TEST REPORT UL2849-2018 Electric Bicycles, Electrically power Assisted Cycles (EPAC Bicycles) , Electric Scooters, and Electric Motorcycles	
Report Number..... :	ZKT-2106232811S
Date of issue..... :	Jun. 29, 2021
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Testing Laboratory Name ..... :	Shenzhen ZKT Technology Co., Ltd.
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Applicant's Name ..... :	**Guangzhou Paselec Co., Ltd.**
Address ..... :	No.93, Team 7, Xiaobu Village, Huashan Town, Huadu District, Guangzhou
Manufacturer's name ..... :	**Guangzhou Paselec Co., Ltd.**
Address ..... :	No.93, Team 7, Xiaobu Village, Huashan Town, Huadu District, Guangzhou
Test specification	
Standard..... :	UL 2849-2016, UL 2849-2018
Test procedure ..... :	ZKT
Non-standard test method ..... :	N/A
Test item description ..... :	**Electric Bicycle**
Trademark ..... :	PASELEC ,RIF PERFORMANCE,RIF
Model and/or type reference ..... :	GS9
Rating(s)..... :	Input:AC100-240V ,2A, 50/60 Hz Output:54.6V⎓2A

Testing procedure and testing location:

Testing Laboratory.....:	**Shenzhen ZKT Technology Co., Ltd.**
Address.....:	1/F, No. 101, Building B, No. 6, Tangwei Community Industrial Avenue, Fuhai Street, Bao'an District, Shenzhen, China
Date of Test.....:	Jun. 23, 2021 to Jun. 29, 2021
Tested by (name + signature).....:	Ache He
Reviewed by (name + signature).....:	Peter Huang
Approved by (name + signature).....:	Awen He

Electric Bicycle
Model:GS9
Input:AC100-240V ,2A, 50/60 Hz
Output:54.6V⎓2A

Manufacturer:Guangzhou Paselec Co., Ltd.
Address: No.93, Team 7, Xiaobu Village, Huashan Town, Huadu District, Guangzhou

Made in China

Remark on above marking:
1.The height of WEEE symbols is more than 7 mm

General remarks:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.

Throughout this report a comma is used as the decimal separator.

Summary of testing:

The submitted sample was complied with UL 2849-2016, UL 2849-2018

Possible test case verdicts:

- test case does not apply to the test object .....: N/A(N)
- test object does meet the requirement .....: P(Pass)
- test object does not meet the requirement.....: F(Fail)

Testing .....:

