JOINT CANADA-UNITED STATES
NATIONAL STANDARD

ANSI/CAN/UL 8801:2022

STANDARD FOR SAFETY

Photovoltaic (PV) Luminaire Systems

Approved American National Standard

ANSI/UL 8801-2022

SCC FOREWORD

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UL Standard for Safety for Photovoltaic (PV) Luminaire Systems, ANSI/CAN/UL 8801

First Edition, Dated June 15, 2022

Summary of Topics

This is the First Edition of ANSI/CAN/UL 8801, Standard for Photovoltaic (PV) Luminaire Systems, dated June 15, 2022. These requirements apply to low voltage luminaire systems whose electrical power is derived from photovoltaic modules.

The new requirements are substantially in accordance with Proposal(s) on this subject dated March 11, 2022.

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ANSI/UL 8801-2022

JUNE 15, 2022

ANSI/CAN/UL 8801:2022

Standard for Photovoltaic (PV) Luminaire Systems

First Edition

June 15, 2022

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

The most recent designation of ANSI/UL 8801 as an American National Standard (ANSI) occurred on June 15, 2022. 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 15, 2022.

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Preface

This is the First Edition of ANSI/CAN/UL 8801, Standard for Photovoltaic (PV) Luminaire Systems.

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

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

This ANSI/CAN/UL 8801 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 UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at http://csds.ul.com.

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

This edition of the standard has been formally approved by the UL Standards Technical Panel (STP) on Photovoltaic (PV) Luminaire Systems, STP 8801.

This list represents the STP 8801 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

STP 8801 Membership

Name	Representing	Interest Category	Region
Barry Besmanoff	Litelab Corporation	Producer	USA
Samantha Doshi	Intertek	Testing & Standards Organization	USA
Pete Jackson	City Of Bakersfield	AHJ/Regulator	USA
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STP 8801 Membership Continued

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Samuel Sudler III	SEA LTD	General	USA
Joseph R. Musso	Underwriters Laboratories Inc.	STP Chair – Non-voting	USA
Northcott, Beth	Underwriters Laboratories Inc.	STP Project Manager – Non-voting	USA

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For further information on UL standards, please contact:

Underwriters Laboratories Inc.
Phone: (613) 755-2729
E-mail: ULCStandards@ul.com
Web site: ul.org

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

INTRODUCTION

1 Scope

1.1 These requirements apply to low voltage luminaire systems whose electrical power is derived from photovoltaic modules. Systems include, at a minimum, a photovoltaic (PV) module, storage batteries, one or more co-located luminaires, and controls to manage the energy flow between these subassemblies. These systems are intended to be installed in accordance with:

a) CSA C22.1, the Canadian Electrical Code (CE Code), Section 64, Renewable Energy Systems; and

b) NFPA 70, the National Electrical Code (NEC), Article 710 as a stand-alone system.

NOTE: In accordance with the CSA C22.1, 64-000(1), renewable energy systems operating within the class 2 limits of 16-200(1)(a) and (1)(b) are exempt from the requirements of Section 64.

1.2 These requirements do not address:

a) The grid-interactive systems covered by CSA C22.1, Section 64 and NFPA 70, Article 705;

b) Systems that include an inverter intended to supply line voltage luminaires or remote equipment; or

c) Individual system subassemblies (PV modules, batteries, luminaires, or controls) that have not been evaluated as a PV luminaire system.

1.3 These systems can include means to connect to and receive energy from the utility grid or similar supplemental supply source; see Annex A, Systems with Supplementary Power Connections. Systems with this feature can be installed in accordance with NEC Article 702, Optional Standby Systems.

1.4 These requirements apply to fixed-in-place systems, to portable systems that are intended to be easily relocated, and to systems intended for periodic user disassembly and storage. These requirements do not apply to handheld luminaires, such as a flashlight, or where light output is an auxiliary function of the handheld device (such as a smart phone).

1.5 These systems are intended for outdoor, exposed installations within a nominal ambient temperature range marked in accordance with 9.3, but no less than -20 °C to +40 °C.

1.6 These systems may include controls and devices to optimize system performance (such as sensors, positioning motors, and communication devices). They may also include output ports for diagnostic purposes or to supply temporary power to portable devices. See Annex B, Power Output Ports and Receptacles.

1.7 These requirements address only some of the mechanical infrastructure used to support or mount parts of the system. The supplemental requirements to fully evaluate the structural integrity of the mechanical infrastructure, including strength and stability of support poles under various environmental conditions such as wind or impact, and the assessment of soil or ground conditions necessary for system physical stability and reliability, are outside the scope of these requirements.

1.8 Except for components intended to connect to the utility for supplemental power in accordance with Annex A, Systems with Supplemental Power Connections, these systems are expected to operate below the 30 Vdc outdoor (wet location) class 2 voltage limits of NFPA 70 or CSA C22.1. As permitted by CSA C22.1, Section 30-1202(3) and NFPA 70, Section 411, these systems do not require grounding other than where required by Annex A. All systems are permitted to use earth ground as a reference. Any system

components carrying higher voltages will require supplemental safeguards (for example, grounding or double insulation) not fully addressed within these requirements.

1.9 These requirements do not consider the vibration and other environmental conditions that may occur for systems installed on watercraft, recreational vehicles, or other mobile platforms.

1.10 These requirements do not address the required performance for certain life safety-related applications, such as for emergency signaling or emergency/egress lighting. Additional requirements from those application-specific standards should be applied to ensure the required performance expectations can be achieved. These requirements also do not address any additional considerations that may be applicable to installation in Classified (Hazardous) Locations.

