



ANSI/CAN/UL 5840:2022

JOINT CANADA-UNITED STATES
NATIONAL STANDARD

STANDARD FOR SAFETY

Electrical Systems of Battery Powered Aviation Ground Support Equipment



SCC FOREWORD

National Standard of Canada

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

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

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

UL Standard for Safety for Electrical Systems of Battery Powered Aviation Ground Support Equipment, ANSI/CAN/UL 5840

First Edition, Dated May 25, 2022

Summary of Topics

This is the First Edition of ANSI/CAN/UL 5840, Standard for Electrical Systems of Battery Powered Aviation Ground Support Equipment, dated May 25, 2022 including applicable requirements for Canada. These requirements cover the electrical system of lithium based battery powered airport ground support equipment (GSE) with respect to a risk of fire, electric shock, and explosion hazards associated with the battery powered electrical system. These requirements also cover these electrical systems when they are used to convert fueled GSE to battery powered GSE.

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

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

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

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

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

No Text on This Page



ANSI/UL 5840-2022

MAY 25, 2022



1

ANSI/CAN/UL 5840:2022

**Standard for Electrical Systems of Battery Powered Aviation Ground
Support Equipment**

First Edition

May 25, 2022

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

The most recent designation of ANSI/UL 5840 as an American National Standard (ANSI) occurred on May 25, 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 May 25, 2022.

COPYRIGHT © 2022 UNDERWRITERS LABORATORIES INC.

No Text on This Page

CONTENTS

Preface 5

INTRODUCTION

1 Scope 7
2 Components 7
3 Units of Measurement 8
4 Referenced Publications 8
5 Glossary 11

CONSTRUCTION

6 General 11
7 Conversion Systems 12
8 Power Levels 12
 8.1 General 12
 8.2 Hazardous voltage and hazardous energy 12
 8.3 Low voltage limited energy 13
9 Combination of Battery, Battery Management System, and Charger 14
10 User Protection During Charging 14
 10.1 General 14
 10.2 Charging battery on board the GSE 15
 10.3 Charging battery off board the GSE 15
11 Risk Assessment 15
12 Functional Safety 16
13 Batteries and Battery Management Systems 16
14 Battery Compartments 17
15 Charging Equipment 17
16 Enclosures of Hazardous Parts 18
 16.1 General 18
 16.2 Materials 18
 16.3 Openings 22
 16.4 Doors/Covers/Windows 23
 16.5 Environmental considerations 24
 16.6 Accessibility of hazardous parts 24
17 Overcurrent Protection 29
18 Motors and Electromechanical Brakes 30
19 Flammability 30
20 Mechanical Assembly 31
21 Spacings and Separation of Circuits 31
 21.1 General 31
 21.2 Barriers 32
 21.3 Separation of circuits 33
22 Internal Wiring 34
23 Printed Wiring Boards 35
24 Interlocks 35
25 Adhesives 36
26 Lasers 36

PERFORMANCE

27 General 36

28	Power Input/Output Verification	37
29	Dielectric Strength Test	38
30	Humidity Conditioning	40
31	Temperature Test	40
	31.1 General	40
	31.2 GSEs with non-removable batteries	43
	31.3 GSEs with removable batteries	43
32	Abnormal Operation	44
	32.1 General	44
	32.2 Component faults	44
	32.3 Relay or solenoid burnout	45
	32.4 Disconnected fan and blocked ventilation	45
	32.5 Motor overload test	45
	32.6 Motor locked rotor test	46
	32.7 Vibration test	46
33	Rain Test	47
34	Impact Test	50
35	Glass Cover Impact	51
36	Mold Stress	51
37	Battery Connector Endurance	52
38	Flexing Test	52

MARKINGS

39	General	53
40	Identification Markings	53
41	Cautionary Markings	53

INSTRUCTIONS

42	General	54
43	Installation Instructions	55
44	Operating Instructions	55
45	User Maintenance Instructions	55
46	Storage Instructions	56

ANNEX A (Normative for Canada and Informative for the US) SAFETY MARKING TRANSLATIONS

Preface

This is the First Edition of ANSI/CAN/UL 5840, Standard for Electrical Systems of Battery Powered Aviation Ground Support 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 5840 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>.