Date of receipt of test item .....: Jun. 23, 2021

Date (s) of performance of tests .....: Jun. 23, 2021 to Jun. 29, 2021

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict

6	**General**		—
6.1	EBikes consist of both pedalec and non-pedalec types, but in all cases functional pedals shall be provided. For pedalec type eBikes, the motor shall disengage its assist function when the eBike achieves a maximum speed of 20 mph (32.2 kph), or if the user stops pedaling, whichever occurs first. For non-pedalec versions of eBikes, the motor is not required to disengage when the user stops pedaling, but the maximum speed is limited to 20 mph. The maximum speed shall be controlled in either case. A non-pedalec type eBike may be provided with a pedalec mode. Additionally, the motor shall not exceed 750 W (1 hp).		P
6.2	Electric scooters and electric motorcycles shall not be provided with pedals and are provided with a seat for the rider to sit on during operation. There is no maximum speed associated with these vehicles. Operation is controlled through the throttle and the user is not required to act in any other manner to propel the vehicle other than manipulation of the throttle control.		N/A
6.3	Charging of the battery may occur with the battery installed on the vehicle, with the battery removed from the vehicle, or a combination of the two. If the battery must be removed for charging, the charging function of the electrical system is not considered by these requirements. If the battery may be optionally removed for charging, but on board charging can occur, this Outline covers the on board charging function.		P
6.4	For portions of the electrical system located on the vehicle, all equipment shall be evaluated as outdoor use equipment. Outdoor use equipment shall comply with all the requirements in this Outline as applicable to outdoor use equipment operating at a maximum altitude of 6562 feet (2000 m) and over an ambient temperature range of -3°C to 40 °C (-22°F to 104°F). For equipment located off board the vehicle, such as chargers, the equipment may be for indoor or outdoor use. Outdoor use is assumed unless the equipment is marked in accordance with 46.3. Indoor use only equipment shall comply with all the requirements in this Outline as applicable to indoor use equipment operating at a maximum altitude of 6562 feet and over an ambient temperature range of 0°C to 40°C (32°F to 104°F).		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
6.5	For off board chargers, the equipment may be permanently connected or cord connected to the supply source. Permanently connected chargers are fixed in place and subjected to the applicable indoor or outdoor use requirements indicated in this Outline. Cord connected chargers are considered movable, but shall be designated as indoor use only, or shall be evaluated to the outdoor use requirements in this Outline.		N/A
6.6	The requirements in this Outline are based on the level of exposure to risks. For the risk of electric shock or the risk of electrical energy – high current (see 5.10 and 5.11 respectively), an enclosure is required to protect the user from contact with the components or circuits that are involved. If the voltage or energy is less than the limits specified in 5.10 or 5.11, then a hazard is not considered to exist and the requirements that address risk mitigation for those hazards need not apply.		P
7	**Connection to Supply Source**		—
7.1	**General**		P
7.1.1	The connection to the supply source is dependent on whether an off board charger is used or an on board charger is used. For off board chargers where the battery is charged on the vehicle, the requirements in 7.2 apply. For on board chargers where the battery is charged on the vehicle, the requirements in 7.3 apply.		P
7.2	**Off board chargers**		N/A
7.2.1	For eBikes and electric scooters intended to be charged by an off board charger, the off board charger shall comply with one of the following. For electric motorcycles, the off board charger shall comply with item (a) only:		N/A
	a) The Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202.		N/A
	b) The Standard for Power Units Other Than Class 2, UL 1012.		N/A
	c) The Standard for Class 2 Power Units, UL 1310.		N/A
	d) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, along with the relevant Part 2 Standard as applicable.		N/A
7.2.2	For off board chargers that comply with 7.2.1 (c), no hazard exists at the output of the charger and requirements to mitigate a shock hazard or an electrical energy-high current hazard may be reduced as described in 6.6. Personnel protection in accordance with Section 8 is not required.		N/A
7.2.3	Off board chargers that comply with 7.2.1 (a), (b), or (d) are not necessarily limited at the output and the requirements for hazard mitigation apply. Personnel protection in accordance with Section 8 shall be provided.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
7.3	**On board chargers**		P
7.3.1	For vehicles intended to be provided with an on board charger, AC supply power shall be conductively connected to the vehicle through an acceptable means as indicated in 7.3.2.		P
7.3.2	AC power shall be delivered to eBikes and electric scooters using any of the following. AC power shall be delivered to electric motorcycles using item (a) only:		N/A
	a) Electric Vehicle Supply Equipment in accordance with the Standard for Electric Vehicle Supply Equipment, UL 2594.		P
	b) Connection to a NEMA 5-20R receptacle using a suitable power supply cord.		P
7.3.3	With reference to 7.3.2 (b), the connection of the power supply cord to the eBike or electric scooter shall be made through the use of a connector that complies with the Standard for Plugs, Receptacles and Couplers for Electric Vehicles, UL 2251, or through a connector that complies with the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977.		P
7.3.4	In all cases with an on board charger, a personnel protection system in accordance with Section 8 shall be provided.		P
8	**Personnel Protection Systems**		—
8.1	Charging of the battery of a vehicle, where voltage or energy levels exceed the lower limits for shock hazards or electric energy, high-current hazards, will require that the exposed conductive surfaces of the vehicle are protected and monitored during charging to prevent a shock hazard due to the charging energy supplied to the vehicle. The personnel protection system supplied shall be as indicated in 8.2 or 8.3.		P
8.2	For vehicle charging system equipment where the installation of the vehicle electrical system on the vehicle is unknown, or not part of the evaluation, the vehicle charging system shall be provided with a system of protection in accordance with the requirements in the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements, UL 2231-1, and the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protective Devices for Use in Charging Systems, UL 2231-2.		P
8.3	For vehicle charging system equipment where the installation of the electrical system on the vehicle is part of the evaluation, the vehicle shall be provided with a system of protection that is considered suitable to protect the user. This may be a system in accordance with 8.2, or may include other suitable means such as double insulation systems onboard the vehicle. The suitability of the protection system shall be judged based on the requirements in this Outline.		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
8.4	With reference to 8.3, requirements pertaining to grounding and bonding, Section 9, or requirements pertaining to double insulation, Section 10, shall apply.		P
9	**Bonding of the Vehicle**		—
9.1	**General**		N/A
9.1.1	For vehicles that are using a grounded system of protection to mitigate hazards associated with electric shock or electrical energy, high current, a means of extending the ground to the vehicle through a bonding conductor shall be provided.		N/A
9.1.2	For vehicles that are using an isolated system of protection to mitigate hazards associated with electric shock or electrical energy, high current, a bonding conductor is not required. A functional ground connection that allows for monitoring the vehicle frame shall be provided, and isolation monitoring shall be in accordance with 8.2 or with double insulated systems in accordance with Section 10.		N/A
9.1.3	The requirements in 9.1.1 and 9.1.2 apply for both on board chargers and off board chargers.		N/A
9.2	**Bonding connections**		N/A
9.2.1	There shall be provision for bonding all dead metal parts of a unit that are exposed or that possess a risk of being contacted by a person during intended operation or adjustment and that are capable of becoming energized as a result of electrical malfunction, to the main ground connection.		N/A
9.2.2	The bonding shall be by a positive means, such as by clamps, rivets, bolted or screwed connections, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455°C (850°F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.		N/A
9.2.3	An equipment-bonding terminal, or lead-bonding point, shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection. To reduce the risk of inadvertent loosening, the head of the screw or bolt shall not be accessible from outside of the enclosure.		N/A
9.2.4	An equipment-bonding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.		N/A
9.2.5	An equipment-bonding point shall be located so that the risk of inadvertently removing the bonding means during servicing is reduced.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