2 Components

2.1 A component of a system covered by this standard shall:

a) Comply with the requirements for that component as specified in this standard;

b) Be used in accordance with its rating(s) established for the intended conditions of use; and

c) Be used within its established use limitations or conditions of acceptability.

2.2 A component of a system covered by this standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the system;

b) Is superseded by a requirement in this standard; or

c) Is separately investigated when forming part of another system component, provided the component is used within its established ratings and limitations.

2.3 Specific components can be incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.4 A component that is relied upon to perform critical safety functions such as overcurrent or overtemperature protection, ground-fault circuit-interruption, or surge suppression, whether individually or in combination with some other component(s), shall comply with the requirements of the applicable UL standard(s) that cover devices that provide those functions.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Referenced Publications

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

4.2 The following publications are referenced in this standard. Where CSA standards are cited, they are part of the C22.2 series as specified below.

CSA C22.1, *Canadian Electrical Code*

CSA C22.2 No. 65, *Wire Connectors*

CSA C22.2 No. 66.2, *Low Voltage Transformers – Part 2: General Purpose Transformers*

CSA C22.2 No. 66.3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

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, *General Use Power Supplies*

CSA C22.2 No. 141, *Emergency Lighting Equipment*

CSA C22.2 No. 178.1, *Transfer Switch Equipment*

CSA C22.2 No. 182.5, *Photovoltaic Connectors*

CSA C22.2 No. 188, *Splicing Wire Connectors*

CSA C22.2 No. 223, *Power Supplies With Extra-Low Voltage Class 2 Outputs*

CSA C22.2 No. 248.1, *Low-Voltage Fuses – Part 1: General Requirements*

CSA C22.2 No. 248.19, *Low-Voltage Fuses – Part 19: Photovoltaic Fuses*

CSA C22.2 No. 250.0, *Luminaires*

CSA C22.2 No. 250.2, *Lighting Systems*

CSA C22.2 No. 250.13, *Light Emitting Diode (LED) Equipment for Lighting Applications*

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 C22.2 No. 60950-1, *Information Technology Equipment, Safety – Part 1: General Requirements*

CSA C22.2 No. 61730-1, *Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements For Construction*

CSA C22.2 No. 61730-2, *Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements For Testing*

CSA C22.2 No. 62133-1, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications – Part 1: Nickel Systems*

CSA C22.2 No. 62133-2, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications – Part 2: Lithium Systems*

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

NFPA 70, *National Electrical Code (NEC)*

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

UL 248-1, *Low-Voltage Fuses – Part 1: General Requirements*

UL 248-19, *Low-Voltage Fuses – Part 19: Photovoltaic Fuses*

UL 486A-486B, *Wire Connectors*

UL 486C, *Splicing Wire Connectors*

UL 508, *Industrial Control Equipment*

UL 924, *Emergency Lighting and Power Equipment*

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

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

UL 1008, *Transfer Switch Equipment*

UL 1310, *Class 2 Power Units*

UL 1598, *Luminaires*

UL 1642, *Lithium Batteries*

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

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

UL 1989, *Standby Batteries*

UL 2054, *Household and Commercial Batteries*

UL 2108, *Low Voltage Lighting Systems*

UL 2703, *Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use with Flat-Plate Photovoltaic Modules and Panels*

UL 5085-2, *Low Voltage Transformers – Part 2: General Purpose Transformers*

UL 5085-3, *Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers*

UL 6703, *Connectors for use in Photovoltaic Systems*

UL 8703, *Concentrator Photovoltaic Modules and Subassemblies*

UL 8750, *Light Emitting Diode (LED) Equipment For Use In Lighting Products*

UL 60947-4-1, *Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters*

UL 60950-1, *Information Technology Equipment – Safety – Part 1: General Requirements*

UL 61730-1, *Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements For Construction*

UL 61730-2, *Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements For Testing*

UL 62133-1, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications – Part 1: Nickel Systems*

UL 62133-2, *Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes – Safety Requirements for Portable Sealed Secondary Cells, and for Batteries Made From Them, for Use in Portable Applications – Part 2: Lithium Systems*

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

4.3 For requirements that refer to compliance with a CSA or UL standard, unless otherwise specified, the CSA standard applies for Canada compliance and the UL standard applies for U.S. compliance.

5 Glossary

5.1 PORTABLE – Easily relocated assemblies, such as stake lights or pop-up structures intended to be moved from place to place.

5.2 PV MODULE – A complete and environmentally protected assembly of interconnected photovoltaic cells, typically consisting of a framed top clear layer over an encapsulant, PV cells, another encapsulant, and a backing/substrate material. Photovoltaic modules can be assembled into photovoltaic panels and photovoltaic arrays.

5.3 SUBASSEMBLY – An integrated combination of parts or components that, together, constitute a subsystem of the overall PV luminaire system.

5.4 SYSTEM – An assembly including, at a minimum, a photovoltaic module, battery, and low voltage luminaire.

CONSTRUCTION

6 System Assembly

6.1 These systems are permitted to be packaged and shipped with some level of field assembly required. Assembly instructions shall be included as part of the installation instructions, shall identify all system parts, the skill and knowledge level necessary for the assembly process, and shall include appropriate detail (including pictures, where appropriate) for the identified skill and knowledge level.

6.2 Subassemblies are permitted to be shipped separately from one another provided that:

a) The instructions provided with all system subassemblies identifies all subassembly parts (such as in a master assembly drawing or parts list); and

b) The instructions provided with each separately shipped subassembly explain how it is to be assembled into the system.

6.3 Any specialized or custom tool(s) needed for assembly purposes shall be provided and shipped with at least one of the parts directly associated with the tool.

