country, the battery system shall comply with the installation codes and standards for all countries where it is intended to be used.

### American Society of Mechanical Engineers (ASME) Codes

ASME B31.3  
*Process Piping Code*

ASME BPVC  
*Boiler and Pressure Vessel Code*

### American Society for Testing and Materials (ASTM) Standards

ASMT D543  
*Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents*

ASTM D638  
*Standard Test Method for Tensile Properties of Plastics*

ASTM D4490  
*Standard Practice for Measuring the Concentration of Toxic Gases or Vapors Using Detector Tubes*

ASTM D4599  
*Standard Practice for Measuring the Concentration of Toxic Gases or Vapors Using Length-of-Stain Dosimeters*

### CSA Group Standards

C22.1  
*Canadian Electrical Code, Part I Safety Standard for Electrical Installations*

CAN/CSA-C22.2 No. 0  
*General Requirements – Canadian Electrical Code, Part II*

C22.2 No. 0.15  
*Adhesive Labels*

CAN/CSA-C22.2 No. 0.17  
*Evaluation of Properties of Polymeric Materials*

CAN/CSA-C22.2 No. 0.2  
*Insulation Coordination*

C22.2 No. 94.2  
*Enclosures for Electrical Equipment, Environmental Considerations*

C22.2 No. 113  
*Fans and Ventilators*

CAN/CSA-C22.2 No. 60950-1  
*Information Technology Equipment – Safety – Part 1: General Requirement*

CAN/CSA-E60730-1  
*Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements*

CAN/CSA-C22.2 No. 62368-1  
*Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

#### **International Electrotechnical Commission (IEC) Standards**

IEC 60068-2-52  
*Environmental Testing Part 2: Tests – Tests Kb, Salt Mist, Cyclic (Sodium Chloride Solution)*

IEC 60068-2-64  
*Environmental Testing – Part 2-64: Tests – Test Fh: Vibration, Broadband Random and Guidance*

IEC 60417 Database  
*Graphical Symbols for Use on Equipment*

IEC 60529  
*Degrees of Protection Provided by Enclosures (IP Code)*

IEC 60812  
*Analysis Techniques for System Reliability – Procedures for Failure Mode and Effects Analysis (FMEA)*

IEC 61025  
*Fault Tree Analysis (FTA)*

IEC 61373  
*Railway Applications – Rolling Stock Equipment – Shock and Vibration Tests*

IEC 61508 (all parts)  
*Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems*

**UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL**



**Documents**  
Document Sharing Hub

IEC TR 62660-4

*Secondary Lithium-Ion Cells for the Propulsion of Electric Road Vehicles – Part 4: Candidate Alternative Test Methods for the Internal Short Circuit Test of IEC 62660-3*

### **International Standards Organization (ISO) Standards**

ISO 7000

*Graphical Symbols for Use on Equipment – Registered Symbols*

ISO 13355

*Packaging – Complete, Filled Transport Packages and Unit Loads – Vertical Random Vibration Test*

### **National Electrical Manufacturers Association (NEMA)**

NEMA 250

*Enclosures for Electrical Equipment (1000 Volts Maximum)*

### **National Fire Protection Association (NFPA) Codes and Standards**

NFPA 70

*National Electrical Code*

### **National Institute for Occupational Safety and Health (NIOSH)**

*Manual of Analytical Methods*

### **Occupational Safety and Health Standards (OSHA)**

*Evaluation Guidelines for Air Sampling Methods Utilizing Spectroscopic Analysis*

### **Society of Automotive Engineers (SAE) Standards**

SAE J2464

*Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing*

### **UL Standards**

UL 50E

*Enclosures for Electrical Equipment, Environmental Considerations*

UL 157

*Gaskets and Seals*

UL 263

*Fire Tests of Building Construction and Materials*

UL 507

*Electric Fans*

UL 583

*Electric-Battery-Powered Industrial Trucks*

UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM  **Documents**  
Document Sharing Hub

UL 746A

*Polymeric Materials – Short Term Property Evaluations*

UL 746B

*Polymeric Materials – Long Term Property Evaluations*

UL 746C

*Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 810A

*Electrochemical Capacitors*

UL 840

*Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment*

UL 969

*Marking and Labeling Systems*

UL 991

*Tests for Safety-Related Controls Employing Solid-State Devices*

UL 1642

*Lithium Batteries*

UL 1989

*Standby Batteries*

UL 1998

*Software in Programmable Components*

UL 2054

*Household and Commercial Batteries*

UL 2436

*Spill Containment for Stationary Lead Acid Battery Systems*

UL 2580

*Batteries for Use in Electric Vehicles*

UL 2744

*Safety of Products in Smart Environments*

UL 60730-1

*Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements*

UL 60950-1

*Information Technology Equipment – Safety – Part 1: General Requirements*

## **ULC Standards**

CAN/ULC-S2580

*Batteries for Use in Electric Vehicles*

UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM  **Documents**  
Document Sharing Hub

ULC/ORD-C583

*Guide for the Investigation of Electric Battery Powered Industrial Trucks*

## **US Department of Defense (DOD) Standards**

MIL STD 1629A

*Procedures for Performing a Failure Mode, Effects, and Criticality Analysis*

## **6 Glossary**

6.1 BATTERY – A general term for either a single cell or a group of cells connected together either in a series and/or parallel configuration.

