



JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL 9540A:2019

STANDARD FOR SAFETY

Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

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ANSI/UL 9540A-2019



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UL Standard for Safety for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, ANSI/CAN/UL 9540A:2019

Fourth Edition, Dated November 12, 2019

Summary of Topics

This Fourth Edition of ANSI/CAN/UL 9450A, Standard for Safety for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, has been issued to reflect the latest ANSI and SCC approval dates, and to incorporate the proposals dated March 29, 2019 and August 16, 2019.

The requirements are substantially in accordance with Proposal(s) on this subject dated March 29, 2019 and August 16, 2019.

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ANSI/CAN/UL 9540A:2019

**Standard for Test Method for Evaluating Thermal Runaway Fire Propagation
in Battery Energy Storage Systems**

First Edition – November, 2017
Second Edition – January, 2018
Third Edition – June, 2018

Fourth Edition

November 12, 2019

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

The most recent designation of ANSI/UL 9540A as an American National Standard (ANSI) occurred on November 12, 2019. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on November 12, 2019.

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Preface

This is the Fourth Edition of the ANSI/CAN/UL 9540A, Standard for Safety for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems.

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 9540A Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

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.

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This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Energy Storage Systems and Equipment, STP 9540.

This list represents the STP 9540 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

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International Classification for Standards (ICS): 13.220; 27.100; 29.220

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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.

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INTRODUCTION

1 Scope

1.1 The test methodology in this standard determines the capability of a battery technology to undergo thermal runaway and then evaluates the fire and explosion hazard characteristics of those battery energy storage systems that have demonstrated a capability to undergo thermal runaway.

1.2 The data generated will be used to determine the fire and explosion protection required for an installation of a battery energy storage system intended for installation, operation and maintenance in accordance with ICC IFC, NFPA 1, NFPA 70, IEEE C2, CAN/CSA C22.2 No. 0, and other codes affecting energy storage systems, and the manufacturer's installation instructions.

1.3 Fire protection requirements not related to battery energy storage system equipment are covered by appropriate installation codes.

1.4 See [Figure 1.1](#) for a schematic of the test sequence in this standard. See Annex [A](#) which explains:

- a) The purpose of the tests included in this standard;
- b) Explanation of individual tests; and
- c) Interpretation and application of the results.

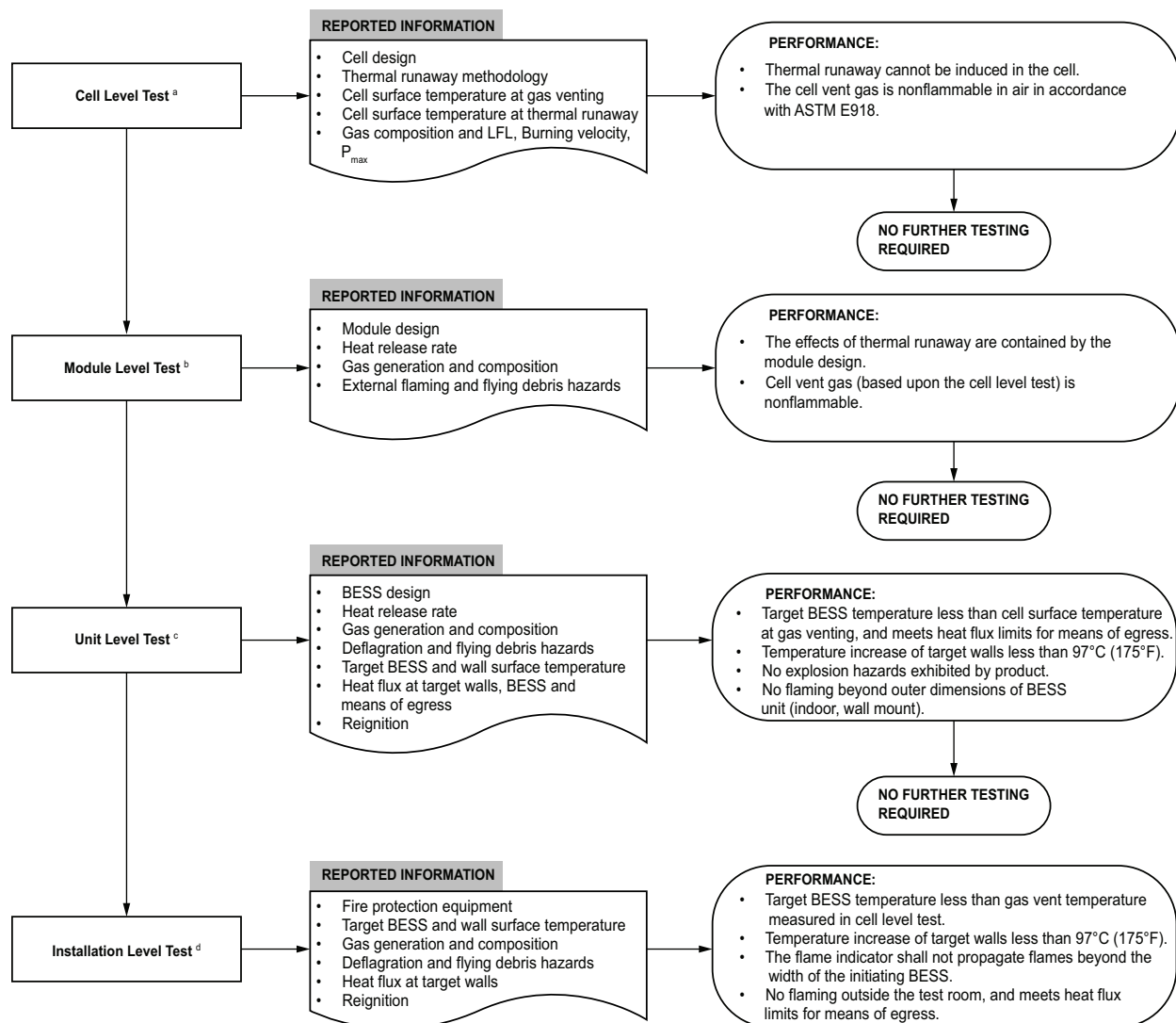
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Figure 1.1
Schematic of Test Sequence



