JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL 9540:2023

STANDARD FOR SAFETY

Energy Storage Systems and Equipment

ANSI/UL 9540-2023

SCC FOREWORD

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UL Standard for Safety for Energy Storage Systems and Equipment, ANSI/CAN/UL 9540

Third Edition, Dated June 28, 2023

Summary of Topics

The Third Edition of UL 9540 dated June 28, 2023 has been issued to reflect the latest ANSI and SCC approval dates, and to incorporate the proposals dated April 29, 2022, October 7, 2022 and February 24, 2023.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated April 29, 2022, October 7, 2022 and February 24, 2023.

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ANSI/CAN/UL 9540:2023

Standard for Energy Storage Systems and Equipment

First Edition – November, 2016
Second Edition – February, 2020

Third Edition

June 28, 2023

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

The most recent designation of ANSI/UL 9540 as an American National Standard (ANSI) occurred on June 28, 2023. 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 June 28, 2023.

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Preface (UL)

This is the Third Edition of ANSI/CAN/UL 9540 Standard for Safety for Energy Storage Systems and Equipment.

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 9540 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.

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

This Edition of the Standard has been formally approved by the Technical Committee (TC) on Energy Storage Systems and Equipment, TC 9540.

This list represents the TC 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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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

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INTRODUCTION

1 Scope

1.1 These requirements cover an energy storage system (ESS) that is intended to receive and store energy in some form so that the ESS can provide electrical energy to loads or to the local/area electric power system (EPS) when needed. Electrochemical, chemical, mechanical, and thermal ESS are covered by this Standard. The ESS shall be constructed either as one unitary complete piece of equipment or as matched assemblies, that when connected, in accordance with the manufacturer's installation instructions, form the ESS. An ESS consists of at least an energy storage function and energy storage protective function. If the ESS includes multiple parts that are housed in separate enclosures, it shall be considered as a multi-part ESS covered by this Standard. Individual parts (e.g. power conversion equipment, a battery, etc.) of an ESS are not considered an ESS on their own. This Standard evaluates the compatibility and safety of these various components and parts integrated into an ESS. The ESS can be an AC ESS or a DC ESS as defined in this Standard.

1.2 The systems covered by this Standard include those intended to be used in a standalone mode (e.g. islanded) including "self-supply" systems to provide electrical energy and those used in parallel with an electric power system or electric utility grid such as "grid-supply" systems, or applications that perform ancillary operational modes associated with power generation such as voltage support and regulation, frequency support and regulation, volt-var, capacity reserve, energy shifting or other utility grid support services.

1.3 Energy storage systems are intended for installation and use in accordance with the National Electrical Code, NFPA 70, the Canadian Electrical Code, Part I Safety Standard for Electrical Installations, CSA C22.1, the National Electrical Safety Code, IEEE C2, the International Fire Code, ICC IFC, the International Residential Code, ICC IRC, the National Fire Code of Canada, NRC NFC, the Fire Code, NFPA 1, and the Standard for the Installation of Stationary Energy Storage Systems, NFPA 855. Requirements for installation, with the exception of installation manuals and documents for installation provided with the system are outside the scope of this Standard.

1.4 This Standard covers energy storage systems for stationary indoor and outdoor installations. This Standard also covers mobile energy storage systems as defined by this Standard. This Standard includes requirements for energy storage systems used in residential and non-residential installations.

1.5 Systems using lead acid or Ni-cad batteries that fall within the scope of UL 1778/CSA C22.2 No. 107.3 and only serve an uninterruptible power system (UPS) application are outside the scope of this Standard.

NOTE: UL 1778/CSA C22.2 No. 107.3 is applicable to UPS that employ chemistries other than lead acid or Ni-cad, but the fire codes and the ESS installation standard do not exclude UPS applications from ESS criteria including compliance to this Standard for these other chemistries.

1.6 The maximum energy capacity of individual electrochemical ESS shall be determined by the following in (a) – (d). Where the results of testing are used, the results shall be determined in accordance with the Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, UL 9540A:

a) The maximum energy capacity of residential use electrochemical ESS shall not exceed 20 kWh (72 MJ). This value shall be permitted to be increased to the value of the unit which meets the performance criteria of the UL 9540A Unit Level test;

b) The maximum energy capacity of non-residential use electrochemical ESS shall not exceed 50 kWh (180 MJ). This value shall be permitted to be increased to the value of the unit which meets the performance criteria of the UL 9540A Installation Level test, provided the ESS is marked in accordance with 45.20;

c) There is no maximum energy capacity limit for non-residential use electrochemical ESS that are tested in accordance with UL 9540A in which the performance level criteria of the cell level test have been met; and

d) There is no maximum energy capacity limit for non-residential use electrochemical ESS intended for use in remote outdoor locations as defined in the applicable installation code, provided they are marked in accordance with 45.21.

NOTE 1: The Standard for the Installation of Stationary Energy Storage Systems, NFPA 855 defines outdoor remote locations as being located more than 30.5 m (100 ft) from exposures.

NOTE 2: Lead acid, Ni-Cad, Ni-MH, and Ni-Zn ESS have exceptions to the capacity energy limits including, in some cases, no limits based upon specific telecom and utility installations as outlined in NFPA 855.

2 Components

2.1 A component or equipment of an energy storage system covered by this Standard shall comply with the safety requirements for that component or equipment. See Annex A for a list of standards covering components generally used in the energy storage systems covered by this Standard. Components and equipment shall comply with the CSA and/or UL standards as appropriate for the country or countries where the energy storage system is to be installed.

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. Energy storage systems covered by this Standard shall comply with the referenced installation codes and standards as appropriate for the country where the energy storage system is to be installed. When the energy storage system is intended for use in more than one country, the energy storage system shall comply with the installation codes and standards for all countries where it is intended to be used.

ASME B31 (all applicable parts), *Power Piping*

ASME BPVC, *Boiler and Pressure Vessel Code*

ASTM D412, *Standard Test Method for Vulcanized Rubber and Thermoplastic Elastomers – Tension*

ASTM D4169, *Standard Practice for Performance Testing of Shipping Containers and Systems*

ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*

29 CFR 1910.95, *Occupational Noise Exposure*

29 CFR 1910.1200, *Toxic and Hazardous Substances*

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

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

CSA C22.2 No. 0.15, *Adhesive Labels*

CSA C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*

CSA C22.2 No. 0.2, *Insulation Coordination*

CSA C22.2 No. 0.8, *Safety Functions Incorporating Electronic Technology*

CSA C22.2 No. 41, *Grounding and Bonding Equipment*

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

CSA C22.2 No. 100, *Motors and Generators*

CSA C22.2 No. 107.1, *Power Conversion Equipment*

CSA C22.2 No. 107.3, *Uninterruptible Power Systems*

CSA C22.2 No. 139, *Electrically Operated Valves*

CSA C22.2 No. 286, *Industrial Control Panels and Assemblies*

CSA C22.2 No. 301, *Industrial Electrical Machinery*

CSA C22.2 No. 60079-2, *Explosive Atmospheres – Part 2: Equipment Protection By Pressurized Enclosure "p"*

CSA C22.2 No. 60529, *Degrees of Protection Provided By Enclosures (IP Code)*

CSA C22.2 No. 61800-5-1, *Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy*

CSA C22.2 No. 62109-1, *Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements*

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

CSA B51, *Boiler, Pressure Vessel, and Pressure Piping Code*

CSA B52, *Mechanical Refrigeration Code*

CSA B149.1, *Natural Gas and Propane Installation Code*

CSA FC 1, *Fuel Cell Technologies – Part 3-100: Stationary Fuel Cell Power Systems – Safety*

CSA Z462, *Workplace Electrical Safety*

CSA Z662, *Oil and Gas Pipeline Systems*

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

ICC IBC, *International Building Code*

ICC IFC, *International Fire Code*

ICC IRC, *International Residential Code*

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

IEC 60364-4-41, *Low-Voltage Electrical Installations – Part 4-41: Protection for Safety – Protection Against Electric Shock*

IEC 60364-6, *Low-Voltage Electrical Installations – Part 6: Verification*

IEC 60417 Database, *Graphical Symbols for Use on Equipment*

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

IEC 60664-1, *Insulation Coordination for Equipment Within Low-Voltage Systems – Part 1: Principles, Requirements and Tests*

IEC 60812, *Failure modes and effects analysis (FMEA and FMECA)*

IEC 60980, *Recommended Practices for Seismic Qualification of Electrical Equipment of the Safety System for Nuclear Generating Stations*

IEC 61000-4-2, *Electromagnetic Compatibility (EMC) – Part 4-2: Testing and Measurement Techniques – Electrostatic Discharge Immunity Test*

IEC 61000-4-3, *Electromagnetic Compatibility (EMC) – Part 4-3: Testing and Measurement Techniques – Radiated, Radio-Frequency, Electromagnetic Field Immunity Test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and Measurement Techniques – Electrical Fast Transient/Burst Immunity Test*

IEC 61000-4-5, *Electromagnetic Compatibility (EMC) – Part 4-5: Testing and Measurement Techniques – Surge Immunity Test*

IEC 61000-4-6, *Electromagnetic Compatibility (EMC) – Part 4-6: Testing and Measurement Techniques – Immunity to Conducted Disturbances, Induced by Radio-Frequency Fields*

IEC 61000-4-8, *Electromagnetic Compatibility (EMC) – Part 4-8: Testing and Measurement Techniques – Power Frequency Magnetic Field Immunity Test*

IEC 61000-6-2, *Electromagnetic Compatibility (EMC) – Part 6-2: Generic Standards – Immunity Standard for Industrial Environments*

IEC 61025, *Fault Tree Analysis (FTA)*

IEC 61180, *High-Voltage Test Techniques for Low Voltage Equipment Definitions, Test and Procedure Requirements, Test Equipment*

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

IEC 62040-1, *Uninterruptible Power Systems (UPS) – Part 1: Safety Requirements*

IEC 62477-1, *Safety Requirements for Power Electronic Converter Systems and Equipment – Part 1: General*

IEEE C2, *National Electrical Safety Code*

IEEE 344, *Seismic Qualification for Equipment for Nuclear Power Generating Stations*

IEEE 693, *Recommended Practice for Seismic Design of Substations*

IEEE 1547, *Interconnecting Distributed Resources with Electric Power Systems*

IEEE 1547.1, *Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems*

ISO 1496-1, *Series 1 Freight Containers – Specification and Testing – Part 1: General Cargo Containers for General Purposes*

ISO 7010, *Graphical Symbols – Safety Colours and Safety Signs – Registered Safety Signs*

ISO 12944 (all parts), *Paints and Varnishes – Corrosion Protection of Steel Structures by Protective Paint Systems*

ISO 13849-1, *Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design*

ISO 13849-2, *Safety of Machinery – Safety-Related Parts of Control Systems – Part 2: Validation*

ISO 26262 (all parts), *Road Vehicles – Functional Safety*

NEMA Z535.1, *Safety Colors*

NEMA Z535.2, *Environmental and Facility Safety Signs*

NEMA Z535.3, *Criteria for Safety Symbols*

NEMA Z535.4, *Product Safety Signs and Labels*

NEMA Z535.5, *Safety Tags and Barricade Tape (for Temporary Hazards)*

NEMA Z535.6, *Product Safety Information in Product Manuals, Instructions, and Other Collateral Materials*

NFPA 1, *Fire Code*

NFPA 68, *Explosion Protection by Deflagration Venting*

NFPA 69, *Explosion Prevention Systems*

NFPA 70, *National Electrical Code*

NFPA 70E, *Electrical Safety in the Workplace*

NFPA 72, *National Fire Alarm and Signaling Code*

NFPA 79, *Electrical Standard for Industrial Machinery*

NFPA 286, *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*

NFPA 484, *Combustible Metals*

NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*

NFPA 855, *Standard for the Installation of Stationary Energy Storage Systems*

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*

NRC NFC, *National Fire Code of Canada*

GR-63-CORE, *Network Equipment Building System (NEBS) Requirements: Physical Protection*

UL 38, *Manual Signaling Boxes for Fire Alarm Systems*

UL 50, *Enclosures for Electrical Equipment, Non-Environmental Considerations*

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 144, *LP Gas Regulators*

UL 157, *Gaskets and Seals*

UL 252, *Compressed Gas Regulators*

UL 268, *Smoke Detectors for Fire Alarm Systems*

UL 268A, *Smoke Detectors for Duct Applications*

UL 429, *Electrically Operated Valves*

UL 429A, *Electrically Operated Valves for Fire Protection Service*

UL 464, *Audible Signaling Devices for Fire Alarm and Signaling Systems, Including Accessories*

UL 467, *Grounding and Bonding Equipment*

UL 508A, *Industrial Control Panels*

UL 521, *Heat Detectors for Fire Protective Signaling Systems*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

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

UL/ULC 842, *Valves for Flammable and Combustible Liquids*

UL 864, *Control Units and Accessories for Fire Alarm Systems*

UL 969, *Marking and Labeling Systems*

UL 991, *Tests for Safety-Related Controls Employing Solid-State Devices*

UL 1004-1, *Rotating Electrical Machines – General Requirements*

UL 1004-2, *Impedance Protected Motors*

UL 1004-3, *Thermally Protected Motors*

UL 1004-4, *Electric Generators*

UL 1004-5, *Fire Pump Motors*

UL 1004-6, *Servo and Stepper Motors*

UL 1004-7, *Electronically Protected Motors*

UL 1004-8, *Inverter Duty Motors*

UL 1004-9, *Form Wound and Medium Voltage Rotating Electrical Machines*

UL 1012, *Power Units Other Than Class 2*

UL 1564, *Industrial Battery Chargers*

UL 1638, *Visible Signaling Devices for Fire Alarm and Signaling Systems, Including Accessories*

UL 1741, *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*

UL 1778, *Uninterruptible Power Systems*

UL 1971, *Signaling Devices for the Hearing Impaired*

UL 1973, *Batteries for Use in Stationary and Motive Auxiliary Power Applications*

UL 1998, *Software in Programmable Components*

UL 2075, *Gas and Vapor Detectors and Sensors*

UL/ULC 2166, *Halocarbon Clean Agent Extinguishing System Units*

UL 2200, *Stationary Engine Generator Assemblies*

UL 2416, *Audio/Video, Information and Communication Technology Equipment Cabinet, Enclosure and Rack Systems*

UL 2755, *Modular Data Centers*

UL 5500, *Remote Software Updates*

UL 9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*

UL 60079-2, *Explosive Atmospheres – Part 2: Equipment Protection by Pressurized Enclosures "p"*

UL 60079-29-1, *Explosive Atmospheres – Part 29-1: Gas Detectors – Performance Requirements of Detectors for Flammable Gases*

UL 60730-1, *Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements*

UL 61800-5-1, *Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy*

UL 62109-1, *Safety of Power Converters for Use in Photovoltaic Power Systems – Part 1: General Requirements*

UL 62368-1, *Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements*

ULC 525, *Audible Signaling Devices for Fire Alarm and Signaling Systems, Including Accessories*

ULC 526, *Visible Signaling Devices For Fire Alarm And Signaling Systems, Including Accessories*

ULC 527, *Control Units for Fire Alarm Systems*

ULC S528, *Manual Stations For Fire Alarm Systems, Including Accessories*

ULC 529, *Smoke Detectors For Fire Alarm Systems*

ULC S530, *Heat Actuated Fire Detectors For Fire Alarm Systems*

ULC S588, *Gas and Vapour Detectors and Sensors, Including Accessories*

MIL-STD-882E, *System Safety*

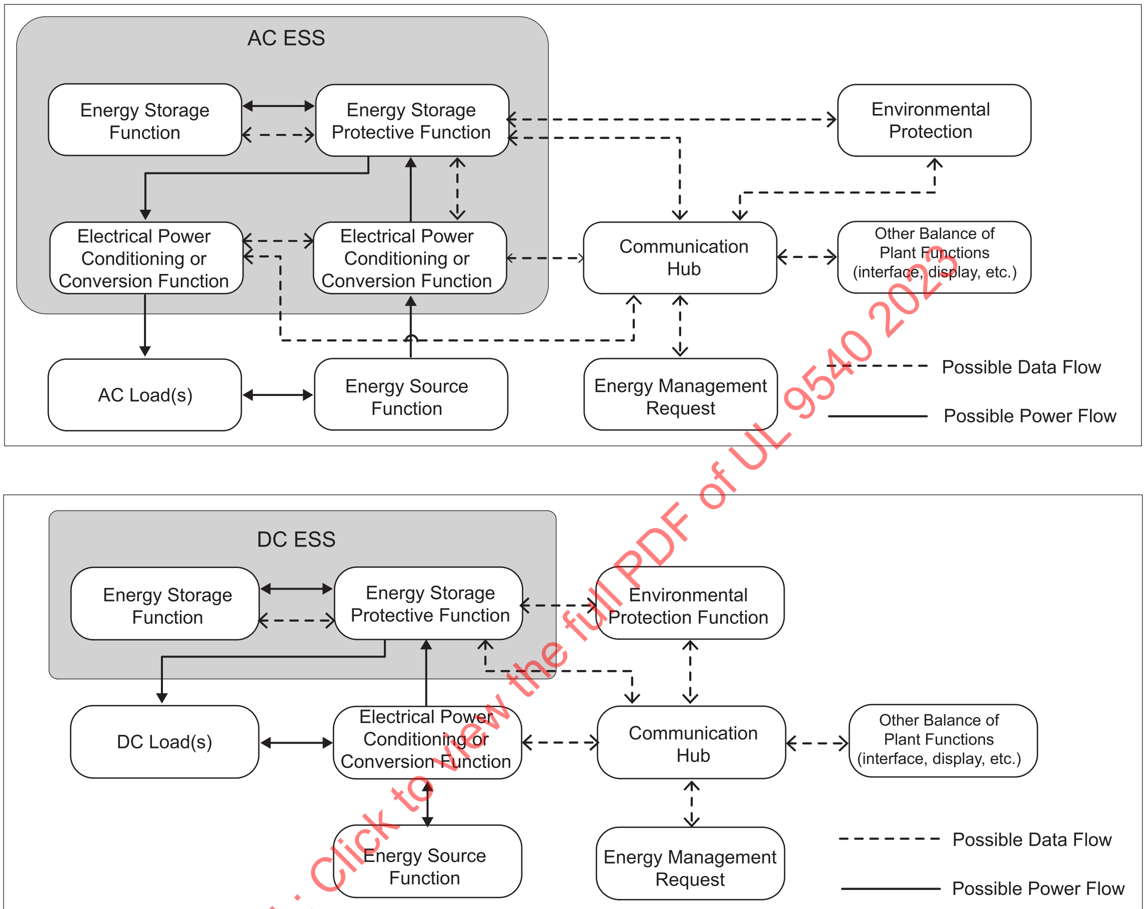
6 Glossary

6.1 For the purpose of this Standard, the following definitions apply.

6.2 AC ESS – An energy storage system comprised of the energy storage function and energy storage protective function which are evaluated for functional safety, and electrical power conditioning or conversion function, providing AC output field wiring terminals. See Figure 6.1.