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

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

This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Battery Powered Aviation Ground Support Equipment, STP 5840.

This list represents the STP 5840 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

STP 5840 Membership

Name	Representing	Interest Category	Region
Bablo, Joseph	UL LLC	Testing and Standards	USA
Carmell, Coleson	Textron Specialized Vehicles	Producer	USA
Frohlich, Mark	JBT Aerotech	Producer	USA
Gray, Martin	Air Canada	Commercial/Industrial User	Ontario, Canada
Harney, James	City Of Chicago	Government	USA
Jordan, Diana Pappas	Underwriters Laboratories Inc.	STP Chair – Non-voting	USA
Kaplan, James	Harlan Global Manufacturing LLC	Supply Chain	USA
Kawakami, Kazuyuki	Panasonic	Supply Chain	Japan

STP 5840 Membership Continued on Next Page



STP 5840 Membership Continued

Name	Representing	Interest Category	Region
Malohn, Susan	Underwriters Laboratories Inc.	STP Project Manager – Non-voting	USA
Meyer, Charles	Lift-a-Loft Corp	Producer	USA
Ogard, John	United Airlines	Commercial/Industrial User	USA
Prather, Aaron	Fedex	Commercial/Industrial User	USA
Salter, John	Southwest Airlines CO	Commercial/Industrial User	USA
Vaughan, Tim	Flux Power INC	Supply Chain	USA
Vaughn, Trenton	Unitron LP	Supply Chain	USA
Wechsler, David	American Chemistry Council	General	USA
Zhang, Qingsong	Civil Aviation University of China Center for Aircraft Fire and Emergency	General	China

International Classification for Standards (ICS): 29.220; 53.060

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 cover the electrical system of lithium based battery powered airport ground support equipment (GSE) with respect to a risk of fire, electric shock, and explosion hazards associated with the battery powered electrical system.

1.2 These requirements also cover these electrical systems when they are used to convert fueled GSE to battery powered GSE.

1.3 In accordance with [1.1](#), the minimum GSE electrical system consists of the battery and integral battery management system, interconnecting cables, and input connections for recharging the battery. In addition, the electrical system can also include power train components, electric motors, electric brakes, charging equipment and the like based on manufacturer preference.

1.4 GSE that is capable of being moved and used as a temporary source of power for other equipment, whether that equipment is either located on board the GSE or off board the GSE, is additionally evaluated based on mobile energy storage systems requirements.

1.5 This standard does not address the functional or operations aspects of the GSE such as steering, lifting, towing, and the like.

1.6 This standard does not address any equipment or electrical systems of equipment that are not considered GSE as defined within this standard.

1.7 In relation to conversion systems, these requirements do not address the function or mechanical state of the GSE being converted, or the parts located external to the manufacturer's defined electrical conversion system that may be powered from the electrical conversion system.

2 Components

2.1 A component of a product 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 product 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 product;
- b) Is superseded by a requirement in this Standard; or
- c) Is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

2.3 Specific components are 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 also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally 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 Products covered by this standard shall comply with the referenced installation codes and standards noted in this clause as referenced in the individual clauses of this standard.