6.4 Electrical connections between subassemblies shall be of a design that requires no more than ordinary mechanical tools and knowledge (e.g., wire nuts, screw or push-in terminals, quick-connects, etc.). Any strain relief or similar devices (i.e., shields or barriers) necessary to protect the integrity of electrical connections after assembly shall be provided, along with instructions as to their proper deployment.

7 System Subassemblies

7.1 General

7.1.1 PV luminaire systems consist of subassemblies expected to comply with all or applicable portions of other safety standards specified in Section 4, Referenced Publications. The requirements in this section provide more specific guidance as to the application of those standards, and to the manner in which these subassemblies are to be integrated to form the lighting system.

7.1.2 Where requirements for the electrical interconnection of components are not specified, the applicable portions of the NFPA 70 or CSA C22.1 are to be applied.

7.2 PV Modules

7.2.1 PV modules shall comply with the class III requirements of CSA or UL 61730-1.

NOTE: For the U.S. and Canada, the output limits of a class III PV module are 30 Vdc, 8 A, 240 W. Multiple PV modules, connected in parallel or series, are permitted where the aggregate output remains within these limits. Fusing as required by 7.2.6 is a permitted means to limit the output.

7.2.2 PV modules shall comply with the following tests from CSA or UL 61730-2:

a) Visual exam for construction integrity (MST 01);

b) Power measurements (MST 02, 03);

c) Temperature test (MST 21); and

d) Module breakage test (MST 32).

For the power measurement at standard test conditions (STC), the correction factors in Table 690.7(A) of NFPA 70 shall be applied when establishing the open circuit voltage, based on the lowest ambient temperature rating for the module.

7.2.3 PV modules with measured output power exceeding 100 W shall additionally comply with the following test sequence from CSA or UL 61730-2:

a) UV pre-conditioning (MST 54), if there are exposed polymeric materials with a functional or safety role that have not been found suitably resistant to UV exposure;

b) Humidity freeze (MST 52);

c) Wet leakage current test (MST 17).

NOTE: An F1 rating as specified in UL 746C is one means of demonstrating suitable resistance to UV exposure.

7.2.4 A separately mounted PV module that is required to comply with the Wet Leakage Current Test in accordance with 7.2.3, shall additionally comply with the Static Mechanical Load Test (MST 34) of CSA or UL 61730-2.

7.2.5 PV modules for portable systems shall additionally be evaluated for compliance with 8.7, Mechanical Tests for Portable PV Luminaire Systems.

7.2.6 Fusing on the output of the PV module shall comply with CSA or UL 248-19 and shall be rated between 1.56 I_{sc} (rounded up to the nearest trade size fuse) and 5 A.

7.2.7 The PV module output or the battery charging circuitry (see 7.5.3) shall include diodes or equivalent means to prevent reverse charging of module components from the battery.

7.2.8 PV module output connectors shall comply with CSA or UL 486A-486B, CSA or UL 486C, or CSA C22.2 No. 182.5 or UL 6703, as applicable, with suitable electrical and environmental exposure ratings for the application.

7.3 PV module adjustment mechanisms

7.3.1 Motors shall comply with CSA C22.2 No. 100 or UL 1004-1 and shall be rated for the environmental conditions, input voltage provided, and for the mechanical load controlled.

7.3.2 Moving parts shall be located, guarded, or enclosed so as to not present pinch points to service personnel performing adjustments or examinations that may warrant being performed with the equipment energized. The assessment for injury risk shall include the degree of exposure, sharpness and speed of the moving part, and likelihood and injury severity of entangled fingers, arms, or clothing.

7.3.3 If module adjustment is motor-assisted, an emergency stop button shall be provided where readily visible and accessible to service persons. The emergency stop button shall be red with a palm or mushroom head type and of the latched type so it is not possible to restart the motor until the emergency stop button is manually reset. The emergency stop shall override all other controls and cause all moving parts to stop.

7.4 Batteries

7.4.1 Batteries shall be securely mounted where not subject to impact or damage after installation, and shall be housed within an enclosure rated 3R in accordance with CSA C22.2 No. 94.2 or UL 50E, or otherwise protected from environmental conditions (such as rain, snow, or ice) that could compromise battery safety. A polymeric enclosure serving this purpose shall additionally comply with the applicable outdoor exposure requirements of UL 746C.

NOTE: An IP54 rating is generally considered comparable to a 3R rating from CSA 94.2 and UL 50E.

7.4.2 If the battery compartment has a removeable cover, that cover shall remain secured to the equipment when opened, by a hinge, tether, or similar means to prevent full removal. The securement means shall be of a design and of sufficient strength and environmental resistance to retain its capability for the expected life of the equipment.

7.4.3 Batteries shall be used in accordance with the battery manufacturer's specifications.

7.4.4 Batteries and battery cells shall comply with applicable construction requirements and the tests specified in the standards specified below, based on battery chemistry:

a) Lithium ion – one of the following:

1) CSA or UL 62133-2: continuous charging, external short-circuit, thermal abuse, overcharge, forced discharge (if >2 series-connected cells); or

2) UL 2054 or UL 1642: short circuit, abnormal charging, abusive overcharge, forced discharge (if >2 series-connected cells), heating, temperature cycling.

b) Nickel – one of the following:

1) CSA or UL 62133-1: low rate charging, temperature cycling, external short circuit, thermal abuse, overcharge, forced discharge (if >2 series-connected cells); or

2) UL 2054: short circuit, abnormal charging, abusive overcharge, forced discharge (if >2 series-connected cells), heating, temperature cycling.

c) Lead – UL 1989: pressure release test, where a pressure release device is used with a sealed battery.