Figure 6.1

AC and DC ESS



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NOTES:

Electrical Power Conditioning Function – Maintaining electrical parameters (e.g. voltage, frequency, waveform, etc.) within defined limits.

Electrical Power Conversion Function – Converting one form of electrical power into another form of electrical power (e.g. from DC to AC, etc.).

Energy Source Function – Source of AC or DC electrical energy that is compatible with the parameters (e.g. voltage, frequency) of the charging function of the ESS.

Energy Storage Function – The conversion of input energy into stored energy, the storing of energy, and conversion of stored energy into output energy.

Energy Storage Protective Function – Maintains ESS within specified operating limits, limiting risk of fire, electrical shock, explosion, mechanical hazards and chemical exposure or any of the preceding associated with the energy storage.

DC Load(s) may include equipment which performs electrical power conditioning or conversion functions.

6.3 ARC FLASH BOUNDARY – The area within which a hazardous arc could occur, and which requires the use of special protective equipment (PPE). See 10.12.

6.4 CATASTROPHIC FAILURE – A severe sudden failure that results in damage to the test subject such that the test subject can no longer serve its primary function. The failure may or may not result in hazard to personnel or to items in the surrounding environment or initiate other failures. The test subject may or may not be repairable in a field environment.

6.5 COMMISSIONING – The process by which an energy storage system, upon installation, is tested and otherwise evaluated to verify that it functions according to its design objectives and specifications.

6.6 DC ESS – An energy storage system containing the energy storage function and energy storage protective function which are evaluated for functional safety and providing DC output field wiring terminals. See Figure 6.1.

6.7 DECOMMISSIONING – The act of removing an energy storage system from service, which includes shutting it down, typically some level of dismantling, and then finally removing it from the site of installation.

6.8 DUT – Device under test.

6.9 DWELLING UNIT – See the definition for "dwelling unit" in Chapter 3, Definitions, of NFPA 855, in Section 0, Definitions of CSA C22.1, in the General Definitions, Section 202 of ICC IFC, and in Chapter 2, Definitions of ICC IRC.

6.10 ELECTRIC POWER SYSTEM (EPS) – Equipment or facilities that deliver electric power to a load. The most common example of an EPS is an electric utility.

6.11 ELECTRIC SHOCK HAZARD – A potential for exposure of persons to hazardous voltage circuits through direct contact from openings in protective enclosures and/or insufficient insulation between hazardous voltage circuits and accessible parts.

6.12 ENCLOSURE – The outer cover of the Energy Storage System that provides protection to its contents.

6.13 ENERGY STORAGE MANAGEMENT SYSTEM (ESMS) – A monitoring and control system of an ESS that may receive and coordinate inputs from various other devices in the ESS impacting the ESS safety and performance.

6.14 ENERGY STORAGE SYSTEM (ESS) – Equipment in one or more enclosures that receives energy and then provides a means to store that energy in some form for later use in order to supply electrical energy when needed. It can be either an AC ESS or a DC ESS. See Figure 6.1. An ESS utilizes one of the following technologies:

a) ELECTROCHEMICAL ESS – Consists of a secondary (rechargeable) battery, electrochemical capacitor, flow battery or hybrid battery-capacitor system that stores electrical energy and any associated controls or devices that can provide the stored electric energy upon demand.

b) CHEMICAL ESS – Consists of hydrogen storage, the hydrogen generator to supply the hydrogen for storage, and a fuel cell power system to provide electric energy upon demand.

c) MECHANICAL ESS – Consists of a mechanical means to store energy such as through compressed air, pumped water or fly wheel technologies and associated controls and systems, which can be used to run an electric generator to provide electric energy upon demand.

d) THERMAL ESS – Consists of a system that uses heated fluids such as air as a means to store energy along with associated controls and systems, which can be used to run an electric generator to provide electrical energy upon demand.

NOTE: The ESS may be a single unit or composed of multiple parts.

6.15 ENERGY STORAGE SYSTEM INTEGRATOR – The entity typically responsible for ensuring the various parts of the ESS work together, and that the ESS works with the external systems that either supply energy into the ESS or use energy from the ESS.

6.16 EXTERNAL WARNING COMMUNICATION SYSTEM (EWCS) – A system integral to the ESS that takes in data from various sources within the ESS and then communicates information on potential ESS safety issues to an external operating station, and also initiates local alarms when deemed necessary.

6.17 FAILURE MODES AND EFFECT ANALYSIS (FMEA) – a rigorous and systematic methodology for analyzing reliability and the impact the failure of any one component associated with a technology and its installation has on safety. For the purposes of this Standard, only the impact to safety is considered.

6.18 FLYWHEEL – An electro-mechanical system that stores energy in the form of kinetic energy. It is composed of an electric machine element and an inertia element. The inertia element is used to store the majority of kinetic energy in the system and the electric machine element is used to discharge and recharge the inertia element. These elements may be separate distinct devices or they may be integrated.

6.19 FUEL CELL POWER SYSTEM – Equipment that converts chemical energy in the form of a fuel and oxidant into electrical energy with heat and by-products from the reaction.

6.20 HABITABLE SPACE – See the definition for “habitable space” in ICC IBC and ICC IRC.

NOTE: In the ICC IBC and ICC IRC definition, bathrooms, toilet rooms, closets, halls, storage or utility spaces and similar areas are not considered habitable spaces. However in NFPA 855, the only indoor areas that are considered suitable for residential ESS installation are in garages, detached accessory structures, enclosed utility closets and storage or utility spaces. NFPA 855, ICC IBC, and ICC IRC specifically prohibit installation of ESS in sleeping rooms or in closets or spaces opening directly into sleeping rooms.

6.21 HAZARDOUS ARC – An electrical arc with sufficient energy to result in physical hazards to someone coming in contact with it. See 10.12.

6.22 HAZARDOUS FLUID – A hazardous material (e.g. toxic, combustible, etc.) that is either a liquid or a gas.

6.23 HAZARDOUS MATERIAL – A hazardous material is a substance, which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors. Hazardous materials are further defined in 29 CFR 1910.1200.

6.24 HAZARDOUS VOLTAGE – Voltage exceeding 30 Vrms/42.4 Vac peak or 60 Vdc is considered hazardous.

6.25 HVAC – Heating, ventilation and air-conditioning.

6.26 INSULATION LEVELS – The following are levels of electrical insulation:

a) BASIC INSULATION – A single level of insulation that is intended to provide protection against electric shock when the insulation has not failed.

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 that can reduce the likelihood of ignition and fire, and that does not protect against electric shock.

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 "insulation system" consists of one homogeneous piece, or 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.

6.27 MOBILE ENERGY STORAGE SYSTEMS (MESS) – An ESS that is not portable, but has a means so that it can be moved (e.g. mounted on a wheeled trailer or skid) to a site to provide power on a temporary basis.

6.28 MULTI-PART ESS – An energy storage system consisting of assemblies or equipment interconnected in the field to comprise a complete system.

6.29 NON-COMBUSTIBLE DIELECTRIC MEDIUM – A transformer fluid that does not ignite, burn, give off flammable vapors or support combustion in air.

6.30 NON-COMBUSTIBLE MATERIAL – A material that will not ignite or burn when subjected to fire or excessive heat as determined by the test of ASTM E136.

NOTE: Materials meeting this criteria include steel, concrete, masonry and glass.

6.31 NON-RESIDENTIAL USE – Equipment suitable for use on or in structures other than those defined in 6.34.

6.32 OUTDOOR USE – An installation where the ESS is located outside of a building and where it may be subject to environmental exposures such as rain and wind.

6.33 REMOTE SOFTWARE UPDATE – A function providing any operation by control devices through external means, which includes, but is not limited to, the use of:

a) Communication lines/protocols;

b) IR/RF TRANSMISSION; or

v) All combinations of (a) – (b) above via internet using, for example, modems, portable telephones, etc.

NOTE: Remote software updates require minimum or no interaction with the ESS. Software updates are received remotely without the use of external hardware such as a USB, SD card, etc.

6.34 RESIDENTIAL USE – Equipment suitable for use on or in detached one- and two-family dwellings and townhouses.

6.35 RESTRICTED ACCESS LOCATION – Location for an ESS as identified in the installation manual and equipment markings, or as required by local codes, where both of the following apply:

a) Access can only be gained by service persons or by users who have been instructed about the reasons for the restrictions applied to the location, the hazards present at the location, and about any precautions that shall be taken; and

b) Access is through the use of a tool or lock and key, or other means of security, and is controlled by the authority responsible for the location.

6.36 RISK – The potential for fire, electric shock, injury to persons, or damage to equipment associated with the intended use of the ESS as specified by the ESS safety requirements.

6.37 RISK ADDRESSED STATE – A state that is characterized by all reasonably foreseeable risks associated with the ESS, as defined by the safety analysis of the system, being addressed such that there is no longer a likelihood of the risk.

6.38 ROOM AMBIENT – Considered to be a temperature in the range of 25 ±5 °C (77 ±9 °F).

6.39 SAFETY CRITICAL CIRCUITS/COMPONENTS – Those circuits or components that are relied upon for critical safety (i.e. mitigating a potential hazard to persons) as identified in the safety analysis of 15.5.

6.40 SAFETY EXTRA LOW VOLTAGE (SELV) CIRCUIT – 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.

Table 6.1
SELV Voltage Limits

Voltage limits	
Normal	**Single fault**
Open circuit voltage with generally sinusoidal shape of 42.4 Vpeak/30 Vrms or 60 Vdc	Open circuit voltage with generally sinusoidal shape of 42.4 Vpeak/30 Vrms or 60 Vdc with excursions up to 71 Vpeak/50 Vrms or 120 Vdc for periods up to 200 ms

6.41 SPECIAL PURPOSE UTILITY-INTERACTIVE (INVERTER / CONVERTER / PRODUCT) – An inverter / converter / product that is functionally similar to a utility-interactive inverter except that it is evaluated for specific applications different from those where utility-interactive inverters are generally used.

6.42 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.

6.43 USER – When pertaining to remote software updates of the ESS controls, the service person or the operator of the ESS.

6.44 UTILITY-INTERACTIVE (INVERTER) – An inverter intended for use in parallel with an electric utility to supply common loads and sometimes deliver power to the utility.

6.45 UTILITY-INTERACTIVE INVERTER / CONVERTER, GRID SUPPORT – An inverter or converter intended for use in parallel with an electric utility that is a Utility Interactive inverter that it is additionally evaluated for specific grid support functions different from those defined in IEEE 1547 and IEEE 1547.1. These units have specific utility interconnection settings that allow them to provide grid support functionality such as voltage and frequency regulation functions and voltage and frequency ride through.

6.46 WALK-IN UNIT – A pre-fabricated building that contains ESS. It includes doors that provide walk-in access for personnel to maintain, test and service the equipment, and is typically used in outdoor use and MESS applications.

CONSTRUCTION

7 Non-Metallic Materials

7.1 Polymeric materials employed for enclosures, or parts of enclosures for ESS shall comply with (a) and (b) below:

a) The enclosure requirements outlined in UL 746C, Path III of the Enclosure Requirements, or CSA C22.2 No. 0.17; and

b) For BESS, the enclosure shall be evaluated to UL 9540A Unit Level testing and meet the unit level performance criteria.

Exception: Equipment of a multi-part ESS that complies with the enclosure requirements in the appropriate standard for that equipment is not required to comply if the equipment enclosure is determined suitable for the intended environmental conditions that the ESS will be exposed to.

7.2 The following factors in (a) – (e) shall be taken into consideration when an enclosure employing nonmetallic materials is being judged. For a nonmetallic enclosure, all of these factors are to be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief test. Suitability to factors (a) – (e) below shall be determined by the tests of this Standard or UL 746C, or the enclosure tests of critical component standards such as UL 1973 or UL 1971, if the enclosure for the critical component is covered under that standard.

a) Resistance to impact;

b) Crush resistance;

c) Abnormal operations;

d) Severe conditions; and

e) Mold-stress relief distortion.

7.3 In addition to the items in 7.2, polymeric enclosures shall have the following properties:

a) Minimum 5 VA flame rating, or the enclosure complies with the 127 mm (5 inch) Flame test of UL 746C, and for large surface areas having for any single unbroken section, a projected surface area greater than 0.93 m^2 (10 ft^2) or a single linear dimension greater than 1.83 m (6 ft) require flame spread testing per the Enclosure Flammability – Large Surface Area Considerations test of UL 746C;

b) Insulation material properties per the Material Property Considerations table of UL 746C;

c) Compliance with the Strain-Relief Test after Mold Stress-Relief Distortion of UL 746C if serving as a securement means for a strain relief;

d) Compliance with the Ultraviolet Light Exposure test of UL 746C if exposed to UV rays in the end use;

e) Compliance with the Water Exposure and Immersion test of UL 746C if exposed to rain in the end use; and

f) Compliance with the Conduit Connections in the Enclosure Requirements table of UL 746C if mounting conduit connections.

7.4 The requirements in 7.3 do not apply to a nonmetallic part that forms part of the enclosure under any one of the following conditions in accordance with UL 94 or CSA C22.2 No. 0.17:

a) The part covers an opening that has no dimension greater than 25.4 mm (1 in) and the part is made of a material Classed as V-0, V-1, V-2, or HB;

b) The part is made of a material Classed V-0, V-1, V-2, or HB and covers an opening which does not give access to the user, when the part is removed, to live parts involving a risk of fire, electric shock, or electric energy-high current levels or moving parts;

c) The part covers an opening that has no dimension greater than 101.6 mm (4 in) and the part is made of a material Classed as V-0, V-1, V-2, or HB, and there is no source of a risk of fire closer than 101.6 mm (4 in) from the surface of the enclosure; or

d) The part is made of a material Classed V-0, V-1, V-2, or HB and there is a barrier or a device that forms a barrier made of a material Classed V-0 between the part and a source of a risk of fire.

Exception: A part of a component is not required to be Classed V-0, V-1, V-2, or HB when it complies with the flammability requirements applicable to the component.

7.5 Materials employed as electrical insulation in the ESS shall be resistant to deterioration that would result in an electrical shock, fire or other safety hazard. Insulation materials that are in direct contact with or close proximity to hazardous live parts in accordance with Figure 6.1 of the Material Property Considerations table in UL 746C or CSA C22.2 No. 0.17, shall additionally meet the insulation criteria outlined in either standard unless employed as part of a component that has been evaluated to a component standard that has comparable safety criteria. Insulated wiring is subjected to the requirements outlined in Section 11.

Exception: As an alternative, polymeric materials used to support live parts shall comply with the Control of Fire Spread in PS2 Circuits requirements or the Control of Fire Spread in a PS3 Circuit requirements in UL 62368-1/CSA C22.2 No. 62368-1, Clauses 6.4.5 or Clause 6.4.6 as applicable.

7.6 Gaskets and Seals relied upon for safety, shall be determined suitable for the environmental conditions and chemical substances they are anticipated to be exposed to in their end use.

7.7 Compliance with 7.6 for gaskets and seals relied upon to prevent ingress of moisture into the enclosure, can either comply with the Gaskets Tests Clause of UL 50E/CSA C22.2 No. 94.2 or comply with UL 157 or ASTM D412 for the anticipated exposures.

8 Metallic Enclosures and Parts Resistance to Corrosion

8.1 Metallic enclosure parts for BESS shall be of non-combustible materials as defined in this Standard.

Exception: Metallic enclosures of BESS that do not meet the definition of non-combustible, shall be evaluated to UL 9540A Unit Level testing and meet the performance level criteria for the unit level test.

8.2 Metallic enclosure parts that provide physical protection to ESS components, or prevent access to hazardous ESS components shall have sufficient strength to provide physical protection and shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion resistance can be found in UL 50E/CSA C22.2 No. 94.2, or the applicable parts of the ISO 12944 standard series. Metallic enclosures of parts of a multi-part ESS that meet the enclosure requirements of their component standard such as UL 1741 and UL 1973 are considered to comply with these requirements without further evaluation.

8.3 Conductive parts with dissimilar metals in contact at terminals and connections shall not be subject to corrosion due to electrochemical action. Combinations above the line in Figure F1 of Annex F shall be avoided. Use of coatings to prevent corrosion such as silver are methods to meet this requirement.

9 Enclosures and Guarding of Hazardous Parts

9.1 The enclosure(s) of an ESS shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its transportation, installation and intended use. The enclosure strength shall be determined and specified to demonstrate compliance. The enclosure strength requirements outlined in UL 50, UL 1741, IEC 62477-1, UL 2755, ISO 1496-1 or equivalent standard shall be applied to demonstrate compliance.

Exception: For smaller systems that are less than or equal to 50 kWh, the enclosure strength may be evaluated to the enclosure requirements of this Standard and tested in accordance with the applicable tests of Section 40.

9.2 Rack assemblies complying with UL 2416 are a means to meet this criteria for internal support structures of the ESS if the assembly is used within its load ratings. See also 10.2 regarding walk-in units and modifications to load bearing walls.

9.3 Openings in the enclosure of an ESS shall be designed to prevent inadvertent access to hazardous parts. Compliance shall be determined in accordance with the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, Clause 12 of IEC 60529 or CSA C22.2 No. 60529, for a minimum IP rating of IP2X and CSA C22.1, the Enclosure Selection Table for Nonhazardous Locations, with consideration of the end use installation.

Exception: An ESS intended for restricted access locations need not meet the accessibility criterion if permanent warning markings for service and other personnel having access to the system are provided directly on the system. Protection from access to hazardous live parts in restricted locations shall be in accordance with Article 110 of NFPA 70, or Sections 2 and 36 of the CSA C22.1, or Section 124 of IEEE C2, as applicable. Suitable cautionary warnings and signage for identifying exposed hazardous voltage circuits shall be provided for protection of service personnel.