9.2.6	An equipment-bonding lead shall be the same size as the grounding lead associated with the AC power source. The lead shall have a free length of at least 6 inches (152 mm) and the surface of the insulation shall be green. No other lead in a field-wiring compartment or visible to the installer shall be so identified.		N/A
9.2.7	For eBikes or electric scooters that are connected to NEMA 5-20R receptacles directly, the equipment-grounding conductor of a power-supply cord shall be connected to dead metal parts within the frame or enclosure by means of a screw, or stud and nut combination, not to be removed during ordinary servicing not involving the power-supply cord. The surface of any insulation on the grounding conductor shall be green with or without one or more yellow stripes and no other conductor shall be so identified.		N/A
9.2.8	An equipment-grounding conductor and the equipment-bonding conductor shall not be spliced, nor shall it involve a trace on a printed wiring board.		N/A
9.2.9	A soldering lug, a connection means that depends on solder, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used for equipment-grounding or equipment-bonding.		N/A
9.2.10	The equipment-grounding terminal or equipment-bonding terminal shall be capable of securing a conductor of a size intended for the application.		N/A
9.2.11	A terminal intended for the connection of an equipment-bonding conductor shall be identified by:		N/A
	a) Being marked ²G², ²GR², ²GND², ²Ground², ²Grounding², or the like;		N/A
	b) The grounding symbol illustrated in Figure 9.1 on or adjacent to the terminal or on a wiring diagram provided on the product.		N/A
	Figure 9.1 **Symbol for equipment bonding connection** 		N/A
10	**Double Insulation**		—
10.1	A system of double insulation provided to comply with 8.3 shall be in accordance with the requirements in the Reference Standard for Double Insulation Systems for Use in Electronic Equipment, UL 2097		P
11	**Safety Circuits and Safety Analysis**		—
11.1	The system's protective circuits shall undergo a safety analysis to verify that all potential hazards associated with the design are addressed in this evaluation.		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
11.2	For battery protective circuits, the protective circuit shall maintain the cells within their normal operating region for charging and discharging through the life of the vehicle. If normal limits are exceeded, the protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond normal operating limits. Compliance is determined through a review of the battery system data including the safety analysis of 11.4 and through the tests in this Outline.		P
11.3	Protection circuits used to monitor operational parameters, such as maximum assist speed, braking, and the like, shall also be evaluated based on the requirements in this section. Compliance is determined through a review of the design and overall system, including the safety analysis of 11.4 and through the tests in this Outline.		P
11.4	An analysis of potential hazards (including an FMEA) shall be conducted on the vehicle's electrical system, including the charger and other safety circuits, to determine that events that could lead to a hazardous condition have been identified and addressed through design or other means. Documents that can be used as guidance for the safety analysis include:		P
	a) The Standard for Analysis Techniques for System Reliability - Procedure for Failure Mode and Effects Analysis (FMEA), IEC 60812;		P
	b) The Standard for Fault Tree Analysis (FTA), IEC 61025;		P
	c) The Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA), SAE J1739; and		P
	d) The Procedures for Performing a Failure Mode, Effects, and Criticality Analysis, MIL-STD-1629A.		P
11.5	The analysis in 11.4 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and the types and levels of protection provided to mitigate the anticipated faults. The analysis shall consider single fault conditions in the protection circuit/scheme as part of the anticipated faults.		P
11.6	When conducting the analysis of 11.4, active devices shall not be relied upon for critical safety unless:		P
	a) They are provided with a redundant passive protection device; or		P
	b) They are provided with redundant active protection that remains functional and energized upon loss of power/failure of the first level active protection; or		P
	c) They are determined to fail safe upon loss of power to the active circuit.		P