4.3 The following publications are referenced in this Standard:

ANSI Z97.1, *Safety Glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test*

ASTM D1525, *Standard Test Method for Vicat Softening Temperature of Plastics*

ASTM E230/E230M, *Standard Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

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

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

CSA C22.2 No. 14, *Industrial Control Equipment*

CAN/CSA C22.2 No. 49, *Flexible Cords and Cables*

CAN/CSA C22.2 No. 75, *Thermoplastic – Insulated Wires and Cables*

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

CAN/CSA C22.2 No. 96, *Portable Power Cables*

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

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

CAN/CSA C22.2 No. 107.2, *Battery Chargers*

CSA C22.2 No. 182.3, *Special Use Attachment Plugs, Receptacles, and Connectors*

CAN/CSA C22.2 No. 210, *Appliance Wiring Material Products*

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

CAN/CSAC22.2 No. 281.1, *Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements*

CAN/CSAC22.2 No. 281.2, *Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protection Devices for Use in Charging Systems*

CSA C22.2 No. 282, *Plugs, Receptacles, and Couplers for Electric Vehicles*

CAN/CSA C22.2 No. 60335-2-29, *Household and Similar Electrical Appliances – Safety – Part 2-29: Particular Requirements for Battery Chargers*

CAN/CSA-E60730-1, *Automatic Electrical Controls – Part 1: General Requirements*

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

IEC 60417, *Graphical Symbols for Use on Equipment*

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

IEC 62061, *Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic, and Programmable Electronic Control Systems*

ISO 12100, *Safety of Machinery – General Principles for Design – Risk Assessment and Risk Reduction*

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*

SAE J1128, *Low Voltage Primary Cable*

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

UL 62, *Flexible Cords and Cables*

UL 66, *Fixture Wire*

UL 83, *Thermoplastic-Insulated Wires and Cables*

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

UL 508, *Industrial Control Equipment*

UL 723, *Test for Surface Burning Characteristics of Building Materials*

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

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

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

UL 758, *Appliance Wiring Material*

UL 796, *Printed Wiring Boards*

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

UL 969, *Marking and Labeling Systems*

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

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

UL 1012, *Power Units Other Than Class 2*

UL 1063, *Machine Tool Wires and Cables*

UL 1236, *Battery Chargers for Charging Engine Starter Batteries*

UL 1276, *Welding Cable*

UL 1310, *Class 2 Power Units*

UL 1426, *Electrical Cables for Boats*

UL 1449, *Surge Protective Devices*

UL 1564, *Industrial Battery Chargers*

UL 1977, *Component Connectors for Use in Data, Signal, Control and Power Applications*

UL 1998, *Software in Programmable Components*

UL 2202, *Electric Vehicle (EV) Charging System Equipment*

UL 2231-1, *Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits, Part 1: General Requirements*

UL 2231-2, *Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits, Part 2: Particular Requirements for Protection Devices for Use in Charging Systems*

UL 2251, *Plugs, Receptacles, and Couplers for Electric Vehicles*

UL/ULC 2271, *Batteries for Use in Light Electric Vehicle (LEV) Applications*

UL/ULC 2580, *Batteries for Use in Electric Vehicles*

UL 2726, *Battery Lead Wire*

UL 2733, *Surface Vehicle On-Board Cable*

UL 2734, *Connectors and Service Plugs for Use with On-Board Electric Vehicle (EV) Charging Systems*

UL 9540, *Energy Storage Systems and Equipment*

UL 60335-2-29, *Household and Similar Electrical Appliances – Safety – Part 2-29: Particular Requirements for Battery Chargers*

UL 60730-1, *Automatic Electrical Controls – Part 1: General Requirements*

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

5 Glossary

5.1 For the purpose of this standard, the following definitions apply.

5.2 BATTERY – One or more electrical cells, electrically connected so that the combination furnishes current as a unit. There is one positive and one negative externally accessible connection and no externally accessible inter-cell connections.

5.3 BATTERY MANAGEMENT SYSTEM – The electrical, electronic and software monitoring and control system of a battery that is often relied upon to maintain the battery and its component cells within their specified operating region for charge and discharge, and may be source of memory of the battery operation throughout its life.

5.4 BATTERY PACK – Batteries that are ready for use in GSE, contained in a protective enclosure, with protective devices, with a battery management system, and monitoring circuitry and that may be removable by the user for charging separately from the device.

5.5 CONVERSION SYSTEM – A defined electrical system that is installed on an existing fueled GSE in order to convert the GSE to an electrically powered GSE. The conversion system boundaries are defined by the manufacturer.