9.4 In service access areas, bare parts of hazardous voltage circuits, shall be located or guarded so that accidental shorting across circuits at opposite polarity, to ground, to SELV circuits or communications circuits, that could be caused by items such as, but not limited to, tools or test probes used by service personnel, is unlikely.

9.5 Enclosures of systems and components of systems located where they will be subject to exposure to water and other elements shall be rated for the level of intended exposure as outlined in Table 110.28 of Article 110 of NFPA 70, or Section 2 of CSA C22.1 or for the ingress protection rating of IPX3 or higher as outlined in IEC 60529 or CSA C22.2 No. 60529 if using as IP rating. Installation instructions shall indicate restrictions with regard to limiting ingress from the environment based upon the enclosure rating.

10 General Electrical Safety of Systems and Additional Requirements for Walk-in Units

10.1 The instructions shall include measures and procedures for worker safety in, on and adjacent to the ESS according to NFPA 70E and CSA Z462, and Section 2 of CSA C22.1, and in accordance with this Standard.

10.2 Walk-in unit enclosures shall have suitable mechanical load ratings for equipment installed within the enclosure, including maximum number of persons who may enter the enclosure when all of the equipment is installed.

10.3 Shipping container type enclosures with cutouts or other modifications to support walls that may affect their load bearing performance shall be re-evaluated to ASTM D4169 for ability to handle the intended loads post modification.

10.4 The enclosures for outdoor walk-in units shall not exceed 16.2 × 2.6 × 2.9-m (53 × 8.5 × 9.5-ft) high, not including HVAC and related equipment that may be secured to the exterior of the enclosure. A walk-in enclosure exceeding these dimensions are subjected to indoor installation criteria in accordance with the applicable codes.

10.5 If the walk-in unit is provided with an explosion venting system, it shall comply with the applicable requirements in 24.5.

10.6 Where persons can access the hazardous areas within a walk-in unit, procedures for safe entry into and exiting the system shall be provided in the instructions provided with the ESS. Means, such as, but not limited to a placard(s) and lock(s), shall be provided to prevent unauthorized persons from entering these hazardous areas. See 46.17.

10.7 Personnel doors of walk-in units shall be designed to prevent persons from becoming trapped within the unit and shall be able to be opened from the inside without use of a tool or key. Door(s) intended for entrance to, and egress from a walk-in unit, shall open in the direction of egress and provide a clear width of at least 80 cm (32 in) and clear height of at least 183 cm (72 in) based on the dimensions specified in the ICC IBC. Each egress door shall be marked in accordance with 45.19 and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked in accordance with 45.19 or with an indication of its actual use. See also 45.18.

10.8 Work space dimensions and requirements within an ESS, provided with walk-in enclosures, shall be in accordance with NFPA 70, or CSA C22.1, or in accordance with IEEE C2 as applicable to where the system is installed. The space requirement shall also provide for appropriate arc flash safety under specified personal protective equipment (PPE). See 45.13.

10.9 Areas of access to walk-in units shall be designed to prevent tripping, slipping or falling when persons enter, exit or while within the unit. Surfaces and parts within a walk-in unit shall be designed to prevent inadvertent hazards to personnel within the enclosure through appropriate guarding, electrical and thermal insulation methods and cautionary warnings and signage in accordance with this Standard. See 10.7 and 45.16.

10.10 Protection against contact with hazardous voltage parts in the ESS, including walk-in enclosures, shall be in accordance with 9.3 or through the use of guarding to prevent access with cautionary warnings and signage where only qualified personnel are allowed access. Entrances to walk-in enclosures that contain exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter. See also 12.2 with regard to disconnect criteria for servicing, etc. and 45.13 and 45.16. The enclosures of walk-in units shall be provided with grounding in accordance with 14.4.

10.11 The type of protection equipment to be provided for arc flash hazards shall be determined by an arc flash risk assessment conducted according to NFPA 70E and CSA Z462. The arc flash assessment results shall be labeled on the ESS. The assessment shall determine:

a) The arc flash incidental energy level;

b) The arc flash boundary, restricted approach boundary; and

c) The required arc flash personal protective equipment.

10.12 The boundary for an unprotected arc flash shall be considered one that has an arc rating above 5 J/cm^2 (1.2 cal/cm^2) incident energy level (e.g. can cause a second degree burn to unprotected skin) per NFPA 70E and CSA Z462.

10.13 Energy storage system enclosures that can be fully entered by persons such as walk in units, shall be designed to automatically provide mechanical ventilation using 100 % outdoor air when anyone is working within the enclosure. The minimum amount of ventilation air shall be 5.1 $L/s/m^2$ (1 $cf/min/ft^2$).

10.14 Electrical circuits that are an integral part of the ESS including those that are part of a walk-in enclosure including lighting, controls, power, HVAC, emergency lighting, alarm circuits, and the like shall comply with the appropriate requirements for the type of equipment and the specific application within the ESS.

10.15 Electrical equipment including electrical equipment that is located in the walk-in enclosure in areas that will be subject to condensation, or the effects of condensation from equipment or systems that are provided with and installed in, on or around the ESS enclosure, shall be suitable for outdoor use or suitably protected against contact with water and protected against unsafe conduction of hazardous voltages to personnel via water as a conduction path.

10.16 Lighting shall be provided in enclosed working spaces associated with the ESS. The lighting source shall provide at least 100 lux and controlled only by manual means. Lighting within an ESS including lighting within a walk-in enclosures shall be installed in accordance with Article 410 of NFPA 70 or Section 30 of CSA C22.1 as applicable to the system where the system is installed.

10.17 Where there is more than one source of energy input to the ESS, the ESS shall be provided with information and markings to indicate which disconnect device or devices are required to be operated to completely isolate the equipment.

10.18 Protection against lightning surges shall be provided in accordance with the requirements of NFPA 70 or CSA C22.1, or IEEE C2 as applicable to where the system is intended to be installed.

11 Wiring and Electrical Supply Connections

11.1 Wiring installed on the equipment, including internal wiring or supplied with the equipment for installation on-site, shall be insulated and acceptable for the intended purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected where the wiring is located.

11.2 Wiring methods and electrical supply connections of energy storage systems shall be in accordance with NFPA 70 or CSA C22.1, or IEEE C2 as applicable to where the system is installed. Energy storage systems which are considered evaluated pieces of equipment shall ensure the electrical supply connections comply with NFPA 70, CSA C22.1 or IEEE C2 as applicable to where the system is installed. Wiring methods for such evaluated pieces of equipment are encouraged to follow the aforementioned codes, but at a minimum shall comply with this Wiring and Electrical Supply Connections Section.

11.3 An ESS shall have provision for connection of the system to an external wiring system consisting of:

a) Wiring terminals or wiring leads; or

b) A means for connection of cable or conduit in accordance with the codes in 11.2.

11.4 A wiring terminal or lead that is supplied as a component of the ESS shall be rated and sized for connection to a field wiring conductor having an ampacity of no less than 125 % of the ac or dc current that the circuit carries during rated conditions and in accordance with the codes in 11.2.

11.5 A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is to be connected, and shall not be smaller than 2.08 mm^2 (14 AWG). A field-wiring lead shall not be less than 152.4-mm (6-in) long.

Exception No. 1: Communications cable may be less than 2.08 mm^2 (14 AWG).

Exception No. 2: Field wiring harness accessories supplied by the manufacturer and evaluated for use with the system.

11.6 Field-wiring compartments, in which branch circuit connections are to be made, shall:

a) Permit the connection of the supply wires after the ESS is installed;

b) Permit the connection to be introduced and connected easily and safely; and

c) Be located so that the connections can be readily inspected after the ESS is installed.

11.7 Internal wiring shall be routed, supported, clamped or secured in a manner that reduces the likelihood of excessive strain on wire and on terminal connections; loosening of terminal connections; and damage of conductor insulation. In safety critical circuits, for soldered terminations, the conductor shall be positioned or fixed so that reliance is not placed upon the soldering alone to maintain the conductor in position.

11.8 A hole by which insulated wires pass through the system enclosure or elements providing separation within the enclosure shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, to prevent abrasion of the insulation.

11.9 Where multiple conductors are installed in parallel, they shall be installed in groups consisting of not more than one conductor per phase, neutral or ground so that the current in each group sums to zero. Where conductors pass through a metal opening, all conductors in a group shall pass through the same opening.

12 General Electrical Equipment

12.1 Replaceable fuses shall have a fuse replacement marking with the fuse ratings located adjacent to each fuse or fuse holder, or on the fuse holder, or in another location provided that it is obvious to which fuse the marking applies. Where replaceable fuses with special characteristics such as time delay or breaking capacity are necessary, the type shall also be indicated. Information on proper fuse replacement of replaceable fuses shall also be included in the service manual instructions.

12.2 Exposed hazardous voltage in an ESS shall be provided with a lockable manual disconnect to enable Lock-Out-Tag-Out (as required in NFPA 70E and CSA Z462) during servicing or for emergency procedures. The lockable manual disconnect shall have sufficient interrupt ratings, shall be accessible to the technician servicing the system and to first responders and shall be located as close to the exposed hazardous voltage conductors as possible. When the lockable manual disconnect is not provided directly on the system by the system manufacturer, the installation instructions shall indicate the type and ratings of the disconnect to be provided in the installation and how it is to be installed in accordance with NFPA 70E and CSA Z462.

Exception: A lockable disconnect is not required where it is infeasible based upon the design of the system (e.g. interspersed in the middle of a high voltage battery string, within a battery system, to segment the string into segments less than the minimum hazardous voltage).

12.3 Fuses, circuit breakers and disconnect devices shall be rated for the application including fault current ratings, suitability for disconnect under load, etc., as applicable to the device and application in the system. The ESS shall be provided with short circuit protection within the system to mitigate hazards associated with a short circuit condition of the integral energy storage technology, including addressing the potential for additive fault currents when multiple battery systems are connected in parallel. This protection shall be provided as part of the energy storage technology or installed as a separate component within the ESS. Protection against overload and short circuits of external circuits shall use branch circuit rated protectors or electronic circuits evaluated for the purpose.

12.4 Transformers installed as part of the ESS shall be of the dry type or type filled with a non-combustible dielectric medium. Such transformers shall be installed in accordance with the requirements of NFPA 70 or CSA C22.1, or in accordance with Section 15 of IEEE C2 as applicable to where the system is installed.

12.5 With reference to 12.4, oil filled transformers shall be permitted for use in outdoor locations in accordance with the applicable local codes or utility requirements.

12.6 Convenience receptacles provided for maintenance and servicing of the ESS shall be rated for outdoor use if the system is intended to be installed where the receptacle is exposed to the outdoor environment or outdoor environmental conditions.

12.7 The inverter and other equipment connected to the output terminals of the battery or other storage device of the ESS shall be able to safely withstand the potential short circuit current from the storage device. The rated input short circuit current of the inverter and other equipment shall be equal to or greater than the rated output short circuit current of the battery or other energy storage mechanism. Compliance can be determined through evaluation of the output short circuit ratings of the energy storage mechanism (e.g. for the battery) as determined by testing in UL 1973. For equipment capable of providing an output short circuit current, the rating shall reflect the protection provided by any internal branch circuit protectors, including electronic circuit regulation, such as limitation of peak currents, inrush currents and time. An energy storage mechanism relying on a branch circuit protector installed on the output of the energy storage mechanism shall provide the maximum short circuit current from that device.

13 Electrical Spacings and Separation of Circuits

13.1 Electrical circuits within the ESS at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits or potential for arc flash (i.e. electrical spacings on printed wiring boards, physical securing of uninsulated leads and parts, etc.). Insulation suitable for the anticipated operating temperatures and voltages shall be used where spacings cannot be controlled by reliable physical separation.

13.2 Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 13.1 or as outlined in UL 62368-1/CSA C22.2 No. 62368-1, Clearances, Clause 5.4.2, and Creepage Distances, Clause 5.4.3.

Exception No. 1: The spacing requirements in UL 840, CSA C22.2 No. 62109-1, UL 62109-1, IEC 60664-1, or CSA C22.2 No. 0.2, shall be acceptable alternatives. The anticipated pollution degree and overvoltage category is determined by the design and application of the ESS assembly or subassembly under evaluation.

Exception No. 2: Electrical spacings within components and parts of an ESS previously determined to comply with an appropriate safety standard for the equipment need not be evaluated.

Table 13.1
Electrical Spacings

Part	Voltage V	Through air mm (in)	Over surface mm (in)
Live parts and dead metal parts that are separated by functional or basic insulation.	0 – 50[a]	1.6 (1/16)	1.6 (1/16)
	51 – 130	3.2 (1/8)	4.8 (3/16)
	131 – 300	6.4 (1/4)	9.5 (3/8)
Accessible dead metal parts and dead metal parts separated from live parts by basic insulation only[b]	0 – 50[a]	1.6 (1/16)	1.6 (1/16)
	51 – 130	3.2 (1/8)	4.8 (3/16)
	131 – 300	6.4 (1/4)	9.5 (3/8)
Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation.	0 – 50[a]	3.2 (1/8)	3.2 (1/8)
	51 – 130	6.4 (1/4)	9.5 (3/8)
	131 – 300	12. 7 (1/2)	19 (3/4)
An uninsulated live part and:			
1) An uninsulated live part of opposite polarity;	301 – 600	9.5 (3/8)	12.7 (1/2)
2) An uninsulated grounded part other than the enclosure; or	601 – 1000	14.0 (0.55)	17.8 (0.70)
3) An exposed metal part (basic insulation).	1001 – 1500	21.6 (0.85)	30.5 (1.20)
An uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable (basic insulation).	301 – 600	12.7 (1/2)	12.7 (1/2)
	601 – 1000	20.3 (0.80)	25.4 (1.00)
	1001 – 1500	30.5 (1.20)	41.9 (1.65)

[a] Spacings shall be permitted to be decreased from those indicated in the table if it can be determined through test or analysis that the circuits are supplied by limited power sources as defined in the Circuits Intended for Interconnection with Building Wiring Annex of UL 62368-1/CSA C22.2 No. 62368-1.

[b] This is a spacing resulting from supplementary insulation if ungrounded.

13.3 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 60 Vdc or above 30 Vrms, 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 60 Vdc or for basic or functional insulation. Some examples include potting, encapsulation, and vacuum impregnation. Materials employed as electrical insulation shall meet the requirements of 7.5.

13.4 Conductors of circuits operating at different voltages shall be reliably separated from each other through the use of mechanical securements such as barriers or wire ties to maintain spacing requirements unless they are each provided with insulation acceptable for the highest voltage involved. An insulated conductor shall be reliably retained so that it cannot contact an uninsulated live part of a circuit operating at a different voltage.

14 Insulation Levels and Protective Grounding

14.1 Hazardous voltage circuits shall be insulated from accessible conductive parts and safety extra low voltage (SELV) circuits as outlined in 14.2 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 that complies with 14.3;

b) A system of double or reinforced insulation; or

c) A combination of (a) and (b).

14.2 Safety extra low voltage (SELV) circuits, as defined in 6.40, that are insulated from accessible conductive parts through functional insulation only are considered accessible.

14.3 Accessible non-current carrying metal parts of an ESS containing hazardous voltage circuits that could become live in the event of an insulation fault shall be bonded to the equipment ground terminal. The main grounding terminal shall be identified through use of grounding symbol, green coloring or word “GR” etc. to signify it as the equipment ground terminal and shall not be utilized for any other purpose than for the connection of the grounding and bonding conductors.

14.4 The methods of protective bonding and grounding of an ESS shall be in accordance with Article 250 of NFPA 70 or Section 9 of IEEE C2 as applicable to where the system is located. When sizing the protective bonding and grounding wire, the rating and fault current path of all sources of supply connected to the equipment or system shall be considered. If used, grounding (bonding) braids used in the ESS or from the ESS to the grounding electrode shall comply with UL 467/CSA C22.2 No. 41, and sized according to the Grounding – Size of Terminal or Bonding Conductor requirements of UL 508A or CSA C22.1.

In Canada, the methods of bonding and grounding an ESS shall be in accordance with Section 10 and 36 of CSA C22.1.

14.5 Parts of the protective grounding system shall be securely fastened and provided with metal-to-metal contact that will ensure the continuity of the grounding system. All connections shall be secured against accidental loosening and shall ensure a thoroughly good connection. See 14.6, 14.7, and Section 33.

14.6 With reference to 14.5, 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. Bonding shall be achieved through the use of dedicated connections that are not utilized for other purposes.

14.7 With reference to 14.5, 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) Fusion 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.

14.8 For ESS greater than 100 V between conductors or to ground, the battery circuits can be ungrounded if the system is provided with a ground fault detector and indicator to monitor ground faults.

15 Safety Analysis and Control Systems

15.1 A safety analysis consisting of a hazard identification, risk analysis and risk evaluation including a safety analysis such as a failure modes and effects analysis (FMEA) that identifies critical safety components and circuits of the system, shall be conducted on the equipment forming the ESS and components of the ESS considering any interactions that provide a safety function. The analysis shall consider the compatibility of the parts of the ESS (e.g. battery system, charger, inverter, etc.) with regard to safety of the overall system. The analysis shall be performed by the manufacturer of the ESS or the entity that integrates the components that comprise the ESS, referred to as the energy storage system integrator. Guidance for analysis can be found in the following standards:

a) IEC 60812;

b) IEC 61025; and

c) MIL-STD-882E.

15.2 Even when the major parts of the ESS are in compliance with their individual safety standards and they are being used within their ratings, it cannot be assumed that when the parts are connected together to form an ESS that the system is safe, without further analysis. The analysis of the ESS must evaluate whether or not the various parts of the ESS, even though determined to be safe individually, work compatibly with each other to prevent hazardous conditions from occurring. When conducting this analysis, it is important that the interaction of the various parts of the ESS be evaluated as noted in 15.1 to determine that there are no hazards introduced in the system as a result of their interaction. For example, communications delays between parts that could affect safety, surges or noise introduced from power conditioning devices or noise introduced from electrical connections, shall not affect the functionality or result in damage to these safety controls such as the battery management system (BMS), contactors or the energy storage management system.