Exception: Batteries that comply with comparable requirements in UL 1973 meet the intent of the requirement.

7.4.5 For a system with a replaceable lithium ion battery, the battery replacement marking (see 9.6) shall specify only a comparable battery with an integral battery management system (BMS). If the lithium ion battery is not replaceable, the BMS circuitry is permitted to be integral with the battery or another portion of the system.

NOTE: A battery management system (BMS) maintains lithium ion cells within the manufacturer's specified safe operating range (voltage, current, temperature) for charge and discharge activity. It may be integral to the battery pack, or be one or more circuits within a single purpose or multifunction control device located elsewhere in the system. The BMS for UL 2054 or UL 62133-2 compliant batteries is typically evaluated through tests on the charging circuitry (see 7.5) and thermal management/protection system, while the BMS for UL 1973 compliant batteries typically applies a functional safety evaluation to the charge and discharge control firmware and software. A BMS may include additional protective functions, such as to extend the expected usable life of the battery or improve system energy-use efficiency.

7.4.6 A battery that is intended to be replaced shall be in the form of a battery or battery pack; no individual cells are permitted for replacement.

7.4.7 The battery shall have a storage temperature rating suitable for the ambient temperature range marked in accordance with 9.3.

7.5 Battery charging circuitry

7.5.1 The output characteristics of the battery charging circuit shall be compatible with the rating of the identified battery, as determined by compliance with the tests of 8.2, Battery Charge Rate and Voltage Limit Measurement, 8.3, Battery Charging Circuit Abnormal Test, and, for lithium ion batteries, 8.4, Battery Management System Temperature Protection Performance Test. If the charging circuit is user-adjustable, instructions (or reference to a website where such instructions are available) shall be marked within the battery compartment.

Exception: Battery charging circuitry that is integral to the battery pack and/or has been evaluated for use with that battery pack is not required to be additionally evaluated in accordance with 8.2 and 8.3.

7.5.2 The input characteristics of the battery charging circuitry shall be compatible with the PV module electrical output ratings (V_{oc} and I_{sc}), with allowance for intervening circuitry or control devices.

NOTE: A battery charge controller that complies with UL 1741 (Sections 69 – 79) and marked as compatible with the PV module electrical output rating (V_{oc} and I_{sc}) is considered to comply with this requirement. However, the tests of 8.2, Battery Charge Rate and Voltage Limit Measurement and 8.3, Battery Charging Circuit Abnormal Test are still required.

7.5.3 The battery charging circuitry shall have means to prevent current flow from a charged battery to reverse charge any PV module components, unless such means are integral with the PV module.

7.5.4 Temperatures on the battery and its charging circuit componentry shall remain within their rated specifications when operated in accordance with 8.1, Temperature Test.

7.6 Battery output circuits

7.6.1 The output of a battery circuit shall be provided with DC-rated overcurrent protection suitable for branch-circuit protection and rated in accordance with NFPA 70, Section 240.4(D) or CSA C22.1, Section 14-100, as applicable.

Exception: Batteries whose output complies with the Limited Power Source Test of UL 2054 do not require additional overcurrent protection.

7.6.2 The protective device shall be located adjacent to the battery connecting means ahead of any conductors or components likely to malfunction under short-circuit conditions such as capacitors, solid-state devices, or similar.

7.6.3 Conductors connected to the load side of the battery shall be sized in accordance with the applicable provisions of NFPA 70 or CSA C22.1, as specified in 7.1.2.

7.7 Controls

7.7.1 All control inputs and outputs accessible during use or maintenance shall be within wet location class 2 limits. All control devices, other than sensors or output ports intended for environmental exposure, shall be housed within an enclosure rated 3R in accordance with CSA C22.2 No. 94.2 or UL 50E, or otherwise protected from environmental conditions (such as rain, snow, or ice) that could compromise system safety. A polymeric enclosure serving this purpose shall additionally comply with the applicable outdoor exposure requirements of UL 746C.

NOTE: An IP54 rating is generally considered comparable to a 3R rating from CSA C22.2 No. 94.2 or UL 50E.

7.7.2 Compliance with applicable performance tests shall consider the full range of control signals, including under single fault conditions unless the control device has been evaluated and found to retain its output limitations under such conditions.

NOTE: Reliability of control devices can be established through compliance with UL 8750, Supplement SA, Requirements for Safety-Related Electronic Circuits.

7.7.3 Integral auxiliary equipment, such as heaters to maintain batteries within prescribed temperature limits, shall be evaluated for risk of fire (including ignition of other devices or materials) under their most severe anticipated operating conditions, including single fault conditions in associated control circuits.

7.8 Luminaires

7.8.1 Luminaires shall be suitable for wet locations and comply with CSA C22.2 No. 250.2 or UL 2108. Luminaires that comply with CSA C22.2 No. 250.0 or UL 1598 that are suitable for wet locations and operate at 30 Vdc or less, are also permitted.

NOTE: Polymeric enclosures of wet location rated equipment are typically evaluated for impact resistance down to -35 °C. This should be considered in the context of the system ambient range marking of 9.3.

7.8.2 LED arrays, drivers, and related LED components that are not integral to the luminaire shall comply with the applicable requirements of CSA C22.2 No. 250.13 or UL 8750, and shall be used within their intended ratings and conditions of service.

7.8.3 With respect to 7.8.2, LED optics are permitted to have a flammability rating of HB for systems intended to be mounted away from structures.

7.8.4 Luminaires and related lighting components shall have an input rating (voltage and current or wattage) compatible with the battery output or that of any intervening controller.