6.2 BATTERY PACK – Batteries that are ready for use, contained in a protective enclosure, which may or may not contain protective devices, cooling systems and monitoring circuitry. Although batteries may be the dominant energy storage device in the pack, the battery pack may include electrochemical capacitors as a type of hybrid pack.

6.3 CAPACITOR PACK – Electrochemical capacitors that are ready for use in a battery system, contained in a protective enclosure, with or without protective devices, cooling systems, and monitoring circuitry. Although electrochemical capacitors may be the dominant energy storage device in the pack, the capacitor pack may include batteries as a type of hybrid pack.

6.4 CAPACITY, RATED ( $C_n$ ) – The total number of ampere-hours that can be withdrawn from a fully charged battery at a specific discharge rate to a specific end-of-discharge voltage (EODV) at a specified temperature as declared by the manufacturer.

6.5 CASCADING – The runaway failure or thermal propagation of a battery system or battery module when:

- a) One battery cell is triggered into catastrophic failure and this cell causes the failure of neighboring cells; and/or
- b) Continued thermal propagation of catastrophic cell failures until part of or the entire system is on fire or causing excessive hazardous gas generation or leakage of hazardous liquids.

6.6 CASING – The container that directly encloses and confines the contents of a cell or electrochemical capacitor.

6.7 CELL – The basic functional electrochemical unit containing an assembly of electrodes, electrolyte, separators, container, and terminals. It is a source of electrical energy by direct conversion of chemical energy.

6.8 CELL BLOCK – One or more cells connected in parallel.

6.9 CHARGING – The application of electric current to battery or capacitor terminals, which results in a Faradic reaction that takes place within the battery that leads to stored electro-chemical energy or in the case of the capacitor, due to electrical charge being stored without a chemical reaction taking place.

6.10 CHARGING, CONSTANT CURRENT (CC) – Charging mode where current is held constant while charging voltage is allowed to vary.

6.11 CHARGING, CONSTANT VOLTAGE (CV) – Charging mode where voltage is held constant while charging current is allowed to vary.

6.12 COMBUSTIBLE VAPOR CONCENTRATION – A concentration in air greater than 25% of the lower flammable limit (LFL) of the flammable vapor being measured or a concentration that can be ignited in accordance with 7.1.

6.13 DUT – Device under test.

6.14 BATTERY SYSTEM – Consists of a pack (i.e. battery, capacitor or hybrid pack) and external controls and circuitry related to the pack such as cooling systems, disconnects or protection devices external to the pack.

6.15 ELECTROCHEMICAL CAPACITOR – An electric energy storage device where electrical charge is typically stored as a result of non-Faradaic reactions at the electrodes. (A subset of electrochemical capacitors referred to as an "asymmetric" type have non-Faradaic reactions at one electrode and Faradaic reactions at the other electrode.) A highly-porous surface of the electrodes increases the surface area for holding charge resulting in much larger capacitance and energy density. Electrochemical capacitors differ from common electrolytic capacitors in that they employ a liquid rather than a solid dielectric with charge occurring at the liquid-solid interface of the electrodes when a potential is applied. Some other common names for an electrochemical capacitor are "double layer capacitor", "ultracapacitor", "electrochemical double layer capacitor", "super capacitor", and "EDLC".

6.16 ENCLOSURE – The protective outer cover of the pack or battery system that provides mechanical protection to the pack/system's contents.

6.17 END-OF-DISCHARGE VOLTAGE (EODV) (Cell) – The voltage, under load, of the cell at the end of discharge. The EODV may be specified by the manufacturer, as in the case of a voltage-terminated discharge typical for lithium ion chemistries.

6.18 EXPLOSION – A violent release of energy that produces projectiles or a pressure wave from the DUT and results in DUT contents being forcibly expelled through a rupture in the enclosure or casing.

6.19 FIRE – The sustained combustion of the DUT's contents as evidenced by flame, heat, and charring or other damage of materials.