5.6 ENCLOSURE – That portion of a unit that reduces the accessibility of a part that involves a risk of fire, electric shock or injury to persons, or reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

5.7 GROUND SUPPORT EQUIPMENT (GSE) – Mobile equipment that is powered from a battery power source and is designed and intended to be used for servicing or providing support for transport aircraft when located in the ramp area of an airport.

5.8 MOBILE ENERGY STORAGE SYSTEMS (MESS) – An energy storage system 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.

CONSTRUCTION

6 General

6.1 The information provided in this section, and in Sections [7](#) – [10](#), is essential guidance for defining and structuring the evaluation path for GSE electrical systems. This information is general in nature, but shall be applied as applicable for the specific design and use cases of the GSE electrical system being evaluated.

6.2 In order to properly apply the requirements in this standard and correctly determine which requirements are applicable to a given product, all electrical systems on GSE shall be determined as containing hazardous voltage or energy in accordance with [8.2](#), Hazardous voltage and hazardous energy, or having inherently non-hazardous voltage and energy in accordance with Low voltage limited energy, [8.3](#). For electrical systems with hazardous voltage or energy, Section [10](#), User Protection During Charging, is applicable, but it is not applicable if the voltage and energy is non-hazardous.

6.3 For GSE that is intended to be used as a temporary source of power for other equipment, the GSE shall be evaluated to the applicable mobile energy storage systems requirements in UL 9540. This does not apply to other items on the GSE where the electrical system is located, such as electrical motors and the like. The requirement applies to GSE that carry a battery bank or larger battery that can be used to provide electrical power to an electrical device that does not contain its own power source or has a power source that has been depleted and requires an outside power source.

7 Conversion Systems

7.1 Electrical conversion systems are required to comply with all requirements in this standard. The electrical conversion system shall be defined based on what is included in the evaluated system. No component of the overall evaluated system can include components that were already located on the GSE prior to conversion.

7.2 The means of installation on the GSE, including all steps for removing existing components or systems, will need to be documented in accordance with the Installation Instructions, Section [43](#). These installation instructions shall provide statements related to any assessment criteria to determine if the GSE is capable of being converted including any reject criteria. Additionally, any maintenance steps that are required to correct or prepare the GSE for conversion shall be included.

8 Power Levels

8.1 General

8.1.1 For all products covered by this standard, a specific power level will be associated with the power transfer to the GSE during charging and with the use of the battery power source on the GSE. This will require rated voltage and current levels to be specified, but can also include voltages or currents that are available within the GSE being evaluated. Different approaches can be used based on the potential hazards associated with a given power level.

8.1.2 For the purposes of this standard, different designations will be used. This includes hazardous voltage and/or hazardous current resulting in hazardous energy, and in all cases these designations indicate a voltage, current or energy level that is potentially dangerous to the user and means of protection for the user is required. Additional designations cover Low Voltage, Limited Energy (LVLE) which indicates voltage and current levels that are not inherently hazardous to the user and the need for specific protection means may be reduced as indicated in this standard.

8.2 Hazardous voltage and hazardous energy

8.2.1 Any circuit that is operating at a voltage above 42.4 volts peak or 60 V dc is considered to be operating at a hazardous voltage. In these cases, the user must be protected against contact with the part or circuit by the use of an enclosure or proper insulation in both normal operation or under single fault operation. Single fault operation can include damage to the enclosure or failure of the insulation. The requirements for both enclosures and insulation are included in this standard and shall be applied as appropriate in all cases where hazardous voltages exist.

8.2.2 Hazardous energy exists in any circuit or part that is operating with a stored energy level of 20 J or more, or has an available continuous power level of 240 VA or more, at a potential of 2 volts or more. In these cases, the user shall be protected against contact with the part or circuit by the use of an enclosure or proper insulation in both normal operation or under single fault operation. Single fault operation can include damage to the enclosure or failure of the insulation. The requirements for both enclosures and insulation are included in this standard and shall be applied as appropriate in all cases where hazardous energy exist.