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Clause	Requirement + Test	Result - Remark	Verdict

11.7	Devices relied upon for critical safety as noted in 11.4 shall be tested for functionality in accordance with appropriate functional safety requirements unless already evaluated through the other tests of this Outline. Functional safety criteria for vehicle electrical systems can be found in one of the following standards as appropriate to the design of the electronic and software protection scheme:		P
	a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, and the Standard for Software in Programmable Components, UL 1998;		P
	b) The Standard for Automatic Electrical Controls for Household and Similar Use - Part 1: General Requirements, UL 60730-1; and		P
	c) The Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 1: General Requirements, IEC 61508-1, and all parts.		P
11.8	Any vehicle containing hazardous voltage shall have a manual disconnect to prevent inadvertent access to hazardous voltage parts during servicing. The manual disconnect shall:	Using the plug for disconnect	P
	a) Disconnect both poles of the hazardous voltage circuit;		P
	b) Be accessible and able to be operated without the use of a tool in the event of a collision or during servicing;		P
	c) Require manual action to break the electrical connection;		P
	d) Ensure disconnection is physically verifiable and can include actual removal of the battery system from the UAV or unplugging the battery system connector/plug; and		P
	e) When engaged (i.e. under disconnection), it does not create exposed conductors capable of becoming energized and is insulated to inhibit a shock hazard during actuation.		P
11.9	If a hazardous voltage automatic disconnect device is provided to isolate accessible conductive parts from the hazardous voltage circuit of the battery system, it shall:		N/A
	a) Not be able to be reset automatically although it may be able to be reset deliberately upon clearing of the fault;		N/A
	b) Disconnect both poles of the hazardous voltage circuit;		N/A
	c) Be capable of handling full load disconnects of the hazardous voltage circuit that it is isolating; and		N/A
	d) Not result in a hazardous condition upon automatic actuation.		N/A
12	**Enclosures**		—