6.20 FLOWING ELECTROLYTE BATTERY – A rechargeable battery that stores its active materials, in the form of liquid aqueous electrolytes, external to the battery. The electrolytes, which serve as energy carriers, are pumped through two half cells separated by an ion-permeable separator, which provides separation of the two electrolytes while still allowing for the passage of ions during charging and discharging. Charging and discharging results in a chemical reduction reaction in one electrolyte and an oxidation reaction in the other electrolyte. Ions selectively pass through the separator membrane to complete the redox reaction. When in use the electrolytes are continuously pumped in a circuit between reactor and storage tanks. Two commercially available flowing electrolyte batteries technologies, the zinc bromine and the vanadium redox types, are described below:

a) **ZINC BROMINE** – A flowing electrolyte battery technology that has zinc at the negative electrode and bromide at the positive electrode with an aqueous solution containing zinc bromide and other compounds contained in two separate reservoirs. During charging, energy is stored as zinc metal within the cell and polybromide in the cathode reservoir. During discharge, the zinc is oxidized to zinc oxide and the bromine is reduced to bromide.

b) **VANADIUM REDOX** – A flowing electrolyte battery technology that contains vanadium salts in various stages of oxidation in a sulfuric acid, or in a mixture of sulfuric and hydrochloric acid electrolyte. Charging and discharging the battery changes the oxidation state of the vanadium in the electrolyte solutions.

**6.21 FULLY CHARGED** – A battery system, pack, module or cell which has been charged to its full state of charge (SOC) as specified by the manufacturer.

**6.22 FULLY DISCHARGED** – A battery system, pack, module or cell, which has been discharged to its end-of-discharge voltage (EODV) as specified by the manufacturer.

**6.23 HAZARDOUS VOLTAGE** –

In the United States, a sinusoidal voltage exceeding 42.4 V<sub>peak</sub> or 60 V<sub>dc</sub> is considered hazardous.

In Canada (per C22.1 and CAN/CSA-C22.2 No. 0), voltage exceeding 30 V<sub>rms</sub>/42.4 V<sub>ac</sub> peak or 42.4 V<sub>dc</sub> is considered hazardous. Batteries and battery systems intended for building into equipment evaluated to Canadian standards, such as CAN/CSA-C22.2 No. 60950-1 or CAN/CSA-C22.2 No. 62368-1, will need to meet the hazardous voltage limits dictated by that standard.

**6.24 INSULATION LEVELS** – The following are levels of electrical insulation:

a) **BASIC INSULATION** – Insulation to provide basic protection against electric shock.

b) **DOUBLE INSULATION** – Insulation comprising both basic insulation and supplementary insulation.

c) **FUNCTIONAL INSULATION** – Insulation that is necessary only for the correct functioning of the equipment. Functional insulation by definition does not protect against electric shock. It may, however, reduce the likelihood of ignition and fire.

d) **REINFORCED INSULATION** – Single insulation system that provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this standard. The term "insulation system" does not imply that the insulation has to be in one homogeneous piece. It may comprise several layers that cannot be tested as basic insulation and supplementary insulation.

e) **SUPPLEMENTARY INSULATION** – Independent insulation applied in addition to basic insulation in order to reduce the risk of electric shock in the event of a failure of the basic insulation.

6.25 **LEAKAGE** – A condition where liquid escapes through an opening in a designed vent or through a rupture or crack or other unintended opening and is visible external to the device under test.

6.26 **LIGHT ELECTRIC RAIL (LER)** – A term used to specify a commuter train that obtains all of its motive energy from electricity.

6.27 **LIMITED POWER CIRCUIT** – A circuit supplied by a power source that meets SELV limits and whose power and current are further limited in accordance with the Limited Power Source Test of UL 2054. A limited power source is equivalent to a Class 2 circuit in accordance with Article 725 of NFPA 70 or Section 16 of C22.1. A similar concept to limited power is the term “low-voltage limited energy” (LVLE) as defined in Section 16 of UL 583 or ULC/ORD-C583.

6.28 **LITHIUM ION CELL** – A rechargeable cell where electrical energy is derived from the insertion/extraction reactions of lithium ions between the anode and the cathode. The lithium ion cell has an electrolyte that typically consists of a lithium salt and organic solvent compound in liquid or gel or solid form and has either a hard metal casing or a flexible polymeric pouch casing.

6.29 **MAINS SUPPLY (AC)** – An ac power distribution system external to the equipment for supplying power to ac powered equipment. Examples of ac mains supply include public or private utilities and equivalent sources such as motor-driven generators and uninterruptible power supplies.

6.30 **MANUFACTURING PRODUCTION LINE TESTING** – Testing at the manufacturer’s facilities used as a manufacturing check of their production. Depending upon the testing, it either can be a 100% production test, or can be a periodic check or sampling of production. This testing is sometimes referred to as routine testing.