7.9 Electrical conductors and connections

7.9.1 All conductors shall be sized, insulated, and thermally and environmentally rated for their conditions of service. Conductors on the PV module output shall be sized at no less than 125 % of the output short circuit current rating.

7.9.2 All conductor terminations shall be made mechanically secure, using appropriately rated termination devices and splicing means suitable for the level of exposure.

7.9.3 A disconnect means (switch or detachable connector) shall be provided on the output of the PV module and on the output of the battery. These disconnecting means shall be readily accessible and marked to identify their purpose.

7.10 Mechanical structure

7.10.1 A hinged or pivoted panel or cover shall be positioned and securable such that it is not subject to falling or swinging due to gravity in a manner likely to cause injury to service persons.

7.10.2 All luminaires, PV modules, and accessory equipment whose mounting design is subject to gravitational forces shall comply with 8.6, Static Load Mounting Means Test. Where equipment or parts of equipment can be adjusted, the test shall be performed in the most disadvantageous position.

Exception: A PV module mounted using a system that complies with UL 2703 that has been tested with and identified for use with that module, is not required to be tested in accordance with 8.6.

PERFORMANCE

8 Performance

8.1 Temperature test

8.1.1 General – all systems

8.1.1.1 Where individual system subassemblies, when installed, are physically separated from one another so as to have no significant thermal interaction, it is permitted to conduct the Temperature Test on those subassemblies without the system being assembled as in service.

NOTE 1: PV modules or low voltage luminaires mounted remote from each other, and from the battery and control circuits, are examples of subassemblies that can be temperature tested separate from the system.

NOTE 2: When mounted remote from one another and from the battery and control circuits, no further temperature testing is required for a PV module that complies with the CSA or UL 61730-2, Temperature Test (see 7.2.2) or for a low voltage luminaire that complies with the UL 2108 or CSA C22.2 No. 250.2, Temperature Test (see 7.8.1). However, these subassemblies are still permitted to serve as the power source (PV module) or load (luminaire) for conducting the Temperature Test.

8.1.1.2 Systems with a housing that includes the PV module, luminaire, and battery are to be tested in accordance with 8.1.2, Systems With An Integral PV Module. Systems with a PV module mounted where thermally distant (minimum 6 inches above or aside) from the battery housing are to be tested in accordance with 8.1.3, Housing With Thermally Remote PV Module. Systems with both the PV module and luminaire mounted where thermally distant from the battery housing are to be tested in accordance with 8.1.4, Housing With Thermally Remote PV Module And Luminaire.

8.1.1.3 Other than for battery protection circuitry, system sensors and/or controls designed to modify the charge and discharge sequences (for example, photosensors to activate or de-activate the luminaire) shall be bypassed except where specifically indicated. For systems with supplementary power sources, see also 8.1.7.

8.1.1.4 The temperature of all thermally sensitive components, and components with defined thermal limits, including batteries, shall not exceed their rated temperature specifications.

NOTE: Where the temperature of a battery case is to be monitored, attention should be given as to whether the specified compliance limit relates to the battery cell or the battery assembly / pack. Where compliance is based on the cell case temperature, care should be taken to not damage the battery during thermocouple application.

8.1.1.5 The test is permitted to be conducted in any ambient of 20 °C or higher, up to the maximum marked ambient in accordance with 9.3. When the test is conducted in an ambient lower than the marked maximum, compliance with 8.1 is to be determined by adding the difference between the test ambient and maximum marked ambient to the measured temperatures, except where modified in 8.1.2, 8.1.3, or 8.1.4, as applicable.

8.1.2 Systems with an integral PV module

8.1.2.1 This test method is applicable to systems whose housing allows for thermal interaction between the PV module and battery.

NOTE: This method recognizes that the PV module generates maximum heat while the luminaire is thermally passive, and the luminaire generates heat while the PV module is thermally passive. The battery generates heat during both charge and discharge activities, with the charge cycle concurrent with PV module operation (daylight and higher ambient conditions) and the discharge cycle concurrent with luminaire operation (evening and lower ambient conditions). Thermal interaction between the battery and PV module or luminaire will be dependent on their spatial relationship.

8.1.2.2 The integral PV module is to be exposed to the Standard Test Conditions (STC) in accordance with the CSA or UL 61730-2 Temperature Test until the ambient conditions inside the housing are stabilized, as measured by two thermocouples spaced apart within the housing interior and not in contact with any surfaces. Temperatures are considered stable when three consecutive measurements no less than 15 minutes apart vary by no more than one degree.

NOTE 1: The housing internal ambient temperature measurement can also be obtained concurrent with the PV module temperature test if required per 7.2.2.

NOTE 2: As a safety precaution for lithium ion battery systems, this initial step may be performed with the battery removed, to validate that the battery storage temperature limit is not exceeded.

8.1.2.3 The system shall be allowed to cool to room temperature, the battery fully discharged, and additional thermocouples placed on components whose temperature is to be measured. The system is to be placed in an environmental chamber capable of 10 °C per hour graduated temperature adjustment. A DC power source with output matching that of the PV module is to be connected in lieu of the PV module output, and means shall be provided to monitor the battery charge and discharge current. The system is to be placed and oriented in the chamber in a manner representative of its intended installation (e.g., PV module facing up; luminaire facing down).

NOTE: Light output from the luminaire can often be used as evidence of battery discharge.