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
12.1	The enclosure shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its intended use, in order to reduce the risk of fire or injury to persons.		P
12.2	A unit shall be provided with one or more enclosures that house all live parts. The enclosure shall protect the various parts of the unit against mechanical damage from forces external to the unit. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, injury to persons, and electrical energy - high current levels shall comply with the applicable enclosure requirements specified in this Outline.		P
12.3	Openings in the enclosure shall be designed to inhibit inadvertent access to hazardous parts. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, of the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, for a minimum IP rating of IP3X. Evaluation per IEC 60529, consists of the use of the Test Rod 2.5 mm, 100 mm long, shown in Figure 1 of the Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications, UL 2271, applied with a force of 10 N ±10 percent.		P
12.4	Openings in an outdoor use enclosure shall be designed to prevent ingress of water as installed in the vehicle in accordance with intended use and IP rating in accordance with the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, with a minimum rating of IPX4 and resistant to hazards associated with partial immersion. Compliance is determined by the Water Exposure Tests in Section 38.1. Openings in indoor use only products need only comply with 12.3.		P
13	**Materials**		—
13.1	**Nonmetallic materials**		P
13.1.1	The materials employed for enclosures shall comply with the applicable enclosure requirements outlined in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, Path III, except as modified by this Outline.		P
13.1.2	Polymeric materials employed for enclosures shall have a minimum flame rating of V-1 in accordance with Flammability, Section 14, or the enclosure may alternatively be evaluated to the 20 mm end product flame test in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.		P

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Clause	Requirement + Test	Result - Remark	Verdict
13.1.3	The following factors in (a) – (e) shall be taken into consideration when an enclosure employing nonmetallic materials is being evaluated. For a nonmetallic enclosure all of these factors shall be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief test. Suitability to factors (a) – (e) below may be determined by the tests of this Outline.		P
	a) Resistance to Impact;		P
	b) Crush Resistance;		P
	c) Abnormal Operations;		P
	d) Severe Conditions; and		P
	e) Mold Stress Relief Distortion.		P
13.1.4	The polymeric materials employed for enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application. Enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80°C (176°F), as determined in accordance with the Standard for Polymeric Materials - Long Term Property Evaluations, UL 746B.		N/A
13.1.5	The outdoor use enclosure materials intended to be directly exposed to sunlight and rain in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C.		P
13.1.6	Materials employed as electrical insulation in the assembly shall be resistant to deterioration that would result in a risk of electrical shock, fire or other safety hazard. Compliance is determined by the tests of this Outline. Materials employed for direct support of live parts at hazardous voltage, shall additionally meet the direct support insulation criteria outlined in the Material Property Considerations in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, unless employed as part of a component that has been evaluated to a suitable component standard. Insulated wiring is subjected to the requirements outlined in Section 17, Internal Wiring and Terminals.		P
13.1.7	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.		P
13.2	**Metallic materials**		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict

13.2.1	Metal enclosures shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.		P
13.2.2	Metal enclosures may be provided with an insulating liner to prevent shorting of live parts to the enclosure. If using an insulating liner for this purpose, the insulating liner shall consist of non-moisture absorbent materials that have a temperature rating suitable for temperatures during operation including charging.		P
13.2.3	Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action.		P
14	**Flammability**		—
14.1	Nonmetallic materials used for enclosures shall have a minimum flammability rating of V-1 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. As an alternative, finished enclosures may be tested in accordance with the 20 mm end-product flame test in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C. Metallic materials used for enclosures are considered to comply without further evaluation, except magnesium shall not be used for enclosure materials.		P
14.2	Nonmetallic materials used for internal parts within the overall enclosure shall be rated V-2 minimum.		P
14.3	Internal parts of components shall comply with the flammability requirements of the component standard in accordance with Components, Section 2.		P
14.4	Small parts, and gaskets, that are not located near live parts, and are located in a manner such that they cannot propagate flame from one area to another within the equipment, are not required to have a specific flame rating.		P
14.5	Nonmetallic materials located outside the enclosure, and not used to complete the enclosure, are considered decorative parts. These parts shall be rated HB minimum.		P
14.6	Printed wiring board materials shall be rated V-1 minimum.		P
14.7	For the requirements outlined in 14.2 – 14.6, the flammability rating of the material shall be provided as part of the material rating or the flammability rating may be determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.		P
15	**Spacings and Separation of Circuits**		—