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^a See Section [7](#).

^b See Section [8](#).

^c See Section [9](#).

^d See Section [10](#).

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2 Units of Measurement

2.1 Values stated without parentheses are the requirement. Values in parentheses are a soft conversion from SI to IP units of the requirement.

3 Normative References

3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

3.2 The following model codes or standards are referenced in this standard.

ASHRAE 34, *Designation and Safety Classification of Refrigerants*

ASTM D93, *Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester*

ASTM D3828, *Standard Test Methods for Flash Point by Small Scale Closed Cup Tester*

ASTM E502, *Standard Test Method for Selection and Use of ASTM Standards for the Determination of Flash Point of Chemicals by Closed Cup Methods*

ASTM E918, *Standard Practice for Determining Limits of Flammability of Chemicals at Elevated Temperature and Pressure*

CSA 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*

EN 15967, *Determination of Maximum Explosion Pressure and the Maximum Rate of Pressure Rise of Gases and Vapours*

ICC IFC, *International Fire Code (IFC)*

IEEE C2, *National Electrical Safety Code (NESC)*

ISO 817, *Refrigerants – Designation and Safety Classification*

NFPA 1, *Fire Code*

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*

NFPA 69, *Standard on Explosion Prevention Systems*

NFPA 70, *National Electrical Code*

NFPA 101, *Life Safety Code*

NFPA 220, *Standard on Types of Building Construction*

UL 746A, *Polymeric Materials – Short Term Property Evaluations*

UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*

UL 1685, *Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables*

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

UL 9540, *Energy Storage Systems and Equipment*

UL 2591, *Battery Cell Separators*

4 Glossary

4.1 For the purpose of these requirements, the following definitions apply.

4.2 BATTERY ENERGY STORAGE SYSTEM (BESS) – Stationary equipment that receives electrical energy and then utilizes batteries to store that energy to supply electrical energy at some future time. The BESS, at a minimum consists of one or more modules, a power conditioning system (PCS), battery management system (BMS) and balance of plant components.

NOTE: For flow battery systems the energy is stored within one or more electrolyte storage tanks.

a) INITIATING BATTERY ENERGY STORAGE SYSTEM UNIT (INITIATING BESS) – A BESS unit which has been equipped with resistance heaters in order to create the internal fire condition necessary for the installation level test (Section 9).

b) TARGET BATTERY ENERGY STORAGE SYSTEM UNIT (TARGET BESS) – The enclosure and/or rack hardware that physically supports and/or contains the components that comprise a BESS. The target BESS unit does not contain energy storage components, but serves to enable instrumentation to measure the thermal exposure from the initiating BESS.

4.3 BATTERY SYSTEM – Is a component of a BESS and consists of one or more modules typically in a rack configuration, controls such as the BMS and components that make up the system such as cooling systems, disconnects and protection devices.

4.4 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.

4.5 DUT – Device under test.

4.6 ELECTRICAL RESISTANCE HEATERS – Devices that convert electrical energy supplied from a laboratory source into thermal energy.

4.7 END OF DISCHARGE VOLTAGE (EODV) – The manufacturer's specified minimum voltage level during discharge.

4.8 ENERGY RESERVOIR – The solution which stores the active energy in the flow battery energy storage system. This can be in the form of one electrolyte, two electrolytes, or one electrolyte with solid metal particles.