8.1.2.4 The chamber shall be initially set at 30 °C. The DC power source is to be energized and the chamber temperature gradually raised (10 °C per hour) until at least one of the two internal ambient thermocouples reach the temperature measured in 8.1.2.2. The chamber temperature shall be further increased, at the same 10 °C per hour rate, an amount equal to the difference between the maximum marked ambient and the ambient used for the 8.1.2.2 measurement. The chamber temperature is to remain at this level until the first of the following events occur:

a) Charging is halted by action of the battery management system;

b) The battery charging drops to less than 10 % the maximum rate observed during the first 30 minutes of charging; or

c) The temperature on the battery case exceeds its maximum specified charging temperature by 2 °C (or more) for 2 minutes.

If event (c) occurs, the results are non-compliant. If event (a) or (b) occurs, the test shall continue until all temperatures are stable.

8.1.2.5 The DC power source shall then be de-energized, the battery directed to discharge and supply the luminaire, and the chamber temperature lowered at a rate of 10 °C per hour. If discharging occurs while the battery is outside (above) its maximum permitted discharge temperature, results are non-compliant and the test is to be discontinued. Otherwise, when the chamber reaches 30 °C, it shall be maintained at that temperature until the first of the following events occur:

a) Six hours have transpired since initiation of battery discharge;

b) All temperatures are consistently moving lower; or

c) The temperature on the battery case exceeds its maximum specified discharging temperature by 2 °C (or more) for 2 minutes.

If event (c) occurs, the results are non-compliant.

8.1.2.6 The charge and discharge cycle specified in 8.1.2.4 and 8.1.2.5 shall then be repeated.

8.1.3 Housing with thermally remote PV module

8.1.3.1 This test method is applicable to systems with an integral luminaire (or LED array) and whose PV module is located no less than six inches (15 cm) above or to the side of the housing containing the battery.

8.1.3.2 The battery is to be fully discharged and thermocouples placed on components whose temperature is to be measured. The system shall be placed in an environmental chamber capable of 10 °C per hour graduated temperature adjustment. A DC power source with output matching that of the PV module is to be connected in lieu of the PV module output, and means shall be provided to monitor the battery charge and discharge current. The system shall be placed and oriented in the chamber in a manner representative of its intended installation.

NOTE: Light output from the luminaire can often be used as evidence of battery discharge.

8.1.3.3 The chamber shall be initially set at 30 °C. The DC power source shall be energized and the chamber temperature gradually raised (10 °C per hour) to the maximum marked ambient in accordance with 9.3. The chamber temperature shall remain at this level until the first of the following events occur:

a) Charging is halted by action of the battery management system;

b) The battery charging drops to less than 10 % of the maximum rate observed during the first 30 minutes of charging; or

c) The temperature on the battery case exceeds its maximum specified charging temperature by 2 °C (or more) for 2 minutes.

If event (c) occurs, the results are non-compliant. If event (a) or (b) occurs, the test is to continue until all temperatures are stable.

8.1.3.4 The DC power source shall then be de-energized, the battery directed to discharge and supply the luminaire, and the chamber temperature lowered at a rate of 10 °C per hour. If discharging occurs while the battery is outside (above) its maximum permitted discharge temperature, results are non-compliant and the test is to be discontinued. Otherwise, when the chamber reaches 30 °C, it shall be maintained at that temperature until the first of the following events occur:

a) Six hours have transpired since initiation of battery discharge;

b) All temperatures are consistently moving lower; or

c) The temperature on the battery case exceeds its maximum specified discharging temperature by 2 °C (or more) for 2 minutes.

If event (c) occurs, the results are non-compliant.

8.1.3.5 The charge and discharge cycle described in 8.1.3.3 and 8.1.3.4 shall then be repeated.

8.1.4 Housing with thermally remote PV module and luminaire

8.1.4.1 This test method is applicable to systems whose luminaire and PV module are both located no less than six inches (15 cm) above or to the side of the housing containing the battery.

8.1.4.2 The battery is to be fully discharged and thermocouples placed on components whose temperature is to be measured. The battery housing and luminaire shall be placed in an environmental chamber capable of 10 °C per hour graduated temperature adjustment, oriented as intended and spaced

apart from one another so as to represent the same limited thermal interaction as expected when installed. A DC power source with output matching that of the PV module is to be connected in lieu of the PV module output, and means shall be provided to monitor the battery charge and discharge current.

NOTE: Light output from the luminaire can often be used as evidence of battery discharge.

8.1.4.3 The chamber shall be initially set at 30 °C. The DC power source shall be energized to initiate battery charging (the luminaire will not be activated) and the chamber temperature gradually raised (10 °C per hour) to the maximum marked ambient in accordance with 9.3. The chamber temperature is to remain at this level until the first of the following events occur:

a) Charging is halted by action of the battery management system;

b) The battery charging drops to less than 10 % of the maximum rate observed during the first 30 minutes of charging; or

c) The temperature on the battery case exceeds its maximum specified charging temperature by 2 °C (or more) for 2 minutes.

If event (c) occurs, the results are non-compliant. If event (a) or (b) occurs, the test is to continue until all temperatures are stable.

8.1.4.4 The DC power source shall then be de-energized, the battery directed to discharge and supply the luminaire, and the chamber temperature lowered at a rate of 10 °C per hour. If discharging occurs while the battery is outside (above) its maximum permitted discharge temperature, results are non-compliant and the test is to be discontinued. Otherwise, when the chamber reaches 30 °C, it shall be maintained at that temperature until the first of the following events occur:

a) Six hours have transpired since initiation of battery discharge;

b) All temperatures are consistently moving lower; or

c) The temperature on the battery case exceeds its maximum specified discharging temperature by 2 °C (or more) for 2 minutes.

If event (c) occurs, the results are non-compliant.