6.31 **MATERIAL, HYGROSCOPIC** – A material that has a strong affinity to attract moisture, will absorb moisture onto its molecular structure if exposed to ambient air, and internal moisture cannot be removed with hot air alone. Examples of hygroscopic materials are: nylon, ABS, acrylic, polyurethane, polycarbonate, PET, and PBT.

6.32 **MATERIAL, NON-HYGROSCOPIC** – A material that does not have an affinity for moisture and any moisture collected is adsorbed on the surface, typical moisture collection is due to condensation, and moisture is easily removed by passing a sufficient stream of warm air over the material. Examples of non-hygroscopic materials are: polyethylene, polypropylene, polystyrene, PVC.

6.33 **MAXIMUM WORKING VOLTAGE** – The highest voltage to which the insulation or component under consideration is or can be subjected to when the equipment is operated under conditions of normal use.

6.34 **MODULE** – A subassembly consisting of a group of cells or electrochemical capacitors connected together either in a series and/or parallel configuration (sometimes referred to as a block) with or without protective devices and monitoring circuitry. A module is a component of a battery system. See Figure 1.2.

6.35 **MONOBLOC BATTERY** – A battery design that contains a common pressure vessel construction, a single vent assembly and shared hardware.

6.36 MOSOC – Maximum operational state of charge. Refer to 6.1.

6.37 NICKEL CELL – A general term for a nickel cadmium or nickel metal hydride rechargeable cell that has a nickel hydroxide positive electrode and either a cadmium metal or metal hydride negative electrode and that has a liquid alkaline (i.e. KOH) electrolyte.

6.38 NORMAL OPERATING REGION – That region of voltage, current, and temperature within which a cell or electrochemical capacitor can safely be charged and discharged repetitively throughout its anticipated life. The manufacturer specifies these values, which are then used in the safety evaluation of the device and may vary as the device ages.

6.39 PROTECTIVE DEVICES, ACTIVE – Devices provided to prevent hazardous conditions that require electrical energy in order to operate. An example of an active control would be a battery management system (BMS).

6.40 PROTECTIVE DEVICES, PASSIVE – Devices provided to prevent hazardous conditions that do not require electrical energy in order to operate. An example of a passive protective device would be a fuse.

6.41 RESTRICTED ACCESS LOCATION – Location where access to the energy storage system is limited to trained service personnel or others trained to understand the restrictions associated with the system such as access to hazardous parts and precautions to be followed around the equipment. Access to restricted access locations shall be secured by a tool such as a lock and key or other means that is controlled by a person(s) responsible for the location.

6.42 ROOM AMBIENT – Considered to be a temperature in the range of  $25 \pm 5^{\circ}\text{C}$  ( $77 \pm 9^{\circ}\text{F}$ ).

6.43 RUPTURE – A mechanical failure of the DUT's enclosure/casing from either internal or external causes, that results in spillage and/or exposure of internal contents of the DUT, but does not result in projectiles and violent energy release, which occur during an explosion.

6.44 SAFETY EXTRA LOW VOLTAGE CIRCUIT (SELV) – A circuit that exhibits voltages that are not in excess of those in Table 6.1 and are safe to touch both under normal operating conditions and after a single fault. An extra low voltage (ELV) is equivalent to SELV under normal conditions (not single fault) only.

**Table 6.1**  
**SELV voltage limits**

| Voltage limits                                                                                                             |                                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Normal                                                                                                                     | Single Fault                                                                                                                                                                                                          |
| Open circuit voltage with generally sinusoidal shape of 42.4 V <sub>peak</sub> , 30 V <sub>rms</sub> or 60 V <sub>dc</sub> | Open circuit voltage with generally sinusoidal shape of 42.4 V <sub>peak</sub> , 30 V <sub>rms</sub> or 60 V <sub>dc</sub> with excursions up to 71 V <sub>peak</sub> or 120 V <sub>dc</sub> for periods up to 200 ms |
| In Canada, see 6.23.                                                                                                       |                                                                                                                                                                                                                       |

6.45 SODIUM-BETA (HIGH TEMPERATURE) CELLS – Cells that utilize metallic sodium and ceramic beta-alumina solid electrolyte and that operate at elevated temperatures. The following are two commercial technologies under this group:

a) SODIUM NICKEL CHLORIDE CELL – A rechargeable cell that has sodium as its negative electrode, a positive electrode that may consist of nickel, nickel chloride or sodium chloride and a ceramic beta-alumina solid electrolyte. The normal operation of the cell is within a temperature range of 270 – 350°C (518 – 662°F) so that the active materials are in a molten state and to ensure ionic conductivity.

b) SODIUM/SULFUR CELLS – A rechargeable cell that has sodium as its negative electrode, a positive electrode that consists of sulfur, and a ceramic beta alumina electrolyte. The normal operation of the cells is within a temperature range of 310 – 370°C (590 – 698°F) so that the active materials are in a molten state and to ensure ionic conductivity.