15.3 The safety analysis shall consider mechanical, thermal and other potential hazards associated with the ESS in addition to potential electrical hazards. This is especially critical when evaluating systems with hazardous kinetic energy, thermal ESS operating at hazardous temperatures and/or containing hazardous materials, and systems with parts under hazardous pressure levels. Analysis of flywheel systems shall be conducted on the bearing failure detection system, which shall detect signs of bearing failure before catastrophic bearing failure occurs. The bearing failure detection system shall be designed to initiate safety mechanisms within the flywheel control system to bring the flywheel to a safe state upon detecting signs of impending bearing failure. Analysis of flywheel systems shall also include the feedback and control for any active magnetic bearings or passive bearing used in conjunction with active unloading systems.

15.4 Analysis of thermal ESS shall ensure that there is sufficient monitoring and control of pressure, thermal and fluid flow to ensure that the various parts of the system are maintained within their specifications for pressure temperature and fluid levels.

15.5 Electrical and electronic controls of the ESS that are determined to be critical for safety shall comply with an appropriate safety standard for the control and used within their ratings. Electronics and software controls determined to be critical for safety are to be tested to verify electromagnetic immunity in accordance with Section 36 if this testing is not part of the functional safety standard requirements, and shall be evaluated for functional safety to one of the following sets of standards and safety ratings as applicable to the system:

a) UL 991 and UL 1998;

b) CSA C22.2 No. 0.8 (Function Class B requirements);

c) The Annex for Requirements for Electronic Controls, Annex H of UL 60730-1 or CSA E60730-1 (Function Class B requirements);

d) IEC 61508 (all parts) (minimum of Safety Integrity Level (SIL) "2" requirements for active protective devices with software controls);

e) ISO 13849-1 and ISO 13849-2 (minimum of Performance Level (PL) "c" requirements for active protective devices with software controls); or

f) ISO 26262 (all parts) (minimum Automotive Safety Integrity Level (ASIL) "C" requirements for active protective devices with software controls).

15.6 The required SIL, PL, or ASIL for a safety function shall be permitted to be reduced if the manufacturer provides additional safety analysis (e.g. Layer of Protection Analysis) showing that the required risk reduction level has been reduced by other measures within the ESS.

15.7 When conducting the functional safety evaluation of electronic controls, the interaction of the various parts of the system need to be considered for their impact on each other. In particular, a number of disruptive interactions shall be considered in all cases. These interactions include:

a) Noise, or other disturbances introduced into the system as a result of the interaction of the various ESS components such as between the PCS and the BMS of the battery or other electronic controls, shall be considered when evaluating the reliability of electronic and programmable electronic controls;

b) The surge protection evaluation of the BMS and other electronic controls shall be sufficient to address potential surges that may be transmitted from the PCS or other equipment;

c) Surge suppression protection shall be provided to protect the BMS or other electronic safety controls devices, if the control functionality of a BMS or other controls can be impacted as a result of this interaction;

d) Parts such as power conditioning system (PCS) connected to the storage devices of the system (e.g. batteries), shall be able to safely withstand a fault current from the storage devices including current that is transmitted prior to operation of the short circuit protection; and

e) Delays or other faults in communication signals between the various parts of the ESS that can impact safety.

15.8 Software and its associated hardware determined critical to safety that can be updated remotely shall meet the requirements outlined in Section 16, Remote Software Update Enabled ESS. Section 16.1 applies to software evaluated in accordance with UL 1998 and Section 16.2 applies to software evaluated in accordance with UL 60730-1 or CSA E60730-1.

16 Remote Software Update Enabled ESS

16.1 Critical and/or critical supervisory software (UL 1998)

16.1.1 The requirements in 16.1.2 – 16.1.7 apply when the manufacturer declares the ESS has critical and supervisory and related critical supervisory sections of software per UL 1998, and has the functionality to remotely update this software.

NOTE 1: A software update occurs when software replaces or modifies the previous version by a new or the same version of the critical/supervisory sections of UL 1998 software.

NOTE 2: These requirements are not intended to address cybersecurity.

16.1.2 The critical/supervisory sections of UL 1998 software, intended to be updated, shall comply with UL 1998.

16.1.3 User authorization is required prior to any remote update of critical/supervisory sections of UL 1998 software.

NOTE: User authorization can be a one-time event. This one-time event may be when the homeowner of a residential ESS registers their ESS with the manufacturer, or downloads the application needed to remotely operate the residential ESS controls on their smart device (e.g. cell phone, tablet, etc.).

16.1.4 The remote update of software shall occur when the ESS is in a risk addressed state.

16.1.5 The remote software update shall comply with UL 5500, with the following modifications:

a) The device specific requirements for a remote update of software, per the requirements for Application of Received Software Download Package in UL 5500, shall occur when the ESS is in a risk-addressed state; and

b) The bulleted items in the compliance criterion of the requirements for Documentation & Tracking in UL 5500 are replaced with the following:

1) Communication protocol (Compliance with the requirements for Establish Remote Connection, and the requirements for Download/Transmission in UL 5500);

2) Software update process (Compliance with the requirements for Hardware / Architecture / Software Download Package Compatibility Check, Application of Received Software Download Package, and Conclusion of Remote Software Update Process in UL 5500);

3) Identity and access management (Compliance with the requirements for Authentication, and Authorization in UL 5500); and

4) Validation measures (Compliance with the requirements for Remote Software Update Validation: General, Failure/Status Identification Detection, Response to Error Detection, and Software Download Package Version in UL 5500).

16.1.6 The correct operation of the ESS safety functions shall be maintained after the critical/supervisory sections of software in accordance with UL 1998 software is updated.

16.1.7 Compliance is checked by a functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update. Consideration shall be made for a functional test (based on an impact analysis of the changes made to the software) to verify the proper operation of the ESS system protective control functions.

NOTE: When determining which safety functions need to be verified after the update has been completed, consideration is to be given to the specific aspects of the software that have been updated.

16.2 Class B software (UL 60730-1 or CSA E60730-1)

16.2.1 The requirements in 16.2.2 – 16.2.8 apply when the manufacturer declares the ESS has Class B software in accordance with UL 60730-1 or CSA E60730-1, and has the functionality to remotely update this software.

NOTE 1: An update occurs when software replaces or modifies the previous version of the Class B software, UL 60730-1 or CSA E60730-1 software. Additionally, an update occurs when the same version of Class B software, is replaced during the remote update process.

NOTE 2: These requirements are not intended to address cybersecurity.

16.2.2 The Class B software of UL 60730-1 or CSA E60730-1 intended to be remotely updated, shall comply with the requirements for Controls Using Software in UL 60730-1 or CSA E60730-1.

16.2.3 The remotely actuated control function, including the software update function, shall comply with the requirements for Remotely Actuated Control Functions in UL 60730-1 or CSA E60730-1. With respect to transmission faults, Note 1 of Clause H.11.12.4.1.3.1, Transmission, is considered normative.

NOTE 1: A remotely actuated control function is a function providing any operation by control devices through external means. This includes, but is not limited to:

a) The use of communication lines/protocols;

b) IR/RF transmission; or

c) All combinations of (a) – (b) above via Internet using, for example modems, portable telephones, etc.

NOTE 2: Remote software updates require minimum or no interaction with the ESS. Software updates are received remotely without the use of external hardware such as a USB, SD card, etc.

16.2.4 Remotely actuated control functions may be connected to separate, independent devices, which may themselves contain control functions or provide other information. Any data exchange between these devices shall not compromise the integrity of the Class B control function.

16.2.5 User authorization is required prior to any remote update of Class B software, UL 60730-1 or CSA E60730-1. This will be evaluated in accordance with UL 60730-1 or CSA E60730-1, Clause H.11.12.4.4.3.

NOTE: User authorization can be a one-time event. This one-time event may be when the homeowner registers their residential ESS with the manufacturer, or downloads the application needed to remotely operate the ESS on their smart device (e.g. cell phone, tablet, etc.).

16.2.6 The remote update of software shall occur when the ESS is in a risk addressed state.

16.2.7 The correct operation of the ESS's safety functions shall be maintained after the Class B software is updated per UL 60730-1 or CSA E60730-1.

16.2.8 Compliance is checked by a functional test of a remote software update using the procedure outlined in Operational Verification of Remote Software Update Capability in 36.9 after implementing a remote software update. Consideration shall be made for a functional test (based on an impact analysis of the changes made to Class B software) to verify the proper operation of the ESS protective control functions.

NOTE: When determining which safety functions need to be verified after the update has been completed, consideration is to be given to the specific aspects of the software that have been updated.

17 Remote Controls

17.1 Energy storage systems which have the ability to be controlled and operated remotely shall be provided with an accessible means to disconnect the system from the remote control for maintenance or other local servicing of the system. The remote control disconnect shall either be provided on the system or instructions in the installation manual shall provide the location and type of disconnect to be provided in the end use installation. The use of a remote control systems shall not lead to an unsafe condition as determined by the system safety analysis and shall not be able to override local safety controls. If the remote control disconnect is to be provided as part of the installation (not built into the ESS), the instructions shall include information on the electrical connections including means to prevent the disconnect from being overridden by the remote control system.

17.2 Remote disconnect controls such as Emergency Power Off (EPO) buttons shall be marked to clearly indicate what system or part of the system they control. Remote disconnect control such as EPOs that disconnect and de-energize the complete ESS, need to not be marked in this manner.

18 Communication Systems

18.1 General

18.1.1 Instructions for installation and operation of the ESS shall identify the communication protocols used by the ESS for communication with external systems intended to be connected to the ESS. Energy storage system components and subassemblies that need to communicate with each other to ensure safe operation of the system, shall utilize harmonized communication protocols, and evaluation of the compatibility of these interconnecting communication systems shall be included in the safety analysis of Section 15.

18.2 External warning communication system (EWCS)

18.2.1 Electrochemical ESS using lithium-ion batteries as the storage mechanism that have an energy capacity of 500 kWh or greater shall be provided with an external warning communication system, as outlined in 18.2.2 – 18.2.6, that gives an advance notification to operators of a potential safety issue with the ESS.

18.2.2 The information inputs to the EWCS shall come from those devices in the ESS that can supply information of potential problems that could lead to a hazardous state of the system, including from the battery management systems (BMS) or the energy storage management system (ESMS). The EWCS shall use compatible communication interface methods with its various sources of information from the ESS.

18.2.3 The EWCS shall communicate with an operator station that is monitoring the ESS. The EWCS shall be capable of sending information to an external operating station. The EWCS shall also communicate to a local warning system that utilizes audio and visual warning signals when the ESS is operating in a hazardous state. Those conditions that require immediate intervention and notification of the fire service shall result in operation of an external warning signal such as a warning light and audio alarm.

NOTE: The methods of communication to the external operating station can vary depending upon the design of the system.

18.2.4 The EWCS and the sources providing information to the EWCS shall be evaluated as part of the safety analysis of the system in Section 15. The analysis shall identify those signals/information from the various sources that would warrant the EWCS to provide warning communications to operators and local alarms that the system may have a potential safety issue that needs to be addressed to prevent further escalation. Those signals that signify the need for an escalation of the warning to the local fire department shall also be identified in the analysis. The analysis shall determine that the EWCS is capable of receiving the signals from the various sources to send communication to the operators as necessary.

NOTE: Examples of information that may be fed into the EWCS from the BMS or EMS are overvoltage conditions, over temperature conditions, excessive BMS error messages, operation of overcurrent devices, integral gas detection indicating cell venting, etc.

18.2.5 The EWCS shall be installed as an integral component of the ESS. It can be supplied by the lithium batteries it is monitoring, but the EWCS shall also have a dedicated backup power source independent of the batteries it is monitoring to prevent data to and from the EWCS being lost or interrupted as part of the primary power source failure, or delayed by more than 10 s. The backup power source shall be capable of providing power for at least 5 h for the data input and operator communication portion of the system. This back power source need not supply any visual or audible sirens supplied as a part of the system for more than 5 min.

18.2.6 Instructions on the installation, operation and any ongoing maintenance of the EWCS including its back up power source shall be provided with the ESS instructions. If installed indoors, the instructions shall reference applicable criteria from the Notification Appliances Chapter of NFPA 72, for location and required intensity of visual and audio alarms to be installed in the installation. Visual alarms shall be in accordance with UL 1638, and audio alarms shall be in accordance with UL 464/ULC 525. The maximum sound level for audio alarms shall not exceed 110 dBA at the minimum hearing distance. For outdoor installations, visible alarms installed on the ESS, shall be located no less than 203.2 cm (80 in) nor more than 243.8 cm (96 in) above the ground.

19 Heating and Cooling Systems

19.1 Energy storage systems that rely upon thermal management systems, either integral to the system or provided at the installation site, to prevent overheating or operation outside the specified safe operating range of the energy storage technology shall be designed to safely shutdown upon failure of the thermal management system unless it can be demonstrated, that the thermal management system failure does not result in a hazardous situation.

20 Piping Systems, Pressure Vessels, Fuel and Other Fluid Supply Connections and Controls

20.1 Piping systems, pressure vessels, fuel and other fluid supply connections and controls shall comply with 20.2 – 20.10.

Exception No. 1: Systems that are evaluated as part of a battery to UL 1973 need not comply with 20.2 – 20.10.

Exception No. 2: Coolant systems can be evaluated to the performance requirements of the Specific Requirements for Liquid Cooled PDS clause in UL 61800-5-1 or CSA C22.2 No. 61800-5-1.

20.2 Piping systems utilized to carry fluids in an ESS such as water, heated air, fuel gases, etc. shall comply with ASME B31 (all applicable parts), or CSA B51, or CSA B52, or CSA Z662, or CSA B149.1 as applicable.

20.3 Pressure vessels and related equipment including pressure relief devices that fall under the scope of ASME BPVC, or CSA B51, shall comply with the applicable requirements.

20.4 Flammable fuel supply connections on the ESS shall be suitable for the material contained and in accordance with the applicable part of ASME B31 based upon the fluid, temperatures and pressures they are subjected to.

20.5 A means shall be provided to prevent backflow of process gases, etc. into the fuel supply lines either as part of the ESS design or indicated in the installation instructions.

20.6 The ESS shall be designed so that process water used in the system shall be prevented from contaminating potable water sources in accordance with local regulations through the use of check valves or other means as part of the system design.

20.7 Piping, hose, and tubing containing fluids, shall be routed and secured to prevent leakage that could result in a fire, explosion or shock hazard (e.g. liquid leaking onto electrical circuits that can lead to short circuits). Pressure relief valves shall be located so that fluids are not directed toward live parts or safety critical circuits should they operate.

20.8 ESS containing liquids, including ESS with coolant systems containing liquid coolant, shall be provided with some means of leak detection to monitor for loss of coolant that could lead to a potential hazardous condition. Coolant leaks that are detected shall result in a warning signal to the ESS monitoring and control system and shall initiate an alarm if provided.

20.9 Manual shut off valves shall be provided on or near the ESS in a location where they can be accessed to allow for disconnection of the fuel or water supply to the ESS for maintenance, etc. If not provided on the system itself, installation instructions shall indicate type, ratings and location for installation of appropriate manual shut off valves. Automatic (nonelectric type) and manual valves intended for the use in flammable fluid lines shall comply with UL/ULC 842. Solenoid valves shall comply with UL 429 or CSA C22.2 No. 139. Where flammable liquids are in use, an automatic shutoff valve shall be provided to limit the release of fuel during an abnormal condition.

20.10 Pressure regulators used on flammable or other hazardous gas lines shall comply with UL 252, CSA Z662, or CSA B149.1, as applicable.

21 Containment of Moving Parts in Mechanical ESS

21.1 Mechanical ESS having moving parts with the capacity to store kinetic energy (flywheel systems) shall be provided with a means to contain the moving parts in the event they could become loosened during operation or through the influence of external forces. If it is possible for moving parts to become dislodged upon breakage or damage to their securement means, the containment mechanism shall adequately contain the loosened moving parts to prevent hazards to persons or the surrounding built environment. See Section 37.

21.2 The alternator/generator elements associated with mechanical ESS shall comply with UL 1004-1 and other parts (UL 1004-2, UL 1004-3, UL 1004-5, UL 1004-6, UL 1004-7, UL 1007-8, UL 1004-9) as applicable or CSA 22.2 No. 100.

22 Noise Levels

22.1 The noise level from an ESS during operation, including noise levels in walk-in ESS that can be entered during operation, shall be limited to an 8-hr time-weighted average of 85 dBA when tested in accordance with 29 CFR 1910.95 (C)(1)(2). Measurements of the sound are determined in accordance with 29 CFR 1910.95 or equivalent method. Systems that have noise levels in excess of this limit shall be provided with warning labels and instructions that address hearing protection and other protective measures to be taken for those who may be exposed to the noise in accordance with 29 CFR 1910.95.

NOTE: 29 CFR 1910.95 (C) (1)(2) indicates an 8-hr limit of 90 dBA, unless exposures can exceed 85 dBA greater than 50 % of the time. The lower 85 dBA is chosen as this is a limit in accordance with NIOSH limits and other standards. This still exceeds the limits of the EU machinery directive, which is 80 dBA.

23 Hazardous Fluid Control

23.1 Where the system contains fluid in excess of 208 L (55 gal) in a single vessel or an aggregate of more than 3785 L (1000 gal), secondary containment shall be provided. Methods utilized for spill control shall be sufficient to contain all of the fluid from the largest liquid vessel within the system and designed to prevent inadvertent filling with rain if located outdoors. Where flammable liquids are contained, any applicable fire detection and protection systems shall be specified or included as determined per Section 26. The spill control system shall accommodate additional water from any specified fire protection system for a period of 10 min. Automatic leak detection to annunciate the spillage of fluid shall be provided.

Exception: If containment is not provided as part of the product, then instructions regarding the need to provide containment, fire detection and protection systems and leak detection shall be included in the instruction manual. The instructions shall also specify the minimum volume of the containment and information about compatibility of the containment system with the fluid to be contained. See 46.12.

23.2 Where a system contains conductive fluids, the system shall be designed in a manner to prevent the fluids from causing a short circuit in the event of a spill. If spill control is not provided with the system, then the instruction manual shall provide directions on the spill control system design to prevent any short circuits from fluid spilled.

23.3 Neutralization of spills of any hazardous fluids shall be provided if necessary to insure compatibility with any materials the fluids may contact when in the spill control system. Such neutralization shall occur without the intervention of people and shall have the capacity to neutralize the volume of fluid specified in 23.1 to a pH level that is compatible with the materials in the spill control system. If required, neutralization shall be provided to insure safe clean up and disposal of the spill.