8.1.4.5 The charge and discharge cycle specified in 8.1.4.3 and 8.1.4.4 shall then be repeated.

8.1.5 The temperature of any subassembly exterior surface intended to be mounted within 7 feet of grade, or in contact with a supporting structure (unless marked in accordance with 9.9), shall not exceed 90 °C.

Exception: The light emitting portion of a luminaire has no thermal limit other than the generic or specific temperature rating of the material itself.

8.1.6 For an integrated portable PV luminaire system, the thermal limits specified in Table 8.1 apply to accessible surfaces.

Table 8.1
Thermal Limits Applicable To Accessible Surfaces

Part	Limit °C (°F)		
	Metal	Glass, porcelain, enamel [a]	Polymeric [a]
Handles or parts intended for carrying	55 (131)	65 (149)	75 (167)
Controls intended for short term contact	60 (140)	70 (158)	85 (185)
Other exterior parts subject to casual contact.	70 (158)	80 (176)	95 (203)
[a] Nonmetallic materials shall not be used above their generic or specific temperature ratings.			

8.1.7 The temperature test for a system with a supplemental power source (in accordance with Annex A, Systems with Supplemental Power Connections), and sensors/controls to engage and disengage the supplemental source, shall be modified in accordance with (a) or (b) below, as applicable. Thermocouples shall be applied to appropriate locations on the supplemental power source to monitor the temperature of any critical components.

a) Supplemental Battery Charging, Section A2. During the first discharge cycle of 8.1.2.5, 8.1.3.4, or 8.1.4.4 as applicable, the supplemental source is to resume charging the battery. This power configuration shall continue uninterrupted until stable temperatures are obtained. The mechanism to de-energize the luminaire upon daylight conditions (photosensor, current flow from the PV module, timer, or other) shall then be triggered. The second cycle (8.1.2.6, 8.1.3.5, or 8.1.4.5) shall then be initiated.

b) Supplemental Luminaire Power, Section A3. These systems will bring power directly to the luminaire (bypassing the battery) when battery power is insufficient. When this occurs, temperatures on the luminaire shall continue to be monitored, until stable. The mechanism to disconnect the supplemental power source upon daylight conditions (photosensor, current flow from the PV module, timer, or other) shall then be triggered. The second cycle (8.1.2.6, 8.1.3.5, or 8.1.4.5) shall then be initiated.

8.2 Battery charge rate and voltage limit measurement

8.2.1 This test is applicable to battery charging circuitry that is not integral to the battery pack and previously evaluated for compatibility with the battery in accordance with 7.5.1.

8.2.2 A DC power supply shall be connected in lieu of the designated PV module, with its output set at the maximum voltage and current rating of the designated PV module. Starting with a fully discharged battery, the supply shall be energized and current flow from the charging circuit into the battery shall be monitored during the charge cycle to determine the maximum rate. The test shall be continued until the rate of charging has decreased from its maximum rate and is stable, but not less than 3 hours.

8.2.3 The maximum rate (current) and voltage shall not exceed the battery manufacturer's recommendation.

8.3 Battery charging circuit abnormal test

8.3.1 This test applies to battery systems where the battery charging circuitry is not integral to the battery pack and previously evaluated for compatibility with the battery in accordance with 7.5.1.

8.3.2 Single fault conditions that may increase the output charging voltage or current shall be imposed, one at a time, on the charging circuitry. Using the same setup as for the test of 8.2, Battery Charge Rate And Voltage Limit Measurement, the battery shall be charged under these conditions for 7 hours. The test may be discontinued prior to 7 hours if it can be determined that stable conditions have occurred.

8.3.3 This test shall not result in any of the following:

a) Chemical leaks caused by cracking, rupturing or bursting of the battery jacket;

b) Spillage of liquid from any pressure relief device in the battery;

c) Explosion of the battery; or

d) Emission of flame or expulsion of molten material outside of the enclosure.

If the assembly becomes inoperable during any test sequence, a new sample may be used to continue the test program.

8.4 Battery management system temperature protection performance

8.4.1 This test validates whether the battery management systems (BMS) de-activates charging or discharging when the battery temperature falls outside the manufacturer's specified thermal range for charge and discharge in accordance with 7.4.7. See 8.4.7 for systems that use supplemental heating or cooling for battery temperature management.

NOTE: A BMS included in a system that complies with the temperature test of 8.1.2.4, 8.1.3.3, or 8.1.4.3 is considered to comply with 8.4.3 below.

8.4.2 Thermocouple(s) shall be applied to appropriate location(s) on the battery case. The battery (alone, or with a subassembly, or the full system – see informational note below) is to be placed within an environmental chamber able to be gradually adjusted in increments of 10 °C per hour across the full permitted (manufacturer specified) range of battery charge and discharge temperatures. A DC power supply shall be connected to supply the battery charging system, in lieu of the designated PV module, with its output set at the maximum voltage and current rating of the designated PV module.

NOTE: The battery alone or any subassembly of the full system is permitted to be in the environmental chamber for this test, provided that it is reasonable to expect comparable performance with the entire system within the chamber.

8.4.3 Starting with a fully discharged battery in a 25 °C (±5 °C) environment, the supply shall be energized and current flow from the charging circuit into the battery shall be monitored. The chamber temperature is to be gradually raised at the rate of 10 °C per hour until the higher of the maximum marked ambient in accordance with 9.3) or the maximum temperature used for 8.1.2.4 (if applicable) is reached. These conditions shall be continued until the first of the following events occur:

a) Charging is halted by action of the BMS;

b) The maximum ambient has been maintained for at least 30 minutes and charging current is stable for at least 30 minutes. Charging current stability is established when the current is less than 10 % the maximum rate observed during the first 30 minutes; or

c) The temperature on the battery case exceeds the maximum specified charging temperature by 2 °C (or more) for 2 minutes.