6.46 STATE OF CHARGE (SOC) – The available capacity in a battery system, pack, module or cell expressed as a percentage of rated capacity.

6.47 THERMAL RUNAWAY – The incident when an electrochemical cell increases its temperature through self-heating in an uncontrollable fashion. The thermal runaway progresses when the cell's generation of heat is at a higher rate than the heat it can dissipate. This may lead to fire, explosion and gassing.

6.48 TOXIC VAPOR RELEASE – A release of vapor(s) in a concentration in excess of the Occupational Safety and Health Administration (OSHA) 8-h time-weighted-average (TWA) permissible exposure limit, which corresponds to the National Institute of Safety and Health (NIOSH) 10 h per day, 40 h per week permissible exposure limits.

In Canada, the limit values may vary between agencies.

6.49 VENTING – A condition when the cell electrolyte and/or battery/capacitor solvent is emitted as vapor, smoke or aerosol from a designed vent or through a sealing edge.

## CONSTRUCTION

### 7 General

#### 7.1 Non-metallic materials

7.1.1 Polymeric materials employed for enclosures shall comply with the requirements as outlined in Table 6.1 Path III of UL 746C except as modified by this standard.

*Exception No. 1: Polymeric materials utilized for light electric rail (LER) enclosures for motive applications shall have a minimum flammability of V-1 or better, in accordance with UL 94 if intended for building into an enclosure or compartment within the train.*

*Exception No. 2: LER enclosure parts for motive applications may alternatively be evaluated to the 20 mm end-product flame tests in accordance with UL 746C.*

7.1.2 The factors taken into consideration when an enclosure is being judged are as follows. For a nonmetallic enclosure, all of these factors shall be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief distortion test.

- a) Resistance to impact;
- b) Crush resistance;
- c) Abnormal operations;
- d) Severe conditions; and
- e) Mold-stress relief distortion.

7.1.3 The polymeric materials employed as enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application. Pack enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80°C (176°F), as determined in accordance with UL 746B.

7.1.4 The pack enclosure materials intended to be exposed to sunlight in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with UL 746C.

7.1.5 Polymeric materials used as direct support for live parts other than those circuits determined non-hazardous (i.e. limited power circuits) shall comply with the insulation requirements of UL 746C.

*Exception: Insulation materials that meet the criteria outlined in UL 60950-1/CAN/CSA-C22.2 No. 60950-1, Clause 4.7.3.3 "Materials for components and parts outside of fire enclosures" or Clause 4.7.3.4 "Materials for components and parts inside of fire enclosures" are considered acceptable.*

7.1.6 Gaskets and Seals relied upon for safety shall be determined suitable for the temperatures they are exposed to and other conditions of use. Compliance is determined by the applicable tests of UL 157.

## 7.2 Metallic parts resistance to corrosion

7.2.1 Metal pack enclosures shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in UL 50E/C22.2 No. 94.2.

7.2.2 Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Table D.1 of Appendix D shall be avoided.

## 7.3 Enclosures

7.3.1 The enclosure of a battery system shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its intended use, in order to reduce the risk of fire or injury to persons. Compliance is determined by the tests of this standard.

7.3.2 A tool providing the mechanical advantage of a pliers, screwdriver, hacksaw, or similar tool, shall be the minimum mechanical capability required to open the enclosure.

7.3.3 Openings in the enclosure shall be designed to prevent inadvertent access to hazardous parts. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12 of IEC 60529 or CAN/CSA-C22.2 No. 60529, for a minimum IP rating of IP2X or IPXXB, and C22.1, the Enclosure Selection Table for Nonhazardous Locations, Table 65. (Evaluation per IEC 60529 or CAN/CSA-C22.2 No. 60529, Clause 12, consists of the use of the IEC articulate probe applied with a force of 10 N  $\pm$ 10%).