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict

15.1	Electrical circuits within the vehicle electrical system, and charger, at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits (i.e. electrical spacings on printed wiring boards, physical securing of uninsulated leads and parts, etc.). Insulation suitable for the anticipated temperatures and voltages shall be used where spacings cannot be controlled by reliable physical separation.		P
15.2	Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 15.1 or the spacings requirements outlined in the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1, in Clearances, Creepage Distances and Distances Through Insulation.		P
15.3	As an alternative to the spacing requirements of Table 15.1, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment, UL 840, may be used. For determination of clearances, the overvoltage category is considered Overvoltage Category II; and the pollution degree would be Pollution Degree 3 unless reduced by design in accordance with UL 840.		P
15.4	As an alternative to the clearance values outlined in the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1, in Clearances, Creepage Distances and Distances Through Insulation, the alternative method for determining minimum clearances in the Annex for Alternative Method for Determining Minimum Clearances, Annex G, of the UL 60950-1, may be applied.		P
	Table 15.1 Electrical spacings		P

	Voltage V	Through Air in (mm)	Over Surface in (mm)
Live parts and dead metal parts that are separated by functional or basic insulation	0 – 50[a] 51 – 130 131– 300	1/16 (1.6) 1/8 (3.2) 1/4 (6.4)	1/16 (1.6) 3/16 (4.8) 3/8 (9.5)
Accessible dead metal parts and dead metal parts separated from live parts by basic insulation only – this ordinarily is a spacing resulting from supplementary insulation	0 – 50[a] 51 – 130 131– 300	1/16 (1.6) 1/8 (3.2) 1/4 (6.4)	1/16 (1.6) 3/16 (4.8) 3/8 (9.5)
Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation	0 – 50[a] 51 – 130 131– 300	1/8 (3.2) 3/16 (4.8) 1/2 (12.7)	1/8 (3.2) 1/4 (6.4) 1/2 (12.7)

[a] Spacings at these voltages may be decreased from those indicated in the table if it can be determined through test or analysis that there is no hazard (i.e. circuits supplied by limited power sources as defined in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1).

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Clause	Requirement + Test	Result - Remark	Verdict
15.5	There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a component 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 the device passes the Dielectric Strength Test, Section 32, and the Isolation Resistance Test, Section 33. 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.		P
15.6	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.		P
16	**Printed Wiring Boards**		—
16.1	A printed-circuit board shall comply with the requirements in the Standard for Electrical Printed-Wiring Boards, UL 796, and shall have a flammability rating as indicated in Section 14.		P
16.2	A resistor, capacitor, inductor, or other part that is mounted on a printed-circuit board to form a printed-circuit assembly shall be secured so that it does not become displaced and cause a risk of electric shock or fire by a force that is capable of being exerted on it during assembly, intended operation, or servicing of the power supply.		P
17	**Internal Wiring and Terminals**		—
17.1	Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment.		P
17.2	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.		P
17.3	An external terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when the vehicle is in use.		P