Exception: If neutralization is not provided as part of the product, then instructions regarding the need to provide neutralization shall be included in the instruction manual. The instructions shall also specify the type and quantity of neutralizing material required to meet the requirements of 23.3. See 46.12.

23.4 Energy storage systems that contain fluids shall be designed to prevent venting of toxic vapors in concentrations considered to be hazardous based on an evaluation conducted in accordance with Sections 38 and 39.

24 Combustible Vapor Concentrations

24.1 Enclosures of ESS that contain flammable fluid systems or batteries that vent hydrogen or other flammable gases to the atmosphere under normal operations shall be ventilated to prevent hazardous vapor concentrations unless electrical equipment located within the classified area/zone within the enclosure is rated for a Class I Division 1 classification or Zone 1 area/zone. Concentrations in non-hazardous areas/zones of the ESS shall be limited to 25 % of the lower flammability limit (LFL) under normal maximum operating conditions. Mechanical ventilation relied upon to maintain concentrations below the required limits shall be interlocked, so that the system shuts down upon failure of the ventilation system.

Exception: Vented battery systems with aqueous electrolytes such as lead acid or nickel cadmium that are provided with ventilation openings in their enclosures in accordance with 24.3, need not comply.

24.2 Electrochemical ESS which are not addressed in 24.1 and which are dependent on mechanical ventilation as a protection measure against emission of flammable gas that can occur during fault conditions to prevent hazardous gas concentrations within the system, shall be equipped with a fault detection system that activates the mechanical ventilation in a manner which prevents the LFL from exceeding 25 % in any non-hazardous area/zone within the ESS.

24.3 For ESS that contain batteries or similar storage devices, openings to prevent hazardous concentrations of flammable gases within an enclosure can be used. Openings in the enclosure provided for ventilation 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).

24.4 As an alternative to 24.3, ventilation openings shall have a minimum opening area of:

$$A = 0.005NC_5\,(cm^2)$$

Where:

A = Total cross sectional net free area of ventilation openings required (cm^2)

N = Number of cells in battery

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

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.

24.5 Electrochemical ESS with integral enclosures where there is the potential for a flammable gas concentration within the enclosure from an abnormal condition such as thermal runaway and propagation, shall be provided with deflagration or explosion protection in accordance with NFPA 68 or NFPA 69. This protection shall be installed on the ESS or its enclosure depending upon the type of protection and installed in a location where its operation shall not result in the introduction of a hazard after installation. See the figure for BESS Deflagration Protection Analysis, in the Annex for Test Concepts and Application of Test Results to Installations in UL 9540A for reference and guidance.

Exception No. 1: The protection is not required if the testing in accordance with UL 9540A with a deflagration hazard analysis demonstrates that the concentration of flammable gas measured during testing remains under 25 % LFL within the room, building, ESS cabinet, or walk-in ESS and there is no potential for partial volume deflagration.

Exception No. 2: For ESS cabinets/enclosures, protection other than as noted can be used if it has been determined that the ESS cabinet/enclosure has been designed to effectively protect against hazards due to combustible concentrations when the ESS has been tested in accordance with the Unit Level or Installation Level test of UL 9540A.

24.6 Portions of ESS, in which flammable vapor concentrations above 25 % LFL may be present during normal operating conditions, shall be provided with construction suitable for the classification in accordance with NFPA 70, CSA C22.1, or IEEE C2 as applicable to the intended installation.

24.7 Electrical compartments adjacent to classified zones within the ESS enclosure shall be maintained at positive pressure in accordance with NFPA 497, UL 60079-2 or CSA C22.2 No. 60079-2.

25 Flammable Solids

25.1 ESS containing hazardous solids (i.e. pyrophoric or water reactive metals) shall be designed and installed in accordance with NFPA 484.

26 Fire Detection, Suppression and Propagation

26.1 General

26.1.1 Fire detection and fire suppression equipment provided as an integral part of an ESS shall comply with applicable product safety standards and shall be installed in accordance with the applicable safety product standards and the manufacturer's instructions.

26.1.2 Energy storage systems with integral fire detection or fire suppression systems shall be provided with instructions for installing, commissioning, maintaining and testing these systems in accordance with applicable installation codes and standards. NFPA 1 and ICC IFC provide information on applicable requirements and codes for fire suppression systems. See also Annex A.

26.1.3 If the ESS manufacturer's instructions indicate that an integral fire detection or fire suppression system is optional, the ESS shall comply with all applicable performance requirements in this Standard with and without the integral fire detection or fire suppression system in place and operational.

26.2 Large scale fire testing

26.2.1 Electrochemical type ESS, including but not limited to capacitor and battery ESS, shall be subjected to the large scale fire testing in accordance with UL 9540A as follows in (a) – (d).

a) Systems with increased energy capacities as required in codes and standards;

b) Systems with decreased separation distances to adjacent ESS units, doors and windows, or exposures. See 46.2 and/or 46.4;

c) Indoor systems; or

d) Systems for installation in dwelling units (where permitted).

NOTE: See Annex E for guidance on code limits related to separation distances and energy capacity.

26.2.2 Electrochemical ESS intended for use in the living or habitable space of a residential dwelling unit (where permitted) shall meet the Performance – Cell Level Test requirements in UL 9540A. Systems complying with these requirements shall be marked in accordance with 45.3(e)(1).

NOTE: CSA C22.1 indicates the following wording for this marking "This equipment meets the cell level performance criteria of UL 9540A". See 45.3(e)(2).

26.2.3 Electrochemical ESS intended for use in dwelling units where UL 9540A testing is indicated per the codes and standards, shall minimally meet the Unit Level Performance Criteria for residential installations identified in UL 9540A with a test that aligns with the manufacturer's installation instructions. These ESS shall be marked in accordance with 45.3(e)(3).

26.2.4 Electrochemical ESS intended for non-residential use shall be subjected to specific large scale fire testing in accordance with UL 9540A for installations described in the manufacturer's instructions.

27 Power Conversion Equipment

27.1 General

27.1.1 Inverters, chargers, and charging charge control equipment that are part of an energy storage system shall be designed and rated for use with the battery system employed in the energy storage system and evaluated to UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, UL 1012, UL 62368-1/CSA C22.2 No. 62368-1, or CSA C22.2 No. 107.1 as applicable to the power conversion equipment and its application in the system.

Exception: UL 1778/CSA C22.2 No. 107.3 may be used as an alternative to the power conversion and charger equipment standard references if applicable to the ESS application serving an uninterruptible power system (UPS).

27.2 Utility grid interaction

27.2.1 Energy storage systems intended to export energy to the electric power systems (EPS)/electric utility shall be designated as utility-interactive, grid support utility-interactive, or special purpose utility-interactive and shall utilize the appropriately evaluated power conditioning systems. See 6.41, 6.44, and 6.45.

27.2.2 The inverter shall be designed to properly interconnect with the particular energy storage technology it is connected to as determined by the system safety analysis.

27.2.3 Products that rely upon internal or external utility interconnection protection functions or devices shall be specifically identified for the particular product in the ESS instructions.

27.3 Utility grid interactive inverter

27.3.1 A utility-interactive inverter, grid support utility-interactive inverters, or subassembly of an ESS shall comply with UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.

27.3.2 Utility-interactive ESS inverters shall be evaluated for compliance with additional utility interactive document(s) and standard(s) if those specific documents or requirements are referenced in the product ratings or instructions.

27.4 Standalone and multi-mode power conditioning systems

27.4.1 Power conditioning systems for standalone and multi-mode applications shall comply with UL 1741, UL 62109-1 or CSA C22.2 No. 62109-1, or CSA C22.2 No. 107.1.

28 Energy Storage System Technologies

28.1 Electrochemical ESS

28.1.1 Batteries, electrochemical capacitors, hybrid battery-capacitor systems or flow batteries used in an electrochemical ESS shall comply with the requirements of UL 1973. Testing and evaluation of the battery system, which would include the battery and its battery management system is conducted as part of evaluation to UL 1973. Inverters and charging equipment that are part of the ESS shall be designed for use with the battery system employed in the ESS. For general information on battery safety, see also informative Annex B.

Exception: For valve regulated or vented lead acid or nickel cadmium battery systems, see Annex D for an alternative approach.

28.2 Chemical ESS

28.2.1 A chemical ESS consists of storage of hydrogen fuel and the means to change the fuel into electrical energy using a fuel cell system or a hydrogen gas turbine. To convert electrical energy into hydrogen fuel, a hydrogen generator using water electrolysis is also part of the overall system. Fuel cell systems that are part of a chemical ESS shall comply with CSA FC 1, Fuel Cell Power Systems.

28.2.2 Stationary engine generators that are part of a chemical ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 286.

28.2.3 Water electrolysis type hydrogen generators used in an ESS to provide hydrogen for storage shall be evaluated and found to be in compliance to an appropriate safety standard for the equipment.

28.2.4 Hydrogen fuel containing parts of a chemical ESS shall be constructed of materials suitable for gaseous hydrogen service at the pressures and temperatures of use. Pressure vessels used for storage of gaseous hydrogen and piping employed as part of a chemical ESS shall comply with Section 20.

28.3 Mechanical ESS

28.3.1 Mechanical ESS such as, but not limited to, flywheel systems or compressed air energy storage (CAES) systems shall be evaluated to determine that hazards associated with moving parts with the capacity to store kinetic energy, and high pressure and high temperature fluids contained in the system are mitigated. Compliance is determined by evaluation to the requirements of this Standard.

28.3.2 Flywheel systems and other systems with moving parts with the capacity to store kinetic energy shall comply with the Containment of Moving Parts tests of Section 37 and the Strength Tests of Section 39. Parts containing hazardous fluids shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.

28.3.3 Flywheel energy storage devices with a maximum surface speed of 200 m/s or less fall within standard electric generator design practice and shall be evaluated in accordance with the Standard for Electric Generators, UL 1004-4 or the Standard for Motors and Generators, CSA 22.2, No. 100.

Exception: In some cases, flywheel energy storage systems with maximum surface speeds of 200 m/s or less may have features such as magnetic bearings that are not commonly found on ordinary electric machines as covered in UL 1004-4 or CSA 22.2, No. 100. The safety of these features shall be evaluated and tested to all applicable requirements in this Standard.

28.4 Thermal ESS

28.4.1 A thermal ESS consists of gases, fluids, and/or solids storing heat energy that can be turned into electrical energy when needed through the use of energy conversion equipment (e.g. engines, generators).

NOTE: The three types of thermal ESS are sensible heat, latent heat and thermochemical thermal ESS.

28.4.2 Thermal ESS shall be evaluated to determine hazards associated with containment of high temperature and high pressure and potentially hazardous fluids are mitigated. Compliance is determined by evaluation to the requirements of this Standard. Parts containing hazardous fluids and fluids at high temperatures and pressures shall comply with the Leakage Tests of Section 38 and the Strength Tests of Section 39.

28.4.3 Stationary engine generators that are part of a thermal ESS shall comply with UL 2200 or CSA C22.2 No. 100, and CSA C22.2 No. 286. Generators that are part of a thermal ESS shall comply with UL 1004-4 or CSA C22.2 No. 100.

28.4.4 Hazardous fluid containing parts of a thermal ESS shall be constructed of materials suitable for use with that fluid at the pressures and temperatures of use. Pressure vessels used for storage and piping employed as part of a thermal ESS shall comply with Section 20. Stresses on containment parts associated with swings of high and low temperature extremes shall be considered when evaluating the suitability.

28.4.5 Containment systems for combustible materials (solids or fluids) shall be designed to prevent the potential for explosion hazards as a result of contact with moisture, contaminants, etc.

28.4.6 A thermal ESS shall have sufficient pressure controls, fluid level controls and temperature controls to prevent the potential for a hazardous condition from occurring through an out of specification operation. Compliance is determined through the safety analysis of the system and the functional safety investigation of the controls per Section 15 and the abnormal operations tests for thermal ESS in accordance with Section 31.

PERFORMANCE

29 General

29.1 The energy storage technologies employed as part of an ESS shall be tested and determined compliant to an applicable technology safety standard. Where no applicable safety standard exists, they shall be tested in accordance with this Standard.

29.2 All tests conducted in accordance with this Standard shall be conducted in an environment with a room ambient temperature of 25 ±5 °C (77 ±9 °F), unless otherwise noted in the test method. Any cooling systems or other auxiliary systems that are part of the ESS shall be operating during testing when their operation can affect the outcome of the test or when otherwise noted in the test method. For testing purposes, samples and parameters used for testing shall consider smallest size conductors and maximum allowed overcurrent protection in addition to worse case loading and temperatures conditions.

29.3 Temperature shall be measured using thermocouples consisting of wires not larger than 0.21 mm^2 (24 AWG) and not smaller than 0.05 mm^2 (30 AWG) connected to a potentiometer-type instrument. Temperature measurements shall be made with the measuring junction of the thermocouple held tightly against the component/location being measured. For those tests that require the sample to reach thermal equilibrium (also referred to as steady state conditions), thermal equilibrium is considered to be achieved if after three consecutive temperature measurements taken at intervals of 10 % of the previously elapsed duration of the test but not less than 15 min, indicate no change in temperature greater than ±2 °C (±3.6 °F).

29.4 The tests contained in this Standard may result in explosions, fire and emissions of flammable and/or toxic fumes as well as electric shock. It is important that personnel use extreme caution and follow local and regional worker safety regulations when conducting any of these tests and that they be protected from flying fragments, explosive force, and sudden release of heat and noise that could result from testing. The test area is to be well ventilated to protect personnel from possible harmful fumes or gases. As an additional precaution, the temperatures on surfaces of parts that may get hot or cold during testing may be monitored during the test for safety and information purposes. All personnel involved in the testing shall be instructed to never approach the device under test (DUT) until temperatures have returned to within room ambient temperatures.

ELECTRICAL TESTS

30 Normal Operations Test

30.1 A normal operations test can be waived for equipment of an ESS where a similar evaluation such as a temperature test has already been conducted under the specific technology standard.

30.2 In conducting the electrical tests required in this Standard, the ESS shall be operated through a minimum of 2 cycles of charge and discharge of the system at the maximum loading rates as specified by the manufacturer. If a duty cycle is specified as noted in 45.4, then the discharge and charge cycles shall be repeated at the specified duty cycle until maximum temperatures during each part of the cycle achieve equilibrium. For each cycle, the ESS shall be discharged completely, recharged immediately to a full state of charge, followed by a delay to achieve the specified duty cycle.

Exception: Normal operations testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS. The rationale used to determine the suitability of the subassembly to represent the complete ESS shall be documented.

30.3 During the test, consideration shall be given to maximum and minimum room ambient conditions. During operation, temperatures on critical components that are temperature sensitive shall be monitored and operating parameters of components of the system monitored to determine that they are operating within their ratings. If the ESS is intended for mounting on a wall, it shall be mounted as intended in accordance with installation instructions on a flat wall in an alcove that is painted a dull black, and temperatures shall be monitored on the wall surfaces during the test.

30.4 During the normal operations test, the manufacturer’s specified limits shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications in accordance with Table 30.1. Temperatures on accessible surfaces of the ESS shall not exceed the limits in accordance with Table 30.2.

Table 30.1
Temperatures on Components

Part	Maximum temperatures on components (T_{max}) °C (°F)
Synthetic rubber or PVC insulation of internal and external wiring	
– without temperature marking	75 (167)
– with temperature marking	Temperature marking
Components, insulation and thermoplastic materials	a
Cell/capacitor casings	b

[a] The temperatures measured on components and materials shall not exceed the maximum temperature rating for that component or material.

[b] The internal battery cell or capacitor case temperature shall not exceed the manufacturer’s recommended maximum temperature.

Table 30.2
Temperatures on Accessible and Mounting Surfaces

Accessible surfaces	Maximum surface temperatures		
	Metal °C (°F)	Glass, porcelain and vitreous materials °C (°F)	Plastic and rubber[a] °C (°F)
External surfaces of equipment which may be touched[b]	70 (158)	80 (176)	95 (203)
Parts inside equipment which may be touched[c]	70 (158)	80 (176)	95 (203)
Wall mount energy storage systems:	**Maximum Temperature Rise[d], °C (°F)**		
Wall Surfaces	75 (167)		

[a] For each material, account shall be taken of the data from that material to determine the appropriate maximum temperature.

[b] For areas on the external surface of equipment and having no dimension exceeding 50 mm (2.0 in), and which are not likely to be touched in normal use, temperatures up to 100 °C (212 °F) are permitted.

[c] Temperatures exceeding the limits are permitted provided that the following conditions are met:

1) Unintentional contact with such a part is unlikely such as equipment located in restricted access locations or due to its location;

2) The part has a marking indicating that this part is hot. It is permitted to use the symbol IEC 60417 Database, No. 5041 to provide this information.

[d] This temperature is the maximum rise in temperature based upon a test ambient temperature of 25 °C (77 °F).

31 Abnormal Operation Tests for Thermal Energy Storage Systems

31.1 General

31.1.1 Thermal ESS shall remain in a safe state should the thermal controls, fluid controls or pressure controls of the system fail.

31.2 Failure of thermal controls

31.2.1 The thermal ESS shall be operated during charging and discharging with a single fault within the thermal control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.

31.2.2 The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the test, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.

31.3 Exposure to out of specification thermal conditions

31.3.1 The thermal ESS shall be subjected to a temperature conditions outside of the operating specifications of the system to determine if the controls will prevent an over temperature condition or other condition that could lead to a hazard. The ESS or a representative subassembly shall be subjected to an ambient of 70 °C (158 °F) or 20 °C (36 °F) above the maximum specified operating ambient, whichever is higher and then an ambient of -30 °C (-22 °F) or 20 °C (36 °F) below the lowest specified operating ambient, whichever is lower. The ESS shall be operated during this conditioning. For example, if supplied by solar, so that charging takes place during the day, the high temperature exposure shall take place during the charging phase. If the discharging phase is in the evening, the cold temperature exposure shall take place during the discharge phase. Only one complete cycle of charge and discharge is required, and the DUT shall be charged or discharged until the end of each condition or until thermal controls stop the operation.

31.3.2 As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids. Thermal controls shall prevent the system from operating outside of safe limits.

31.4 Failure of pressure controls

31.4.1 The thermal ESS shall be operated during charging and discharging with a single fault within the pressure control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.