4.9 FLEXIBLE FILM HEATERS – Electrical resistance heaters of a film, tape or otherwise thin sheet like construction that easily conform to the surface of cells.

4.10 FLOW BATTERY – A battery technology that stores its active materials in the form of one or more electrolytes (with or without solid metal particles) within one or more storage tanks, and when operating, the electrolytes are transferred between the reactor (battery stacks) and the storage tanks.

NOTE 1: Three commercially available flow battery technologies are zinc air, zinc bromine and vanadium redox.

NOTE 2: Unlike a fuel cell system, a flow battery is a closed system and has no net consumption of fuel.

4.11 MAXIMUM SURFACE TEMPERATURE END POINT – The final hold temperature measured on the cell case after conducting the thermal ramp when using the external heater method to achieve thermal runaway of the cell.

4.12 MODULE – A subassembly that is a component of a BESS that consists 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.

4.13 MONOBLOC – A battery design with a common case containing one or more internal cells, electrolyte, a vent or pressure relief valve assembly, intercell connections and hardware. A typical example of a common monobloc battery is an SLI lead acid battery.

4.14 NON-RESIDENTIAL USE – Intended for use in commercial, industrial or utility owned locations.

4.15 RESIDENTIAL USE – In accordance with this standard, intended for use in one or two family homes and townhomes and individual dwelling units of multi-family dwellings.

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

4.17 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 gas evolution.

4.18 UNIT – A frame, rack or enclosure that consists of a functional BESS which includes components and subassemblies such as cells, modules, battery management systems, ventilation devices and other ancillary equipment.

CONSTRUCTION

5 General

5.1 Cell

5.1.1 The cells associated with the BESS that were tested shall be documented in the test report, including cell chemistry (e.g. NMC, LFP), the physical format of the cell (i.e. prismatic, cylindrical, pouch), cell electrical rating in capacity and nominal voltage, the overall dimensions of the cell, and weight.

5.1.2 The cell documentation included in the test report shall indicate if the cells associated with the BESS comply with UL 1973.

5.1.3 Refer to [7.6.1](#) for further details to be included in the cell level test report.

5.2 Module

5.2.1 The modules associated with the BESS that were tested shall be documented in the test report, including the generic (e.g., metallic or nonmetallic) enclosure material, the general layout of the module contents and the electrical configuration of the cells in the modules and the modules in the BESS.

5.2.2 The module documentation included in the test report shall indicate if the modules associated with the BESS comply with UL 1973.

5.2.3 Refer to [8.3](#) for further details to be included in the module level test report.

5.3 Battery energy storage system unit

5.3.1 The BESS unit documentation included in the test report shall indicate the units that comply with UL 9540 and include the manufacturer, model, electrical ratings, and energy capacity of all BESS.

5.3.2 For BESS units for which UL 9540 compliance cannot be determined, the documentation included in the test report shall include the number of modules in the BESS, electrical configuration of the module, and physical layout of the modules in the BESS, battery management system (BMS) and other major components of the BESS. The BESS enclosure overall dimensions and generic (e.g., metallic or nonmetallic) material used for the enclosure shall be documented. Depending upon the configuration of the BESS (e.g. the power conditioning system is external to the BESS enclosure), a battery system(s) can be tested as representative of the BESS. It shall be documented as to whether the battery system complies with UL 1973 in addition to the overall BESS compliance to UL 9540.

5.3.3 If applicable, the details of any fire detection and suppression systems that are an integral part of the BESS shall be noted in the test report.

5.3.4 Refer to [9.7](#), [10.4](#) and [10.7](#) for further details to be included in the unit level and if applicable, installation level test reports.

5.4 Flow Batteries

5.4.1 For flow batteries, the report will cover the chemistry (e.g. vanadium redox, zinc bromine, etc.), a generic description of the electrolyte(s), the overall dimensions of the individual stack as well as the electrical rating in capacity and nominal voltage of the cell stack. The report will also include information on the complete flow battery system including the manufacturer's name and model number of the system, the electrical rating in volts and rated storage capacity in Ah or Wh, the number of cells and stacks in the system, and the maximum volume of electrolyte(s) for the system.

5.4.2 The flow battery documentation included in the test report shall indicate if the flow battery system complies with UL 1973.

5.4.3 See [7.6.2](#) for further details to be included in the flow battery thermal runaway determination level test report.

PERFORMANCE

6 General

6.1 The tests in this standard are extreme abuse conditions conducted on electrochemical energy storage devices that can result in fires, explosions, smoke, off gassing of flammable and toxic materials, exposure to toxic and corrosive liquids, and potential exposure to hazardous voltages and electrical energy. See Annex B for recommended testing practices.

6.2 At the conclusion of testing, samples shall be discharged in accordance with the manufacturer's specifications. All samples shall be disposed of in accordance with local regulations.