8.2.3 With respect to [8.2.2](#), a continuous power level is defined as any power level that is maintained in excess of the defined limit for longer than a duration of 1 min.

8.3 Low voltage limited energy

8.3.1 A Low-Voltage Limited Energy Circuit (LVLE) shall comply with the limits in [Table 8.1](#).

Table 8.1
Low-Voltage, Limited-Energy Circuits

Inherently limited transformer (overcurrent protection not required)				Not-inherently-limited transformer (overcurrent protection required)			
Circuit voltage (volts) ^a	0 – 20 volts AC or DC ^b	Over 20 volts but not more than 30 volts AC or DC ^b	Over 30 volts but not more than 60 volts DC ^b	0 – 15 volts AC or DC ^b	Over 15 volts but not more than 20 volts AC or DC ^b	Over 20 volts but not more than 30 volts AC or DC ^b	Over 30 volts but not more than 60 volts DC ^b
Power limitation (volt-amperes) ^c	–	–	–	350	250	250	250
Current limitation (amperes) ^d	8	8	150/V ^a	1000/V ^a	1000/V ^a	1000/V ^a	1000/V ^a
Maximum overcurrent protection (amperes)	–	–	–	5	5	100/V ^a	100/V ^a
^a Maximum output voltage, regardless of load, with applied rated voltage. ^b The AC waveform shall be sinusoidal. ^c Maximum volt-ampere output regardless of load, and overcurrent protection (if provided) bypassed. ^d Maximum output after 1 min of operation under any noncapacitive load, including short circuit, and with overcurrent protection (if provided) bypassed.							

8.3.2 The power limitations in [Table 8.1](#) may be obtained by the use of any of the following configurations:

- a) An inherently-limited transformer;
- b) A non-inherently-limited transformer coupled with an overcurrent protective device in the output circuit;
- c) A combination transformer and fixed impedance; or
- d) An arrangement determined to be equivalent to (a), (b), or (c).

8.3.3 A part or device, other than the battery, located in or supplied by an LVLE circuit need not be investigated for fire or shock hazards. The secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be judged under the applicable requirements in this standard.

8.3.4 The maximum load current is to be drawn under any condition of loading, including short circuit, using a resistor. The current is to be measured 60 s after the application of the load. The resistor is to be continuously readjusted during this 1 min period to maintain maximum load current. The measured load current shall not exceed the value listed in [Table 8.1](#).

8.3.5 With reference to the voltage limit specified in [Table 8.1](#), measurement is to be made with the product connected to the intended source of supply, during battery operation and during charging, and with all loading circuits disconnected.

8.3.6 The over-current protective device provided in the LVLE circuit used to limit the current shall be rated or set at not more than the values specified in [Table 8.1](#). The device shall not be of the automatically reset type.

8.3.7 If a regulating network is used to limit the output under any conditions, the LVLE current limitation in [Table 8.1](#) shall not be affected by malfunction of a single component, excluding resistors. The network shall comply with the value in [Table 8.1](#) when the current is measured after 5 s.

9 Combination of Battery, Battery Management System, and Charger

9.1 A battery management system is designed and intended for use with a specific battery. The charger that is supplying the power for recharging the battery has specific output characteristics that are integrated into the overall evaluation of the combination. The charger shall comply with Section [15](#), Charging Equipment, and the battery and battery management system shall comply with Section [13](#), Batteries and Battery Management Systems.

9.2 The GSE electrical system evaluation shall be completed using the specific battery and battery management system combination. Additionally, the output characteristics of the charger shall also be factored into the overall evaluation, which may require testing with the specific charger that is intended to be used. Changes to the charger, battery or battery management system should be assessed to insure that the differences will not affect the evaluation or testing responses of the GSE electrical system.