31.4.2 The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.

31.5 Failure of fluid controls

31.5.1 The thermal ESS shall be operated during charging and discharging with a single fault within the various fluid level control systems relied upon for safety. Examples of these systems can include a gas system used to provide an inert atmosphere within containment chambers, a liquid leak control, etc. The test shall be repeated with the single fault in each separate fluid level control system. The test shall be conducted at ambient conditions and the ESS shall be operated at maximum normal operating limits of the system. Temperatures on temperature sensitive components and accessible surfaces shall be measured during the test. Pressures shall also be monitored. The ESS shall be subjected to one charge and one discharge cycle.

31.5.2 The system shall be operated until the discharge or recharge is complete or until the controls shut the system down to prevent hazards. As a result of the tests, there shall be no evidence of fire, explosion, rupture of parts containing hazardous fluids or leakage of hazardous fluids.

32 Dielectric Voltage Withstand Test

32.1 The dielectric voltage withstand test is an evaluation of the electrical spacings and insulation associated with the hazardous voltage circuits within the DUT.

32.2 Circuits at 42.4 Vpeak/ 30 Vrms or 60 Vdc or higher shall be subjected to a dielectric withstand voltage in accordance with the “Determining clearances using required withstand voltage” clause of UL 62368-1/CSA C22.2 No. 62368-1.

Exception No. 1: Semiconductors or similar electronic components liable to be damaged by application of the test voltage shall be bypassed or disconnected.

Exception No. 2: The dielectric voltage withstand test need not be conducted on integral ESS, fuel cells, and inverter systems, etc. that have already been evaluated in accordance with their individual standard requirements. Only those electrical parts external to the tested systems and their connections not previously evaluated need to be tested.

32.3 The voltage applied during the dielectric voltage withstand test is to be applied between the hazardous voltage circuits of the DUT and accessible non-current carrying conductive parts.

32.4 The voltage applied during the dielectric voltage withstand test is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the DUT.

32.5 The voltages applied during the dielectric voltage withstand test shall be applied for a minimum of 1 min.

32.6 The test equipment shall consist of a 500 VA or larger capacity transformer, the output voltage, which is variable and which is essentially sinusoidal if using ac test method, a dc output if using a dc test method. There is no trip current setting for the test equipment since the test is checking for insulation breakdown, which results in a large increase of current. Setting a trip current may result in a false failure of this test, as it is not necessarily indicative of insulation breakdown.

Exception: A 500 VA or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.

32.7 There shall be no evidence of a dielectric breakdown (breakdown of insulation resulting in a short through insulation/arcing over electrical spacings) as evidenced by an appropriate signal from the dielectric withstand test equipment as a result of the applied test voltage. Corona discharge or a single momentary discharge is not regarded as dielectric breakdown (i.e. insulation breakdown).

33 Impulse Test

33.1 The impulse voltage test is intended to evaluate the ESS's ability to withstand lightning or similar surges. Systems provided with protection that has already been evaluated for voltage surges (e.g. inverters meeting IEEE 1547 criteria) need not be tested if it can be determined that the parts connected to the power conditioning system can withstand any let through current that may occur.

33.2 The impulse voltage test shall be performed with an impulse generator able to provide voltage having a 1.2/50 μs waveform (see the Full Impulse Voltage Time Parameters figure of IEC 61180) at voltages in accordance with Table 33.1, and is intended to simulate an overvoltage condition due to lightning or switching of equipment.

Table 33.1
Impulse Voltages

Voltage of Circuit Under Test Vac or Vdc	Impulse test voltage, voltage between circuits and accessible parts.			
	Circuits not connected to mains		Circuits connected to mains	
	Basic or supplementary insulation V	Reinforced insulation V	Basic or supplementary insulation V	Reinforced Insulation V
≤ 50	500	800	800	1500
100	800	1500	1500	2500
150	1500	2500	2500	4000
300	2500	4000	4000	6000
600	4000	6000	6000	8000
1000	6000	8000	8000	12000
> 1000	a	a	a	a

[a] Extrapolation is permitted for circuits above 1000 V.

33.3 Pulses shall be applied at 1.2/50 μs for each polarity in ≥ 1 s time intervals at the peak voltage for the rating of the circuit under test ±5 % per Table 33.1. The test voltage is to be applied between the terminal/circuit under test and accessible parts. For circuits at 1000 V or less, three pulses at each polarity shall be applied. For circuits over 1000 V, 5 pulses at each polarity shall be applied.

Exception: Impulse test levels can be based on the transient voltage surge suppression device rating if provided.

33.4 As a result of the applied impulse voltage test, there shall be no puncture of insulation (i.e. electrical breakdown through solid insulation), occurrence of flashover (i.e. electrical breakdown over the surfaces of solid insulation), or spark-over (i.e. electrical breakdown through fluids such as air).

34 Equipment Grounding and Bonding Test

34.1 The impedance of the system grounding and bonding circuit shall be determined using one of the following methods:

a) The circuit between the grounding terminal and the part to be grounded is measured using impedance measuring equipment;

b) In accordance with the Continuity of the Equipment Grounding Circuit section, Section 18.2 of NFPA 79 (voltage drop measurement of the circuit using a 10 A low voltage supply source); or

c) In accordance with test in the "Resistance of the Protective Bonding System" clause, Clause 5.6.6 of UL 62368-1/CSA C22.2 No. 62368-1 (measuring voltage drop in circuit using a low voltage supply source providing a current based upon circuit protection rating).

d) The fault loop impedance measurement in accordance with IEC 60364-4-41.

In Canada, the circuit under test is referred to as the bonding circuit per CSA C22.1.

34.2 The impedance for all grounding and bonding circuits tested shall not exceed 0.1 Ω, or if using the test method in 30.1(d), the compliance criteria shall be in accordance with IEC 60364-4-41.

35 Insulation Resistance Test

35.1 The resistance of insulation used on hazardous voltage circuits within an ESS shall be greater than or equal to 1 MΩ.

35.2 The insulation resistance shall be measured using high impedance measuring equipment (e.g. mega ohmmeter) while applying a voltage of 500 Vdc between the live parts of the circuit under test and accessible conducting parts including the equipment grounding circuit, for 1 min.

Exception No. 1: Energy storage systems need not be tested if the insulation resistance has been previously evaluated as part of the particular technology safety standard.

Exception No. 2: The insulation resistance test of IEC 60364-6 can be conducted instead.

Exception No. 3: This test can be waived if the permanently connected wiring has:

a) A cross-section of the protective earthing conductor of at least 10 mm^2 if copper, or 16 mm^2 if aluminum; or

b) Provision of an additional terminal for a second protective earthing conductor of the same cross-sectional area as the original protective earthing conductor and installation instructions requiring a second protective earthing conductor to be installed.

Exception No. 4: The touch current measurement test of IEC 62040-1 may be conducted instead.

35.3 Resistor(s) and/or resistor networks may be removed when conducting the insulation resistance test.

36 Electromagnetic Immunity Tests

36.1 General

36.1.1 Electronics and software controls determined to be critical for safety shall demonstrate sufficient immunity to electromagnetic interference by complying with the tests specified in these sections. Alternate test procedures and levels specified in other standards may be used, but only if they are equivalent or more severe than the test procedures and levels specified below. This testing is not required if EMI testing has already been conducted as part of the control's functional safety investigation.

Exception: This testing does not apply to controls within components of the ESS that have already been evaluated for EMI exposure in accordance to their applicable component standard such as UL 1741 for power conditioning systems.

36.1.2 Each test shall begin with an operational DUT.

36.1.3 During the tests in this section, the DUT shall be operated in mode(s) that include the safety function(s) being evaluated. If multiple modes are to be considered (example: equipment controlling the charging and discharging of the energy storage device), the DUT shall either be cycled through those modes during the tests, or the tests repeated in each mode. While cycling through modes, the DUT shall not exhibit any signs of loss of safety functions or risk of fire, electric shock, or personal injury.

36.1.4 After each test in this section, the DUT shall be inspected to verify that it is still operational. This may require Operational Verification (36.8) of the DUT if it is not possible to determine that it is fully operational by inspection. If the DUT is no longer operational, a failure analysis shall be conducted to determine the reason for the failure and to verify that the DUT has failed safely. A DUT that is no longer operational shall not be used on any remaining test.

36.1.5 In addition, after all tests in this section have been completed, all samples used during the tests specified in Section 36 shall comply with the Operational Verification in Section 36.8.

36.2 Electrostatic discharge

36.2.1 The DUT shall demonstrate immunity to electrostatic discharges in accordance with the test procedure specified in IEC 61000-4-2 and the modes of operation stated in 36.1.3.

36.2.2 The following test levels shall be used:

a) ±6 kV contact discharge; and

b) ±8 kV air discharge.

36.2.3 After the test, the DUT shall comply with 36.1.4.

36.3 Radio-frequency electromagnetic field

36.3.1 The DUT shall demonstrate immunity to radio-frequency electromagnetic fields in accordance with the test procedure specified in IEC 61000-4-3 and the modes of operation stated in 36.1.3.

36.3.2 The following test levels shall be used:

a) 10 V/m from 80 MHz to 1 GHz, 1 kHz (80 % AM); and

b) 3 V/m from 1.4 GHz to 6.0 GHz, 1 kHz (80 % AM).

36.3.3 During the test, the DUT shall comply with 36.1.3.

36.3.4 After the test, the DUT shall comply with 36.1.4.

36.4 Fast transient/burst immunity

36.4.1 The DUT shall demonstrate immunity to electrical fast transients/bursts in accordance with the test procedure specified in IEC 61000-4-4 and the modes of operation stated in 36.1.3.

36.4.2 The following test levels shall be used:

a) On signal/control ports intended to be connected to cables longer than 3 m (118.1 in), ±1 kV (5/50 ns, 5 kHz); capacitive clamp shall be used;

b) On input and output DC ports, ±1 kV (5/50 ns, 5 kHz); and

c) On input and output AC ports, ±2 kV (5/50 ns, 5 kHz).

36.4.3 With reference to 36.4.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.4.2(c). External accessible DC ports shall be conducted using the test level specified in 36.4.2(b).

36.4.4 After the test, the DUT shall comply with 36.1.4.

36.5 Surge immunity

36.5.1 The DUT shall demonstrate immunity to surges in accordance with the test procedure specified in IEC 61000-4-5 and the modes of operation stated in 36.1.3.

36.5.2 The following test levels shall be used:

a) For I/O signal/control ports intended to be connected to long-distance cables longer than 30 m (1181.1 in), which leave the building, and/or are for outdoor use, ±1 kV line-to-ground;

b) For input and output DC ports, ±0.5 kV line-to-line, and ±1 kV line-to-ground; and

c) For input and output AC ports, ±1 kV line-to-line, and ±2 kV line-to-ground.

36.5.3 With reference to 36.5.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.5.2(c). External accessible DC ports shall be conducted using the test level specified in 36.5.2(b).

36.5.4 After the test, the DUT shall comply with 36.1.4.

36.6 Radio-frequency common mode

36.6.1 The DUT shall demonstrate immunity to radio-frequency conducted disturbances in accordance with the test procedure specified in IEC 61000-4-6 and the modes of operation stated in 36.1.3.

36.6.2 The following test levels shall be used:

a) For I/O signal/control ports intended to be connected to cables longer than 3 m (118.1 in), 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM);

b) For input and output DC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM); and

c) For input and output AC ports, 10 V (150 kHz to 80 MHz, 1 kHz, 80 % AM).

36.6.3 With reference to 36.6.2, the test levels shall be applied to all external accessible ports of the equipment in an ESS. External accessible AC ports shall be conducted using the test level specified in 36.6.2(c). External accessible DC ports shall be conducted using the test level specified in 36.6.2(b).

36.6.4 During the test, the DUT shall comply with 36.1.3.

36.6.5 After the test, the DUT shall comply with 36.1.4.

36.7 Power-frequency magnetic field

36.7.1 The DUT shall demonstrate immunity to power-frequency magnetic fields in accordance with the test procedure specified in IEC 61000-4-8 and the modes of operation stated in 36.1.3.

36.7.2 The following test level shall be used: 10 A/m.

36.7.3 During the test, the DUT shall comply with 36.1.3.

36.7.4 After the test, the DUT shall comply with 36.1.4.

36.8 Operational verification

36.8.1 After the tests in 36.2 – 36.7 have been completed, all samples used during these tests shall comply with the following.

36.8.2 The manufacturer shall declare the anticipated performance of all safety functions performed by electronics and software controls.

36.8.3 The manufacturer shall provide test procedures to verify that each of the safety functions performed by electronics and software controls is working correctly. This may include, for example, verification of correct safety function performance by simulation.

36.8.4 During the test procedures specified in 36.8.3, each DUT shall exhibit one of the following behaviors:

a) No loss of safety functions; or

b) Transition to an appropriate state to ensure safe operation of the DUT.

36.9 Operational verification of remote software update capability

36.9.1 The test of 36.8 shall be conducted on safety controls intended for remote software updates in accordance with Section 16 to ensure that they are operational after the update. See 16.1.7 and 16.2.8.

MECHANICAL TESTS

37 Containment of Moving Parts

37.1 Control system fault overspeed test

37.1.1 An ESS with moving parts having the capacity to store kinetic energy that is capable of being subjected to overspeed conditions through a fault in the system controls shall be subjected to an overspeed test.

37.1.2 The system controls shall be subjected to single fault in the controls that would allow overspeed of the moving parts. The DUT shall be operated at overspeed conditions until a secondary protection control operates to stop operation of the DUT.

37.1.3 As a result of the overspeed condition, the moving part(s) shall not become loosened or disconnected in a manner that would result in a hazardous condition. If completely loosened or disconnected as a result of the overspeed conditions, the containment means shall safely contain the part(s) in accordance with the Faulted Securement Test in 37.2.

37.1.4 The system controls shall limit the overspeed to a level less than the speed defined in 37.4.

37.2 Faulted securement test

37.2.1 An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the faulted securement test when a fault in primary securement means of the moving part has the potential to result in a hazard.

37.2.2 The moving parts of the system shall be subjected to a single fault of the primary means of securement while operated at the maximum speed anticipated during normal operation. The primary means of securement to be removed, such as a failed bearing, shaft, or other part of the securement of the moving part with respect to the stationary housing, shall be determined through a safety analysis that identifies failure of the selected means as representing the potential worst case condition. Refer to Section 15 for the safety analysis requirements.

37.2.3 This test is not required in cases where test or field data is available to support the safety analysis indicating that there is not a hazard associated with the loss of primary securement.

37.2.4 The system shall be operated until one of the following occurs:

a) The part has operated for 30 min under the faulted condition;

b) A protection control operates to stop operation of the DUT or hazardous moving part; or

c) The part has loosened and is completely or partially disconnected from its securement means.

37.2.5 As a result of the operation with a faulted securement condition, the moving part(s) shall not become loosened or disconnected to result in a hazardous condition. If completely loosened or disconnected, the containment means for the part shall safely contained the part(s).

37.3 Blocked shaft test

37.3.1 An ESS with moving parts with the capacity to store kinetic energy shall be subjected to the blocked shaft test if blocking the shaft or moving parts has the potential to result in a hazard.

37.3.2 With the moving part blocked to prevent movement, the system shall be operated at the maximum ratings allowed for a zero speed condition.

37.3.3 The system shall be operated:

a) With the part blocked for 30 min and then stopped;

b) Until a protection control operates to stop operation of the DUT with the blocked part; or

c) Until any moving parts break off or become completely or partially disconnected from its securement means.

Exception: Moving parts already evaluated for blocked shaft conditions as part of a component evaluation, need not be tested.

37.3.4 As a result of operating the system with a blocked shaft/moving part condition, the part shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no overheating of parts that will result in a hazard such as fire or explosion.

37.4 Mechanical integrity test

37.4.1 An ESS with any moving part having the capacity to store kinetic energy shall have the mechanical (i.e. rotating) energy storage elements designed to have a minimum margin factor of safety. The factor of safety requirements vary depending on the material of construction. The factor of safety based on material type shall be as follows:

a) For assemblies composed of laminated composite materials, the minimum factor of safety shall be at least 2.0 between the maximum principal stress that exists at the point of highest stress in each layer of the mechanical energy storage element and the ultimate strength of that layer at that point. The factor of safety shall be evaluated at maximum normal operating speed and at a room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F).

b) For assemblies composed of ductile metallic materials exhibiting a traditional nonlinear stress-strain curve, the minimum factor of safety shall be at least 1.3 between the maximum von Mises stress that exists anywhere in the mechanical energy storage element at maximum normal operating speed and the tensile yield strength of the material where the stress exists at room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F).

c) For other material types and combinations of materials including metals and laminated composites, the minimum factor of safety shall be at least 2.0 between the maximum combined stress that exists anywhere in the mechanical energy storage element at maximum normal operating speed and the ultimate tensile strength of the material where the highest stress exists at room ambient temperature of 25 °C ±5 °C (77 °F ±9 °F).

37.4.2 The mechanical energy storage element shall be subjected to an overspeed type test demonstrating the required factor of safety. The DUT shall be representative of the latest design revision and subjected to an overspeed and corresponding stress as follows in (a) or (b). For the purpose here, rotor working stress is presumed to scale exactly as the square of the rotation speed.

a) Where the minimum required factor of safety is 2.0, the overspeed shall be at least 139 %. The DUT shall sustain the overspeed for a time period of 1 min without ruptures in of any part of the assembly.

b) Where the minimum required factor of safety is 1.3, the overspeed shall be 120 % minimum. The DUT shall sustain the overspeed for a time period of 1 min. Yielding of the material during the test is permitted as long as the test requirement is met and the DUT can be shut down afterward in a normal manner (i.e. through braking or discharge of the stored energy). This condition implies that margin between the maximum Von Mises stress in the part at normal operating speed and the ultimate tensile strength of the material must be greater than 1.45 to successfully pass the overspeed test.

37.4.3 With reference to 37.4.2, for a hollow cylindrical mechanical energy storage element, as an alternative to the dynamic test, a static test (e.g. hydrostatic or pneumatic strength test) may be performed whereby the DUT is subjected to an internal pressure that creates maximum stress in the DUT that is greater than 2x the maximum stress under normal operating conditions.

37.4.4 With reference to 37.4.2 and 37.4.3, the mechanical energy storage element DUT shall:

a) Be a production mechanical energy storage element;

b) Be according to the latest design revision; and

c) Meet the manufacturer’s quality assurance requirements for production units.