*Exception: For battery systems intended for location in restricted access locations only per 6.41, hazardous parts may be contacted with the articulate probe, but shall be located or guarded to prevent unintended contact by service or other trained personnel. Such equipment shall be provided with installation instructions in accordance with 42.3 and marked in accordance with 41.13.*

7.3.4 Openings in the enclosure shall be constructed to prevent accumulation of flammable gases that could lead to a hazardous condition from concentrations of hydrogen gas due to electrolysis of aqueous electrolytes for applicable battery technologies, such as vented or valve regulated lead acid and nickel batteries and applicable electrochemical capacitor technologies, greater than 25% of the LFL of hydrogen (equivalent to 1% concentration in a volume of air). Ventilation openings shall have a minimum opening area of:

$$A = 0.005NC_5 \text{ (cm}^2\text{)}$$

Where:

$A$  = Total cross sectional area of ventilation holes required (cm<sup>2</sup>)

$N$  = Number of cells in battery

$C_5$  = Capacity of battery at the 5-h rate (Ah)

UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL



Documents  
Document Sharing Hub

*Exception: The area of ventilation openings can be reduced if it can be demonstrated that there is sufficient ventilation within the battery to prevent hydrogen accumulations above 25% of the LFL of hydrogen.*

7.3.5 Packs intended for installation where they may be exposed to moisture either through rain, splashing water or immersion shall be evaluated for their intended resistance to ingress of moisture in accordance with IEC 60529 or CAN/CSA-C22.2 No. 60529, or as outlined in NFPA 70, Article 110, or Section 2 of C22.1 for enclosure type designation and UL 50E/C22.2 No. 94.2, or NEMA 250. See also Section 36.

## 7.4 Wiring and terminals

### 7.4.1 General

7.4.1.1 Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment.

7.4.1.2 A wiring splice or connection shall be mechanically secure and shall provide electrical contact without strain on connections and terminals. Wiring shall be secured and routed away from sharp edges or parts exceeding insulation. Openings in compartments through which insulated wiring is routed shall be smooth and well-rounded or provided with protective insulating bushings or grommet to prevent abrasion. Wiring connections between various parts of a battery module/pack and accessories shall be routed and secured to prevent the potential for short circuit conditions to occur.

7.4.1.3 An uninsulated live part, including a terminal, shall be secured to its supporting surface by a method other than friction between surfaces so that it will be prevented from turning, shifting in position, or creating short circuit.

7.4.1.4 An external battery terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when installed in its end use application.

7.4.1.5 External non-detachable cords and leads that are accessible in the end use installation shall be provided with strain relief that prevents strain to internal conductors under pull and push-back conditions. Compliance is determined by the tests of 24.4 and 24.5.

7.4.1.6 Plugs and receptacles shall be rated for the intended voltage, current, temperature, and if applicable, for disconnect under load conditions.

7.4.1.7 Battery system cables shall be rated for their anticipated service including voltage, current, temperature and environment. External cords for hazardous voltage circuits shall be jacketed to prevent wear to internal conductors and rated and provided with insulation suitable for the intended applications.

7.4.1.8 In multiway plugs and sockets, and wherever shorting could otherwise occur, means shall be provided to prevent contact between parts in SELV circuits or parts at hazardous voltage due to loosening of a terminal or breaking of a wire at a termination. Compliance is checked by inspection, by measurement and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the conductor near its termination point. The conductor shall not break away or pivot on its terminal to the extent that spacings are reduced below the values specified in 7.5.

7.4.1.9 Wiring compartments and wiring terminals provided for connection of the battery system to external circuits shall be constructed as outlined below:

- a) A field wiring compartment in which supply connections are to be made shall be located so that the connections will be accessible for inspection after the unit is installed as intended.
- b) A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure. The knockout shall be surrounded by a flat surface to accommodate seating of a conduit bushing or locknut of the appropriate size.
- c) An outlet box, terminal box, wiring compartment, in which field connections are made shall be free from any sharp edges including screw threads, a burr, a fin or moving part of the like that may abrade the insulation on conductor or otherwise damage wiring.
- d) A field wiring terminal or lead shall be rated for the connection of a conductor or conductors having a minimum ampacity rating of 125% of the rating of the unit.
- e) The distance between the end of the connection point of a field installed wire and the wall of the enclosure toward which the wire is to be directed, shall be in accordance with Table 312.6 (A) or (B) of NFPA 70.

#### 7.4.2 Beads and ceramic insulators

##### 7.4.2.1 Beads and similar ceramic insulators on conductors shall:

- a) Be so fixed or supported that they cannot change their position in such a way that a hazard would be created; and
- b) Not rest on sharp edges or sharp corners.

7.4.2.2 If beads are located inside flexible metal conduits, they shall be contained within an insulating sleeve, unless the conduit is mounted or secured in such a way that movement in normal use would not create a hazard. Compliance is checked by inspection and, where necessary, by the following test. A force of 10 N (2.25 lbf) is applied to the insulators or to the conduit. The resulting movement, if any, shall not create a hazard in the meaning of this standard.

**UL COPYRIGHTED MATERIAL –  
NOT AUTHORIZED FOR FURTHER REPRODUCTION OR  
DISTRIBUTION WITHOUT PERMISSION FROM UL**



**Documents**  
Document Sharing Hub

## 7.5 Spacings and separation of circuits

7.5.1 Electrical circuits within the pack at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits (i.e. electrical spacings on printed wiring boards, physical securing of un-insulated leads and parts, etc.). Insulation suitable for the anticipated temperatures and maximum voltages shall be used where spacings cannot be controlled by reliable physical separation.