9.3 With reference to [9.2](#), if the charger is included in the system being evaluated, the evaluation is to consider that charger alone and reliance on output characteristics will be integrally defined. This applies for both offboard and onboard charging equipment.

9.4 As part of the risk assessment in Section [11](#), Risk Assessment, the manufacturer shall indicate any hazards associated with changing the charger, the battery, or the battery management system in any way. These hazards shall be mitigated by prohibiting the changes or further protections will be required.

10 User Protection During Charging

10.1 General

10.1.1 Charging of the battery may occur while the battery is installed on board the GSE, with the battery removed from the GSE, or both options may apply based on user preference. If the battery is only intended to be charged when it is removed from the GSE, then an inherent means shall be provided to insure that this option is the only option for charging the battery. If no inherent means is provided, and it is possible to charge the battery while on the GSE, the battery shall be considered to be charged both on board and off board the GSE.

10.1.2 If the battery is intended to be charged while on the GSE, whether by inherent construction or user preference, then the requirements in Charging battery on board the GSE, [10.2](#) apply. If the battery is only capable of being charged when removed from the GSE, then the requirements in [10.2](#) do not apply.

10.1.3 The requirements in [10.1.1](#) and [10.1.2](#) are to be used in conjunction with the requirements in Power Levels, Section [8](#). If energy levels are such that no hazard exists, then protection means may be reduced as indicated in this standard.

10.2 Charging battery on board the GSE

10.2.1 Charging of the battery on the GSE, where voltage or energy levels exceed the lower limits for shock hazards or electric energy hazards, will require that the exposed conductive surfaces of the GSE are protected and monitored during charging to prevent a hazard due to the charging energy supplied to the GSE. The personnel protection system supplied shall be as indicated in [10.2.2](#).

10.2.2 For equipment where the specifics of the installation of the on board electrical system is part of the evaluation, the GSE shall be provided with a system of protection that is considered suitable to protect the user. This may include suitable means such as double insulation systems onboard the GSE. The suitability of the protection system shall be judged based on the requirements in this standard. If the specifics of the installation of the electrical systems and its associated protections is not included in the evaluation, such as with conversion systems, then a system of personnel protection in accordance with UL 2231-1 and CAN/CSA-C22.2 No. 281.1 and UL 2231-2 and CAN/CSA-C22.2 No. 281.2 is required to be provided in the charging equipment such that the GSE conductive surfaces are monitored during the power transfer.

10.2.3 The GSE electrical system shall be provided with a means to prevent the provision of power to any electric motor intended for motive power when the GSE is connected to the charger. This means shall be integral to the GSE electrical system, or within the GSE, and shall not be capable of being defeated by the operator.

10.3 Charging battery off board the GSE

10.3.1 For batteries that are removed from the GSE for charging, the charger used to charge the battery shall include all protections for the recharging process. No protection systems in accordance with UL 2231-1 and CAN/CSA-C22.2 No. 281.1 and UL 2231-2 and CAN/CSA-C22.2 No. 281.2 are required to be provided and no protection for recharging is required to be provided on the GSE.

11 Risk Assessment

11.1 A risk assessment of the potential hazards associated with the electrical system of the GSE shall be completed by the manufacturer. The risk assessment shall be completed based on the following:

- a) Identify the conditions of use, under normal and reasonably foreseeable misuse, associated with charging, discharging and general use of the GSE electrical system.
- b) Identify the potential hazards associated with the conditions of use identified in (a) under normal conditions and single fault conditions within the electrical system of the GSE. Subsequent faults due to the single fault condition shall be included.
- c) Identify the protective measures or other protective means provided or implemented in order to mitigate the hazards identified in (b).

Note: A risk assessment following the guidelines in ISO 12100 is considered to be in compliance with the process described above.

11.2 When completing the risk assessment for conversion systems, specific consideration of hazards that could develop due to the condition of the GSE being converted shall be included. This includes damage from collision, wear and tear, rust, and the like. See Conversion Systems, Section [7](#).