37.4.5 Alternatively to the overspeed test requirements of 37.4.2, the standard installation of the energy storage element shall demonstrate containment of a failure of the mechanical energy storage element. Containment is defined as NO primary particles (energy storing components, their fragments, or other moving parts) and NO secondary projectiles (stationary components of the product or their fragments set into motion by the failure event) are to exit the device's outermost housing, containment media, or installation area. This test shall be performed at 100 % of maximum rated operating stress or above.

37.4.6 With reference to 37.4.1 – 37.4.5, the testing shall be repeated in the event of a deviation of any mechanical characteristic or material property that results in an increase of more than 10 % between calculated stress in production energy storage elements and demonstrated stress in the previously qualified mechanical energy storage element.

37.5 Bearing failure test

37.5.1 An ESS with moving parts with the capacity to store kinetic energy that relies upon a primary set of bearings in its moving mechanism, in any form, shall be subjected to a bearing failure test if failing the bearings has the potential to result in a hazard. Refer to Section 15 for the safety analysis requirements.

37.5.2 With the system operating at maximum operating conditions, a failure in the primary bearings shall be induced that results in the loss of the primary bearing function and forces the DUT to spin down on its backup bearing or other suitable support system.

37.5.3 The system shall be operated:

a) Until the DUT's energy is dissipated and it has come to a stop;

b) Until a protection control operates to stop operation of the DUT; or

c) Until any moving parts break off or become completely or partially disconnected from its securement means.

37.5.4 This test is intended to verify that the backup bearing or support system for the energy storage element is effective. This test may also suffice as the faulted securement test described in 37.2 if the safety analysis indicates a bearing failure as the worst case condition.

37.5.5 As a result of operating the system with a failed bearing condition, the moving parts shall not become loosened or disconnected to result in a hazardous condition. If the part becomes completely loosed or disconnected, the containment means for the part shall safely contain the part(s). There shall be no overheating of parts that will result in a hazard such as fire or explosion.

38 Leakage Tests

38.1 Energy storage systems that utilize liquid coolant or contain hazardous fluids shall be subjected to the Leakage Test in accordance with 38.2 and 38.3.

Exception: Leakage testing need not be conducted if parts containing hazardous fluids and their connections have already been evaluated for external leakage as part of a component standard such as the appendix for Test Program for Flowing Electrolyte Batteries, Appendix C, of UL 1973 or CSA FC 1 for fuel cell systems.

38.2 Leakage from ESS containing hazardous fluids shall not result in the risk of fire, electric shock, or injury to persons.

38.3 Compliance is determined by subjecting the fluid-containing parts and their connections to a fluid pressure of 1.5 times the maximum operating pressure (if testing with liquid) or 1.1 times the maximum operating pressure (if air pneumatic testing) of intended use during operation of the system. There shall be no leaks from fluid-containing parts or their connections as a result.

39 Strength Tests

39.1 General

39.1.1 Energy storage systems that contain hazardous fluids including liquid coolant shall comply with the Strength Tests in accordance with 39.2 and 39.3.

39.2 Hydrostatic strength test

39.2.1 Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a hydrostatic strength test of 1.5 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either the liquid used in the system or water. Testing is done at room ambient temperature.

39.2.2 As a result of the hydrostatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.

39.3 Pneumatic strength test

39.3.1 The pneumatic strength test is an alternative to the hydrostatic strength test of 39.2 and is conducted in accordance with 39.3.2.

39.3.2 Parts of the ESS containing hazardous fluids (gases or liquids) shall be subjected to a pneumatic strength test of 1.3 times the design pressure of the system for a period of 1 min after reaching the maximum pressure. The pressure shall be gradually increased until the maximum pressure is reached in approximately 1 min using either air or inert gas. Testing is conducted at room ambient temperature.

39.3.3 As a result of the pneumatic strength test, there shall be no fracture, distortion, rupture or other damage to the fluid containing parts.

40 Enclosure and Mounting Tests

40.1 Wall mount fixture/test

40.1.1 A wall mounting apparatus of a wall mounted ESS shall have sufficient strength to support the system. Compliance is determined by the following test.

Exception: Individual components of an ESS that are provided with their own wall mount apparatus previously tested as part of their component evaluation, need not be tested.

40.1.2 The wall mounting apparatus and ESS shall be installed in accordance with the manufacturer's specifications. A force equal to three times the weight of the ESS is additionally applied to the center of the mounting apparatus in a downward direction. The force shall be held for 1 min.

40.1.3 As a result of the applied force, there shall be no damage to the mounting apparatus and its securement means when testing the wall mounting fixture.

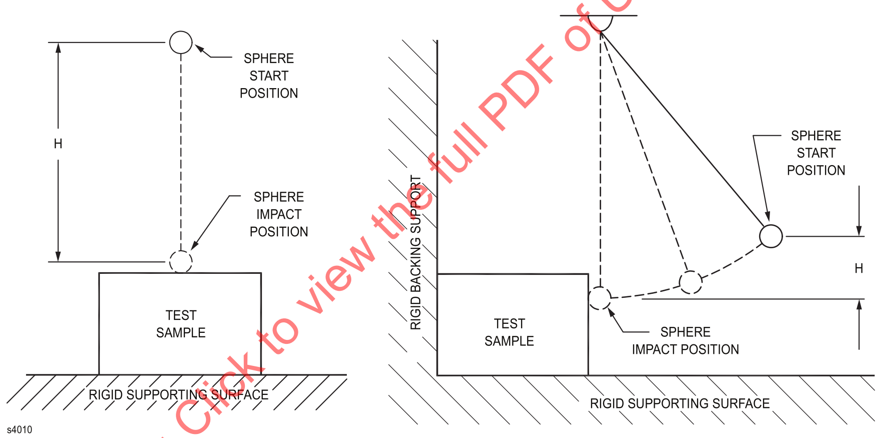
40.2 Enclosure impact

40.2.1 The purpose of this test is to evaluate the mechanical integrity of the enclosure and its ability to provide mechanical protection to the ESS enclosure contents. This test is conducted on electrochemical ESS that are for residential applications or for non-residential applications that are less than or equal to 50 kWh.

40.2.2 A fully charged DUT shall be subjected to a minimum of three impacts of 6.8 J (5 ft-lb) on any surface that can be exposed to a blow during intended use. The impact shall be produced by dropping a steel sphere, 50.8 (2 in) in diameter, and weighing 535 g (1.18 lb) from a height, H, of 1.29 m (50.8 in). For surfaces other than the top of an enclosure, the steel sphere shall be suspended by a cord and swung as a pendulum, dropping through the vertical height of 1.29 m (50.8 in), with the product being impacted placed against a restraining vertical wall. See Figure 40.1. A different sample may be used for each impact.

Figure 40.1

Impact Test



– H indicates the vertical distance the sphere must travel to produce the desired impact, 1.29 m (50.8 in).

– For the ball-pendulum impact test the sphere shall contact the test sample when the string is in the vertical position as shown.

– The DUT shall rest on a concrete floor. An equivalent non-resilient supporting surface may be used.

– The backing surface shall consist of 19-mm (3/4-in) plywood over a rigid surface of concrete.

40.2.3 After the impacts, the DUT shall be subjected to a Dielectric Voltage Withstand Test in accordance with Section 32. The DUT shall be examined for signs of rupture or damage that could lead to a hazard.

40.2.4 As a result of the impact test, there shall be no damage to the enclosure that could result in a hazard such as exposure of hazardous parts or result in a dielectric breakdown.

40.3 Enclosure steady force

40.3.1 The purpose of this test is to determine if the enclosure has sufficient strength to safely withstand a static force that may be applied to it. This test is conducted on electrochemical ESS that are for residential applications or for non-residential applications that are less than or equal to 50 kWh.

40.3.2 The enclosure of a fully charged DUT shall withstand a steady force of 250 N ±10 N (56.2 lbf ±2.25 lbf) for a period of 5 s, applied in turn to the top, bottom and sides of the enclosure fitted to the DUT, by means of a suitable test tool providing contact over a circular plane surface 30 mm (1.2 in) in diameter.

40.3.3 The DUT shall be subjected to a Dielectric Voltage Withstand Test between live parts and the enclosure in accordance with Section 32. The DUT shall be examined for signs of rupture or damage that could lead to a hazard.

40.3.4 As a result of the steady force test, there shall be no damage to the enclosure that could result in a hazard such as exposure of hazardous parts or result in a dielectric breakdown.

40.4 Mold stress

40.4.1 The purpose of this test is to determine if an enclosure made from molded polymeric material can withstand an accelerated aging test without compromising the safety of the enclosure.

40.4.2 One complete fully discharged sample shall be placed in a full-draft circulating-air oven maintained at a uniform temperature of at least 10 °C (18 °F) higher than the maximum temperature of the enclosure measured during the Normal Operations Test in Section 30, but not less than 70 °C (158 °F). The sample shall remain in the oven for 7 h.

40.4.3 After removal from the oven the DUT shall be subjected to a Dielectric Voltage Withstand Test in accordance with Section 32. The DUT shall be examined for signs of rupture and damage

40.4.4 As a result of the mold stress conditioning, the sample shall show no evidence of mechanical damage, such as cracking of the enclosure exposing hazardous parts or result in a dielectric breakdown.

ENVIRONMENTAL TESTS

41 Special Environment Installations

41.1 General

41.1.1 Energy storage systems intended for installation in special environments shall be evaluated for their ability to operate safely in those environments. These environmental conditions can include exposure to salt fog for marine environments, testing for seismic ratings, high altitudes, etc. The requirements of 41.2, 41.3 and 41.4 shall apply depending upon the particular exposure. The installation instructions and nameplate labels on the ESS shall identify the special environmental conditions in accordance with 45.3, 45.17, and Section 46.

Exception No. 1: Testing need not be conducted on systems or parts of the system if already covered as part of the specific technology safety standard.

Exception No 2: Environmental testing on a subassembly may be conducted instead of the complete ESS if through analysis it can be determined to be representative of the ESS. The rationale used to determine the suitability of the subassembly to represent the complete ESS shall be documented.

41.2 Outdoors installations subject to moisture exposure

41.2.1 Energy storage systems intended for installation outdoors where they will be subject to rated levels of moisture exposure shall be tested in accordance with their environmental ratings outlined in their nameplate labels and installation instructions of 45.17 and 46.13.

41.2.2 Based upon the ratings of the system, moisture resistance testing shall be done in accordance with either IEC 60529, UL 50E, or C22.2 No. 94.2.

41.2.3 At the conclusion of the test, the sample is to be subjected to the electric insulation tests of Sections 32 and 35 and examined for signs of water in the system that could result in a hazardous condition.

41.2.4 As a result of the water exposure, there shall be no evidence of water on parts that could result in a hazard and no reduction of spacings or breakdown/deterioration in insulation levels.

41.3 Outdoor installation in marine environments

41.3.1 Energy storage systems intended for installation outdoors in marine environments in accordance with the installation instructions in 46.13 where they will be subject to salt fog exposure, shall be tested as outlined below.

41.3.2 The systems shall be tested in accordance with IEC 60068-2-52 for Severities 1 or 2.

41.3.3 At the conclusion of the testing, the systems shall be subjected to the electrical insulation tests of Sections 32 and 35 to determine that insulation has not been damaged in a manner that would result in an electric shock hazard.

41.3.4 The system shall be examined for signs of damage as a result of salt exposure that would indicate a potential for a safety hazard (e.g. corrosion of parts that could result in weakening of a securement or an enclosure, damage to insulation). If operational, the system is to be operated to determine that it can do so without hazard.

41.3.5 As a result of the test, the ESS shall not show evidence of damage from salt fog exposure that could result in a hazard such as electrical, shock, overheating or damage that could result in a physical hazard.

41.4 Installation in seismic environments

41.4.1 Equipment of an ESS that contains the energy storage mechanism and is intended for installation where they will be subject to seismic activity shall be evaluated and if necessary tested in accordance with their seismic ratings and installations instructions per 45.3 and 46.13. The installation instructions shall indicate the limitations of the particular seismic rating of the equipment. Standards that provide guidance on seismic evaluation such as IEEE 693, IEC 60980, ICC IBC, the seismic testing in GR-63-CORE, or similar, shall be used for this evaluation. Compliance is determined through review of documentation of the seismic evaluation for the appropriate seismic level (i.e. level marked on the equipment) or through testing for the specific seismic level in accordance with a testing standard for this purpose.

Exception No. 1: There is equipment that cannot be practically evaluated by testing alone because of the size of the equipment. For those situations, it may be necessary to do a combination of analysis with testing of parts of the system. This approach is outlined in IEEE 344.

Exception No. 2: Some standards allow for calculations and modelling as an approach for determining compliance for seismic ratings in lieu of testing.

41.4.2 The ESS shall be examined for signs of explosion, fire, combustible concentrations (if applicable to technology), rupture of the enclosure, electrolyte leakage, electric shock and loss of protection controls that lead to any of the other non-compliant results in 41.4.3.

41.4.3 As a result of the test, any of the following results in (a) – (g) are considered a non-compliant result:

a) Explosion;

b) Fire;

c) Combustible Concentrations (if applicable to technology);

d) Rupture (enclosure);

e) Electrolyte Leakage (external to enclosure);

f) Electric shock hazard (resistance below isolation resistance limits or dielectric breakdown);

g) Loss of protection controls.

MANUFACTURING AND PRODUCTION TESTS

42 Electrical Production Tests

42.1 Dielectric voltage withstand test

42.1.1 A dielectric withstand test as outlined in the Dielectric Voltage Withstand Test in Section 32 shall be conducted on 100 % production of ESS with working voltage exceeding 60 Vdc or 30 Vrms/42.4 Vpeak.

Exception No. 1: The time for the production Dielectric Withstand Test can be reduced to 1 s.

Exception No. 2: Testing can be conducted on subassemblies of the system.

Exception No. 3: Testing can be waived if conducted as part of the specific technology evaluation (i.e. tested per UL 1973, etc.).

42.2 Grounding and bonding system check

42.2.1 The grounding and bonding system of an ESS shall be subjected to a check using an impedance measuring device. The measurements shall occur between any two locations of the grounding and bonding system.

42.2.2 No resistance measurements of the grounding and bonding system shall exceed 0.1 Ω or allowed limits per 34.2.

Exception: This testing can be waived if it is determined that the ESS construction and production methods to ensure good grounding and bonding of the system production can be determined through a review of production practices. However, if any point of the grounding system is maintained through a single fastener, a ground bond test shall be conducted.

42.3 Check of safety controls

42.3.1 Energy storage systems shall be subjected to 100 % production screening to determine that any active controls utilized for safety are functioning.

Exception: This check of the safety controls can be conducted on subassemblies or components of the system before final assembly.

43 Mechanical Production Tests

43.1 Integrity at maximum abnormal operating speed

43.1.1 Every production mechanical storage element shall be subjected to a maximum abnormal operating speed test. The test shall be performed at the maximum speed reached during the Overspeed Test of 37.1. The test shall be performed in an environment which will safely contain any mechanical failure of the mechanical storage element.

43.1.2 As an alternative to 43.1.1, the components of a mechanical energy storage element (e.g. forged disk) shall be processed consistently and tested to ensure that the materials used in its construction meet the minimum requirements assumed during the design and analysis of the element. The engineering development and production testing protocol for the components of the energy storage element shall demonstrate the level of uniformity of the material properties throughout critical sections of the component and that the material properties meet required minimum values consistently.

43.2 Production screening of rotors

43.2.1 Rotor assemblies for mechanical ESS shall be subject to 100 % production screening through the use of non-destructive testing or other means to check for cracks and other flaws. Any cracks or flaws found shall be evaluated in accordance with manufacturer's specifications.

43.2.2 As an alternative to 43.2.1, additional in progress quality checks and testing can be incorporated into the manufacturing assembly process to limit the presence of cracks or flaws in finished product. Refer to 44.1.

43.3 Leak check of hazardous fluid systems

43.3.1 ESS that contain hazardous fluids including ESS with liquid coolant systems shall be subjected to a leak check in accordance with Section 38 of the assembled fluid containment system.

44 Production Quality Control

44.1 Manufacturers of ESS shall have documented production process controls in place that continually monitor the following key elements of the manufacturing process that can affect safety, and shall include measured parametric limits enabling corrective/preventative action to address defects (out of limit parameters) found affecting these key elements:

a) Supply chain control; and

b) Assembly processes.

MARKINGS

45 General

Advisory Note: Markings required by this Standard may have to be provided in other languages to conform with the language requirements of the country or region where the product is to be used. In Canada, there are two official languages, English and French. Annex C provides translations in French of the English safety markings specified in this Standard.

45.1 The markings including signage required for compliance to this Standard shall be legible and permanent such as metal stamped, etched, adhesive labels, etc. An adhesive-backed label shall comply with the requirements in UL 969 or CSA C22.2 No. 0.15, for the intended exposure conditions and surface adhered to.

45.2 Markings and signage shall be in lettering that is sized so that it is legible from the distance from which it must be read and shall have lettering in a color that contrasts with the background. Guidance for markings and signs can be found in standards such as ISO 3864-2, NEMA Z535.1, NEMA Z535.2, NEMA Z535.3, NEMA Z535.4, and NEMA Z535.5.

45.3 An ESS shall be provided with a nameplate marking (main label) that includes the following:

a) The ESS model, catalog number or similar identifier and technology of the ESS;

NOTE: Examples of technology markings would be lithium ion, nickel cadmium, latent heat thermal, flywheel.

b) Identifies that the system is a DC ESS or AC ESS as applicable;

c) Identifies the manufacturer responsible for the evaluated ESS;

d) Provides the contact information per 45.10;

e) Residential ESS on or in a dwelling unit shall be marked as follows:

1) If meeting the requirements of 26.2.2: “Suitable for Use in Residential Habitable Spaces”; or

2) For systems intended for installation in Canada, systems meeting the cell level performance criteria of UL 9540A shall be marked with “This equipment meets the cell level performance criteria of UL 9540A”;

3) If meeting the requirements of 26.2.3 "Suitable for Use in Residential Non-Habitable Spaces";

f) Includes the following information and ratings:

1) Output and input current (maximum continuous) for each power port in Amps;

2) Output and input voltage (minimum and maximum) for each power port in Volts;

3) Power input and output (maximum continuous) for each power port in W / kW or VA / kVA;

4) Energy storage capacity in Wh / kWh (maximum);

5) DC or Frequency in Hz and number of phases for each power port;

6) Auxiliary output and input voltage (V), current (A) and frequency (Hz) if applicable;

7) Input short-circuit current rating (SCCR) in A / kA;

8) Maximum overcurrent protective device rating in Amps;

9) Output available fault current (as defined in Article 100 of NFPA 70) and time duration that the equipment can provide;

10) Special environmental ratings and limitations as applicable (e.g. seismic, indoor/outdoor only, etc.); and

11) Suppression system to be installed if applicable.