7.5.2 Electrical spacings in circuits shall be based upon the grade of insulation required as outlined in the Grade of Insulation section of UL 60950-1/CAN/CSA-C22.2 No. 60950-1, and shall comply with the creepage and clearance requirements of the Clearances, Creepage Distances and Distances Through Insulation section of UL 60950-1/CAN/CSA-C22.2 No. 60950-1 for the appropriate pollution degree of the intended environment (see the Pollution Degrees section of UL 60950-1/CAN/CSA-C22.2 No. 60950-1).

*Exception No. 1: As an alternative to these spacing requirements, the spacing requirements in UL 840, may be used. For determination of clearances, a dc source such as a battery does not have an overvoltage category as outlined in the section for Components of UL 840 unless charged through an ac mains connected rectifier, then the overvoltage category should be the same as that required for the rectifier unless the rectifier uses galvanic isolation. If galvanic isolation is employed, then the overvoltage category can be reduced to the next lower overvoltage category. The anticipated pollution degree is determined by the design and application of the electrical energy storage system or subassembly under evaluation.*

*Exception No. 2: As an alternative to the clearance values outlined in UL 60950-1/CAN/CSA-C22.2 No. 60950-1, the clause for Clearances, Creepage Distances and Distances Through Insulation, the alternative method for determining minimum clearances in the Annex for Alternative Method for Determining Minimum Clearances, Annex G, of UL 60950-1/CAN/CSA-C22.2 No. 60950-1 may be applied.*

*Exception No. 3: As an alternative to these spacing requirements, the spacing requirements of Table 7.1 may be applied instead. When using this table, maximum working voltages of circuits can be determined through the test of Section 21. See the note in Table 7.1 regarding adjustment for spacings where double or reinforced insulation is required.*

**Table 7.1**  
**Electrical Spacings**

| Circuit ratings<br>V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Minimum spacings <sup>a</sup>                                                                           |                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Through air                                                                                             | Over surface                                                                                            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Between parts of opposite polarity, live and non-current carrying parts and live and ground connections | Between parts of opposite polarity, live and non-current carrying parts and live and ground connections |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | mm (in)                                                                                                 | mm (in)                                                                                                 |
| 30 – 50 <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1.6 (1/16)                                                                                              | 1.6 (1/16)                                                                                              |
| 51 – 150                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 3.2 (1/8)                                                                                               | 6.4 (1/4)                                                                                               |
| 151 – 300                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 6.4 (1/4)                                                                                               | 9.5 (3/8)                                                                                               |
| 301 – 660                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 9.5 (3/8)                                                                                               | 12.7 (1/2)                                                                                              |
| 661 – 1000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 19.1 (3/4)                                                                                              | 19.1 (3/4)                                                                                              |
| 1001 – 1500                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 21.6 (7/8)                                                                                              | 30.5 (1-1/4)                                                                                            |
| <sup>a</sup> The spacings in this table are suitable between live parts and conductive non-current carrying parts separated by basic insulation only or between basically insulated conductive non-current carrying parts and accessible parts separated by supplemental insulation. Spacings between hazardous voltage parts and accessible parts requiring double or reinforced insulation will require that the values outlined in the table be doubled. Refer to Section 7.6 regarding required insulation levels. |                                                                                                         |                                                                                                         |

**Table 7.1 (Continued)**

| Circuit ratings                                                                                                                                                      | Minimum spacings <sup>a</sup>                                                                           |                                                                                                         |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                      | Through air                                                                                             | Over surface                                                                                            |
|                                                                                                                                                                      | Between parts of opposite polarity, live and non-current carrying parts and live and ground connections | Between parts of opposite polarity, live and non-current carrying parts and live and ground connections |
| V                                                                                                                                                                    | mm (in)                                                                                                 | mm (in)                                                                                                 |
| <sup>b</sup> Spacings at these voltages may be decreased from those indicated in the table if it can be determined through test or analysis that there is no hazard. |                                                                                                         |                                                                                                         |

7.5.3 Conductors of circuits operating at different potentials shall be reliably separated from each other unless they are each provided with insulation acceptable for the highest potential involved.

7.5.4 An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different potential. Some examples include clamping or routing of conductors, use of separating barriers of insulating material or other means that provides permanent separation of the parts.

7.5.5 There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a compound or subassembly if the distance through the insulation, at voltages above SELV levels is a minimum of 0.4-mm (0.02-in) thick for supplementary or reinforced insulation, and passes the Dielectric Voltage Withstand Test. There is no minimum insulation thickness requirement for insulation of circuits at or below SELV levels for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation.