The charging source shall then be de-energized. Result (c) is non-compliant. If result (a) or (b) occurs, continue to 8.4.4.

8.4.4 While the chamber is maintained at the same ambient as specified in 8.4.3, the battery is to be directed into discharge mode by the applicable system control function (i.e., daylight sensor, timer, or other). The chamber temperature shall then be gradually lowered (10 °C per hour) until the first of the following events occur:

a) Discharging occurs outside (above) the battery's maximum permitted discharge temperature;

b) Discharging occurs within the battery's permitted discharge temperature range and continues as expected for no less than 10 minutes.

Result (a) is non-compliant. If result (b) occurs, continue to 8.4.5.

8.4.5 Fully discharge the battery. Starting in a 25 °C (±5 °C) environment, energize the supply source to the charging circuit and monitor current flow into the battery as the chamber temperature is gradually lowered at the rate of 10 °C per hour to the minimum marked ambient in accordance with 9.3. The test shall be continued until the first of the following events occur:

a) Charging is halted by action of the BMS;

b) The minimum ambient has been maintained for at least 30 minutes and charging current is stable for at least 30 minutes. Charging current stability is established when the current is less than 10 % the maximum rate observed during the first 30 minutes; or

c) The temperature on the battery case is below the minimum specified charging temperature by 2 °C (or more) for 2 minutes.

The charging source shall then be de-energized. Result (c) is non-compliant. If result (a) and (b) occurs, continue to 8.4.6.

8.4.6 While the chamber is maintained at the minimum marked ambient temperature, the battery is to be directed into discharge mode by the applicable system control function (i.e., daylight sensor, timer, or other). The chamber temperature shall then be gradually raised (10 °C per hour) until the first of the following events occur:

a) Discharging occurs outside (below) the battery's minimum permitted discharge temperature;

b) Discharging occurs within the battery's permitted discharge temperature range and continues as expected for no less than 10 minutes.

Result (a) is non-compliant.

Exception: Where the battery's minimum permitted discharge temperature is lower than the marked minimum ambient of the system in accordance with 9.3, the test sequence of 8.4.6 can be waived.

8.4.7 For systems that use battery temperature management (heating or cooling), the temperature management system is permitted to remain operable during the testing of 8.4 when the system is shown to comply with the requirements of UL 8750 Supplement SA, Requirements for Safety-Related Electronic Circuits (SREC). A temperature management system not known to comply with the UL 8750 SREC requirements is to be bypassed when determining compliance with 8.4, Battery Management System Temperature Protection Performance.

8.5 Battery discharge abnormal test

8.5.1 This test applies to battery systems that include multiple lithium ion batteries connected in series, including parallel strings of series-connected batteries.

8.5.2 With the load to the battery system disconnected, one battery in the series (or one string of batteries in a parallel string system) shall be completely discharged, while the other batteries (or strings) are fully charged. The load is then to be connected and the battery system permitted to discharge until completely discharged and stable conditions are realized.

8.5.3 This test shall not result in any of the following:

a) Chemical leaks caused by cracking, rupturing or bursting of the battery jacket;

b) Spillage of liquid from any pressure relief device in the battery;

c) Explosion of the battery; or

d) Emission of flame or expulsion of molten material outside of the enclosure.

If the assembly becomes inoperable during any test sequence, a new sample may be used to continue the test program.

8.6 Static load mounting means test

8.6.1 Each subassembly is to be mounted in accordance with its installation instructions, using the hardware provided or specified. Where positional adjustments are permitted, the subassembly shall be installed in the manner that provides for the most severe test of the mounting means. A weight of three times the weight of the subassembly is to be gradually applied at the point of maximum projection from the mounting surface and maintained for one hour. Neither the subassembly or the mounting hardware shall be pulled from the mounting surface.

8.7 Mechanical tests for portable PV luminaire systems

8.7.1 General

8.7.1.1 These tests are intended to evaluate the mechanical strength and integrity of the PV module for systems subject to relocation or temporary storage. Where the PV module is integral to and not separate from other system subassemblies, the entire system can be tested with the compliance determination based on the performance of the PV module only.

8.7.2 Drop impact test

8.7.2.1 Three sample modules are to be placed in a cooling chamber set to – 35.0 ±2.0 °C (– 31.0 ±3.6 °F) for a minimum of 3 hours. Immediately upon removal from the cooling chamber, the samples are to be individually dropped (free fall) three times each, in succession, from a height of 3 feet (914 mm) from the lowest portion of the module onto a concrete surface. Each drop on a given sample is to impact at a point on the unit different from the impact points for the other drops.

8.7.2.2 The samples shall then be visually examined. No live parts shall be accessible to contact using a standard articulated probe, and there shall be no visual evidence of cracking or breaking of a substrate or outer protective laminate material.

8.7.3 Resistance to compression forces test

8.7.3.1 One sample module is to be placed in a cooling chamber set to –35.0 ±2.0 °C (–31.0 ±3.6 °F) for a minimum of 3 hours. Immediately upon removal from the cooling chamber, the samples is to withstand for 1 minute a steady compression force of 75 pounds-force (334 N) applied at right angles to the module surface. The module is to be tested between two parallel, flat, hardwood blocks, each not less than 1/2 inch (12.7 mm) thick. The compression force is to be applied gradually at a rate of 5 pounds-force (22.7 N) per second until the test value is reached.