45.4 With reference to 45.3, if the system is intended to be operated in a duty cycle, the intended duty cycle shall be included on the nameplate.

45.5 With reference to 45.3, the suppression system to be installed, if applicable, shall be marked on the system.

45.6 With reference to 45.3, the operating ambient conditions in °C or °F, the weight of the system in kilograms or pounds, and the overall dimensions of the system can either be marked on the system or provided in the installation instructions.

45.7 For multi-part ESS, a nameplate marking (main label) noted in 45.3 shall be provided on at least one of the parts and shall identify that the system has been evaluated as a multi-part ESS.

45.8 The items in 45.4 – 45.6 shall be included as applicable to the system. With reference to 45.7, each separate part of the multi-part ESS shall have a nameplate marking as required by the equipment safety standard to which it was evaluated.

45.9 With reference to 45.7, where not included in the end-product standard or label, the following information shall be included in the ESS installation instructions as applicable to the ESS:

a) Single-line electrical diagram of the ESS identifying all interconnections and ports;

b) Input short circuit current rating (SCCR) in A / kA that each component can withstand from other parts of the ESS if the connection point is a power input or bi-direction power connection; and

c) Available fault current (as defined in Article 100 of NFPA 70) and time duration that the ESS part can provide to other parts of the ESS if the connection point is a power output or bi-directional power connection.

45.10 Contact information for the system in the event of an emergency or problems with the system shall be marked on the system.

45.11 Energy storage systems shall also be marked with the date of manufacture, which is permitted to be in the form of a code that does not repeat within 20 years. All external terminals and connections shall be provided with identification.

45.12 The point of connection to the charger earth grounding system shall be identified by the word "Ground" or the letters "G" or "GR" or the grounding symbol IEC 60417 Database, No. 5019 (upside down tree within a circle) or otherwise identified by a distinctive green color. Any other grounding terminals shall also be identified in a manner that is distinctive from the main earth ground terminal for the charger system.

45.13 The ESS that contains hazardous voltage circuits shall be marked "WARNING: Hazardous Voltage Circuits" or be marked with the electric shock hazard symbol ISO 3864 No. 5036 (lightning bolt within a triangle). Electrical equipment parts of the ESS such as control panels and the enclosures of disconnecting devices shall also be marked with arc flash markings according to NFPA 70E or CSA Z462 and arc flash personal protective equipment (PPE) requirements, to warn service personnel of potential for arc flash hazards, and necessary protection to be worn if applicable. See also 10.11 regarding arc flash label requirements for equipment.

45.14 ESS other than electrochemical ESS that contain hazardous materials such as flammable solids or fluids or toxic or other hazardous materials shall be marked in accordance with NFPA 704.

45.15 Energy storage systems shall be marked as follows: "WARNING: To Reduce the Risk of Injury, read all instructions" or marked with the symbols W001 (i.e. exclamation point in triangle) and M002 of ISO 7010.

45.16 Energy storage systems with walk-in enclosures shall be provided with necessary cautionary markings per 10.9 and 10.10, and shall be marked with the following or equivalent: “WARNING: Risk of Electric Shock or Other Serious Injury. Care shall be taken when entering enclosure – Authorized personnel only.”

45.17 An ESS intended for installation where exposed to moisture shall be marked with the environmental rating of its enclosure (i.e. IPX2, Type 4X, etc.) suitable for that type of exposure. See 41.2.

45.18 The control devices and indicators required for operation or maintenance shall be marked with their function on or adjacent to the control. See also 10.7 and 45.19 regarding door signs.

45.19 An egress door per 10.7 shall be marked with the word "Exit" and the line-of-sight to an exit sign shall not be interrupted. Any doorway or passage that might be mistaken for an exit shall be marked "Not an Exit" or with an indication of its actual use.

45.20 A non-residential use electrochemical ESS that complies with 1.6(b) shall be marked, "ESS with capacities exceeding 50 kWh shall include the additional fire suppression and/or fire protection identified in the installation instructions."

45.21 A non-residential use electrochemical ESS intended for use in remote outdoor locations per 1.6(d) shall be marked "For use only in remote outdoor locations as permitted in applicable installation codes and standards."

45.22 ESS disconnect controls, such as manual Emergency Power Off (EPO) disconnects, shall be marked to clearly indicate what system or part of the system they control. An EPO need not be provided with this marking if it disconnects and de-energizes the entire ESS.

INSTRUCTIONS

46 General

46.1 The ESS shall be provided with complete instructions for installation, commissioning, operation and maintenance that includes the following information:

a) Procedures for system commissioning and decommissioning;

b) Complete installation instructions, including calibration, programming, control sequence descriptions for battery management and other monitoring systems;

c) Initial acceptance testing procedures;

d) Ongoing inspection and testing procedures;

e) Instructions for retrofitting system components (non-residential use systems); and

f) Instruction for providing working clearances.

46.2 The installation instructions shall identify the maximum rated energy capacity for the system and minimum separation distances from other ESS and from exposures (e.g. combustibles, structures) in accordance with the limitations to the system based on applicable codes or in accordance with the large scale fire testing of 26.2.

46.3 Installation instructions for exterior wall-mounted ESSs shall identify the minimum separation distances from other ESS or from openings (e.g. windows, doors, HVAC inlets or other operable openings) in accordance with the code limitations or in accordance with the large scale fire testing of 26.2. Outdoor rated ESS marked "Suitable for Use in Residential Non-Habitable Spaces" are suitable for installation on exterior walls of residential dwelling units as indicated in the manufacturer's instructions.

NOTE: The separation from openings into the dwelling space in ICC IRC does not apply to exterior openings into residential attached and detached garages.

46.4 For systems that require the large scale fire testing of 26.2 in order to exceed code capacity limitations or reduce separation distances for their anticipated installation, the instructions shall identify the UL 9540A test report that was used to validate the anticipated installation including the testing organization, report designation, and date.

46.5 For ESS requiring large scale fire testing per 26.2, any additional fire suppression and/or fire protection and explosion protection identified in the UL 9540A test report shall be included in the installation instructions.

46.6 Unless further limited by manufacturer's installation instructions, instructions for electrochemical ESS for indoor residential use shall indicate that the units are only intended to be installed in attached or detached garages, sheds, enclosed utility closets, basements, storage or utility spaces within dwelling units and are not intended for installation in habitable spaces and livings spaces in dwelling units.

NOTE: In Canada, CSA C22.1 limits the indoor installation of residential ESS to a garage, a free standing structure or storage building unless meeting the criteria outlined in 26.2.2.

46.7 Installation instructions for indoor electrochemical ESS marked "Suitable for Use in Residential Habitable Spaces" shall be permitted to indicate the units are suitable for use in residential dwelling units, including in the living or habitable spaces, provided that they meet the criteria as noted in 26.2.2.

46.8 The instructions shall be in accordance with the Technical Documentation section, Section 17 of NFPA 79, or CSA C22.2 No. 301, and in accordance with 46.2 – 46.10. For additional guidance see NEMA Z535.6. Instructions for installation, operation and maintenance of the ESS shall address electrical safety including arc flash in accordance with NFPA 70E or CSA Z462.

46.9 All cautionary markings and ratings provided on the system, as well as system specifications needed for installation and operation of the system, shall be included in the instructions. If provided with remote controls, the system installation, operation and maintenance instructions shall be provided with instructions regarding operation of the remote controls and disconnecting the remote control in accordance with 17.1.

46.10 The installation information shall include instructions for making all necessary connections for electrical, communications, piping for fuels and other fluids, etc. as well as connections to other equipment that are part of the system. Multi-part ESS shall have all parts identified in the installation instructions with instructions for the installation and interconnection of those parts. The instructions shall include information on electrical disconnects, shut off valves and other devices required to be installed with the system. The installation instructions shall include the parameters required for electrical connections and installed devices in electrical circuits (communication protocols, circuits and devices) as well as parameters for fuel and other fluid connections and control devices necessary for the operation of the ESS. If the ESS controls were required to undergo a functional safety evaluation, the installation instructions shall include the functional safety standard to which the ESS was found compliant as well as the specific critical functions that were evaluated and found compliant.

46.11 The installations instructions shall specify that the system be installed in accordance with local electrical, building, fire and other codes or utility requirements as applicable to the installation and equipment, by qualified service personnel in accordance with the installation instructions and appropriate practices. Systems intended for installation in restricted access locations per 6.35 shall be designated by the manufacture as to the specifics of those locations if they are to be considered under this Standard. If restricted access locations are identified by the manufacturer, the training required to gain access shall also be identified by the manufacturer including information in the installation, operation and maintenance instructions. Any specific application location information that limits the location of the system to specific facilities, buildings, or locations such as for utility premise installations, residential buildings or commercial buildings, etc. shall be identified in the installation instructions.

46.12 With reference to 46.9, the installation instructions for ESS, such as flow batteries, lead acid batteries, etc., containing free electrolyte (greater than 208 L (55 gal) in a single vessel or an aggregate of 3785 L (1000 gal)) shall be provided with instructions for location of eye wash stations. In addition, if necessary in accordance with building codes, installation instructions shall provide information on spill control to be installed with the system per 23.1 and 23.3.

46.13 Energy storage systems intended for installation only in certain environments such as indoors only or where exposed to moisture, seismic activity or marine environments, or to be installed in restricted access locations, shall indicate this in the installation instructions. Systems intended for exposure to moisture, marine environments or seismic activity per installation instructions shall be evaluated per Section 41.

46.14 The installation instructions for a DC ESS shall include specifications for the equipment performing electric power conditioning or conversion function that is intended to be connected for supplying the DC ESS as shown in Figure 6.1, including if it is part of the DC load that the DC ESS is supplying. The instructions can include the specific equipment or systems to be used or can provide sufficient parameters required to safely connect to the DC ESS such as, but not limited to electrical ratings, communication requirements, environmental requirements, short circuit tolerance as applicable to the DC ESS.

46.15 Indoor installation instructions for residential use ESS shall provide instructions on smoke alarms to be provided in the residence in accordance with building, fire and installation codes.

46.16 The installation instructions shall include any special handling and safeguard measures to be followed during installation and shall include details of support structures such as concrete pads, etc. required for installation at the site.

46.17 An ESS shall be provided with instructions for the proper operation of the system including charging and discharging for battery systems, and operation of system controls, including identification of the communication protocols used for the system per 18.1.1. The operating instructions shall include safety measures and applicable safety warnings for operation and any instructions necessary for emergency procedures. See also 10.1 for all systems and 10.6 for systems with walk-in enclosures.

46.18 The ESS shall be provided with maintenance instructions for service personnel as well as a separate set of instructions for any basic maintenance procedures, including fuse replacement per 12.1, that would be handled by operators of the system. Maintenance instructions shall include frequency of routine maintenance to be performed including annual checks on any subsystems such as HVAC, Fire Suppression System, etc., as well as operational tests to be performed. The maintenance instructions shall include safety measures to be followed during maintenance of the system whether by service personnel or for basic maintenance procedures handled by system operators.

46.19 The maintenance instructions shall be provided with information on field replacement of replaceable materials, components and parts for ongoing maintenance and repair of the system. These instructions shall include detailed information on where to obtain and how to install the replaceable items. The instructions shall indicate that all servicing and replacement of parts are to be done by qualified persons only and that only approved materials, components and parts are to be used for replacements.

46.20 Mechanical ESS utilizing bearings for their moving parts, shall have a scheduled routine inspection and maintenance for bearings outlined in the manual. Instructions shall indicate that bearings shall be inspected for signs of wear either through visible examination or review of bearing monitoring system data and replaced if worn. In the absence of visible signs of wear or monitoring data indicating wear, the instructions shall indicate that the bearings shall be replaced by the scheduled out of service date for the bearings.

46.21 The installation instructions shall contain all ESS operation mode/settings, operation function/settings and protection/settings, which the inverters can provide.

ANNEX A (Normative)

A1 Standards for Components

A1.1 The CSA Group and UL standards listed below are used for evaluation of components and features of products covered by this Standard. Components shall comply with all the applicable CSA Group and UL component standards. These standards shall be considered to refer to the latest edition and all revisions published to that edition.

CSA Group Standards

CSA C22.2 No. 14, *Industrial Control Equipment*
CSA C22.2 No. 18.3, *Conduit, Tubing, and Cable Fittings*
CSA C22.2 No. 29, *Panelboards and Enclosed Panelboards*
CSA C22.2 No. 38, *Thermoset-Insulated Wires and Cables*
CSA C22.2 No. 42, *General Use Receptacles, Attachment Plugs, and Similar Wiring Devices*
CSA C22.2 No. 45.1, *Electrical Rigid Metal Conduit – Steel*
CSA C22.2 No. 49, *Flexible Cords and Cables*
CSA C22.2 No. 56, *Flexible Metal Conduit and Liquid-Tight Flexible Metal Conduit*
CSA C22.2 No. 64, *Household Cooking and Liquid-Heating Appliances*
CSA C22.2 No. 65, *Wire Connectors*
CSA C22.2 No. 75, *Thermoplastic-Insulated Wires and Cables*
CSA C22.2 No. 94.1, *Enclosures for Electrical Equipment, Non-Environmental Considerations*
CSA C22.2 No. 113, *Fans and Ventilators*
CSA C22.2 No. 127, *Equipment and Lead Wires*
CSA C22.2 No. 153, *Electrical Quick-Connect Terminals*
CSA C22.2 No. 158, *Terminal Blocks*
CSA C22.2 No. 178.1, *Transfer Switch Equipment*
CSA C22.2 No. 182.1, *Plugs, Receptacles, and Cable Connectors of the Pin and Sleeve Type*
CSA C22.2 No. 210, *Appliance Wiring Material Products*
CSA C22.2 No. 211.2, *Rigid PVC (Unplasticized) Conduit*
CSA C22.2 No. 227.2.1, *Liquid-Tight Flexible Nonmetallic Conduit*
CSA C22.2 No. 235, *Supplementary Protectors*
CSA C22.2 No. 248-1 (all parts), *Low-Voltage Fuses – Part 1: General Requirements*
CSA C22.2 No. 60947-4-1, *Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters*
CSA E61131-2, *Programmable Controllers – Part 2: Equipment Requirements and Tests*

UL Standards

UL 1, *Flexible Metal Conduit*
UL 5, *Surface Metal Raceways*
UL 6, *Electric Rigid Metal Conduit – Steel*
UL 6A, *Electric Rigid Metal Conduit – Aluminum, Red Brass and Stainless Steel*
UL 44, *Wires and Cables, Thermoset-Insulated*
UL 62, *Flexible Cords and Cables*
UL 66, *Fixture Wire*
UL 67, *Panelboards*
UL 83, *Wires and Cables, Thermoplastic-Insulated*
UL 162, *Foam Equipment and Liquid Concentrates*
UL 193, *Alarm Valves for Fire-Protection Service*
UL 199, *Automatic Sprinklers for Fire Protection Service*
UL 199G, *Fire Testing of Specific Application Sprinklers for Use in Attic Spaces*
UL 199H, *Fire Testing Of Specific Application Sprinklers For Use In Horizontal Concealed Spaces*
UL 199J, *Fire Testing of Specific Application Sprinklers for Use on Windows*
UL 248-1, *Low Voltage Fuses – Part 1: General Requirements* (all parts)
UL 260, *Dry Pipe and Deluge Valves for Fire-Protection Service*
UL 310, *Terminals, Electrical Quick-Connect*
UL 346, *Waterflow Indicators for Fire Protective Signaling Systems*

UL 360, *Liquid-Tight Flexible Steel Conduit*
UL 393, *Indicating Pressure Gauges for Fire-Protection Service*
UL 486A-486B, *Wire Connectors*
UL 498, *Attachment Plugs and Receptacles*
UL 499, *Electric Heating Appliances*
UL 507, *Electric Fans*
UL 508, *Industrial Control Equipment*
UL 514B, *Conduit, Tubing, and Cable Fittings*
UL 651, *Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings*
UL 651A, *Schedule 40 and 80 High Density Polyethylene (HDPE) Conduit*
UL 693, *Excess Pressure Pumps for Wet Pipe Sprinkler Systems*
UL 746A, *Polymeric Materials – Short Term Property Evaluations*
UL 746B, *Polymeric Materials – Long Term Property Evaluations*
UL 753, *Alarm Accessories for Automatic Water-Supply Control Valves for Fire Protection Service*
UL 758, *Appliance Wiring Material*
UL 796, *Printed-Wiring Boards*
UL 796F, *Flexible Materials Interconnect Constructions*
UL 1008, *Transfer Switch Equipment*
UL 1059, *Terminal Blocks*
UL 1063, *Wires and Cables, Machine-Tool*
UL 1077, *Supplementary Protectors for Use in Electrical Equipment*
UL 1091, *Butterfly Valves for Fire-Protection Service*
UL 1450, *Motor-Operated Compressors, Vacuum Pumps, and Painting Equipment*
UL 1478A, *Pressure Relief Valves for Sprinkler Systems*
UL 1626, *Residential Sprinklers for Fire-Protection Service*
UL 1660, *Liquid-Tight Flexible Nonmetallic Conduit*
UL 1682, *Plugs, Receptacles, and Cable Connectors, of the Pin and Sleeve Type*
UL 1767, *Early-Suppression Fast-Response Sprinklers*
UL 1953, *Power Distribution Blocks*
UL 1977, *Component Connectors for Use in Data, Signal, Control and Power Applications*
UL 2127, *Inert Gas Clean Agent Extinguishing System Unit*
UL 2351, *Spray Nozzles for Fire-Protection Service*
UL 2351A, *Nozzle Adaptors with Integral Filter for Fire Protection Service*
UL 2733, *Surface Vehicle On-Board Cable*
UL 60947-4-1, *Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters*
UL 60947-5-2, *Low-voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches*
UL 61131-2, *Programmable Controllers – Part 2: Equipment Requirements and Tests*