## 7.6 Insulation levels and protective grounding and bonding

7.6.1 Hazardous voltage circuits shall be insulated from accessible conductive parts and circuits as outlined in 7.6.2 through the following:

- a) Basic insulation and provided with a protective grounding system for protection in the event of a fault of the basic insulation; or
- b) A system of double or reinforced insulation; or
- c) A combination of (a) and (b).

7.6.2 Safety extra low voltage (SELV) circuits as defined in 6.44 that are insulated from accessible conductive parts through functional insulation only are considered accessible.

7.6.3 Article 250, Section VIII of NFPA 70 and Section 10 of C22.1 outline dc system grounding requirements including identifying types of dc circuits and systems that must be grounded. Batteries that rely upon protective grounding, shall comply with 7.6.4 through 7.6.9.

7.6.4 Accessible non-current carrying metal parts of a battery system with hazardous voltage circuits, that could become live in the event of an insulation fault, shall be bonded to the equipment ground terminal.

7.6.5 Parts of the protective grounding system shall be reliably secured in accordance with 7.4.1.2 and provided with good metal-to-metal contact. All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. The resistance between the protective conductive terminal of 7.6.8 and the accessible non-current carrying conductive parts outlined in 7.6.2 shall not exceed 0.1  $\Omega$ .

7.6.6 With reference to 7.6.5, when connecting conductive parts to be bonded, paint or coatings in areas of contact shall be removed or paint piercing lock washers shall be used with securement bolts or screws to provide good metal to metal contact. Thread-locking sealants, epoxies, glues, or other similar compounds, and solder alone shall not be used as a securement means as these are not considered reliable. In addition, rivets, hinges (unless metal-to-metal piano type hinges), and parts that may be removed as a result of servicing shall not be relied upon as connections for ensuring continuity of the protective grounding and bonding system.

7.6.7 With reference to 7.6.5, methods of securement considered reliable and ensuring good metal-to-metal contact can consist of the following methods:

- a) Terminal blocks;
- b) Pressure connectors, grounding lugs and similar grounding and bonding equipment connectors;
- c) Exothermic welding processes;
- d) Machine screw-type fasteners that engage not less than two threads or are secured with a nut; and
- e) Thread-forming machine screws that engage not less than two threads in the enclosure.

7.6.8 The main ground terminal of the protective grounding system shall be identified by one of the following:

- a) A green-colored, not readily removable terminal screw with a hexagonal head;
- b) A green-colored, hexagonal, not readily removable terminal nut;
- c) A green colored pressure wire connector; or
- d) The word "Ground" or the letters "G" or "GR" or the grounding symbol (IEC 60417, No. 5019) or otherwise identified by a distinctive green color.

7.6.9 Conductors, relied upon for the protective grounding and bonding system, shall be sized to handle intended fault currents and if insulated, the insulation shall be green or green and yellow striped in color. Grounding conductors shall be sized in accordance with Article 250.122 of NFPA 70 or Rule 10-810 of C22.1.

## 7.7 System safety analysis

7.7.1 An analysis of potential hazards (including an FMEA) shall be conducted on the device under test to determine that events that could lead to a hazardous condition have been identified and addressed through design or other means.

7.7.2 Documents that can be used as guidance for the safety analysis include:

- a) IEC 60812;
- b) IEC 61025;
- c) MIL-STD-1629A; and
- d) IEC 61508, all parts.

7.7.3 The analysis of 7.7.1 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and the types and levels of protection provided to mitigate the anticipated faults. The analysis shall consider single fault conditions in the protection circuit/scheme as part of the anticipated faults and/or identify the safety integrity level or similar safety classification.

7.7.4 When conducting the analysis of 7.7.1, active protective devices shall not be relied upon for critical safety unless they comply with the following in (a) – (c). Refer to 6.39 and 6.40 for definitions of active and passive protective devices.

- a) They are provided with a redundant passive protective device; or
- b) They are provided with redundant active protection that remains functional and energized upon loss of power/failure of the first level active protection; or
- c) They are determined to fail safe upon loss of power to the active circuit; or
- d) Meet the identified safety integrity level per IEC 61508 or similar safety classification.

7.7.5 Devices relied upon for critical safety as noted in 7.7.4 shall be tested for functionality in accordance with appropriate functional safety requirements unless already evaluated through the other tests of this standard.

7.7.6 The safety system analysis for those battery systems that are identified as smart grid enabled, smart grid compatible or smart grid interactive as defined in 1.1 of UL 2744, shall include analysis of impact to safety as a result of integration of the battery system in a smart environment.