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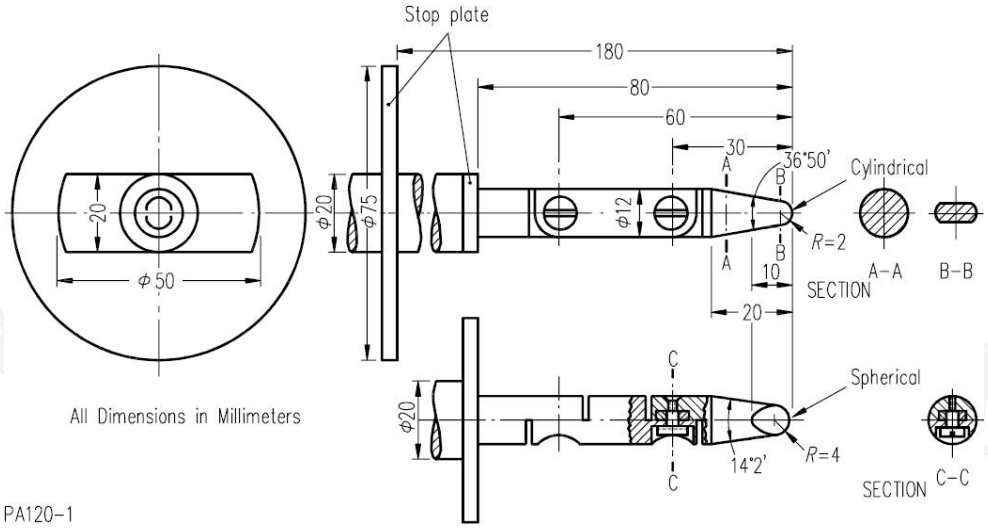
Clause	Requirement + Test	Result - Remark	Verdict
17.4	An external terminal for charging shall be designed to prevent an inadvertent shorting and misalignment and a reverse polarity connection when connected to the charger.		P
17.5	Any other external terminals with hazardous voltage shall be designed to prevent access by the user. Compliance is determined by use of the articulate probe shown in Figure 17.1.		P
17.6	A hole by which insulated wires pass through a metal wall shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, upon which the wires may bear, to prevent abrasion of the insulation.		P
17.7	Wiring for hazardous voltage on board the vehicle shall be enclosed in junction boxes with hazardous voltage warning labels such as ISO 7010, No. W012 (i.e. lightning bolt within triangle), or shall be protected by suitable enclosures that are not accessible to the user.		P
	Figure 17.1 Articulate probe 		P
18	**Transformers**		—
18.1	**General**		P
18.1.1	A transformer coil, unless inherently moisture resistant, shall be treated with an insulating varnish and baked, or otherwise impregnated to exclude moisture or acid vapor. Film-coated magnet wire is moisture resistant for this case.		P
18.1.2	A thermal cutoff or other device employed to reduce the risk of fire or electric shock due to overheating of a transformer during abnormal operation shall comply with the requirements applicable to such a device in addition to the applicable requirements in this Outline. For example, a thermal cutoff shall comply with the applicable requirements in this Outline and those in the Standard for Thermal-Links - Requirements and Application Guide, UL 60691.		P

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Clause	Requirement + Test	Result - Remark	Verdict
18.1.3	A transformer used to supply an accessible signal circuit shall have its primary winding electrically isolated from its secondary winding and shall be constructed as specified in 18.2.1 – 18.2.4 so that there is no electrical connection - under normal and overload conditions- between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, where such connection results in a risk of fire or electric shock.		P
18.1.4	With reference to the requirement in 18.1.3, a transformer complying with the requirements in any of the following standards complies with this requirement:		P
	a) Standard for Low Voltage Transformers, Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers, Part 3: Class 2 and Class 3 Transformers, UL 5085-3;		P
	b) Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411; or		P
	c) Standard for Class 2 Power Units, UL 1310.		P
18.2	**Coil insulation**		P
18.2.1	A transformer winding including the start, all taps, finish, and crossover leads up to the point where insulated leads are provided shall be constructed, when used, as specified in Table 18.1.		P
	Table 18.1 Transformer insulation		P

Insulation required		Type of insulation
1.	Insulation between the primary wires of opposite polarity and between secondary wires of opposite polarity having a potential greater than 30 volts, rms (42.4 volts peak)	a, b, c, or d
2.	Insulation between the primary and any secondary winding	a, b, c, or d
3.	Insulation between any winding or lead connections and dead metal parts	b, c, d, e, f, or g
4.	Insulation between the crossover leads and (1) the turns of a different winding, (2) the metal enclosure of a unit, or (3) the core	a, d, e, g, or h

a.	Electrical grade paper that is waxed or otherwise treated to retard the absorption of moisture and that has a total thickness of not less than 0.028 inch (0.71 mm); polyethylene terephthalate film, not less than 0.007 inch (0.178 mm) thick; or aramid paper, not less than 0.0085 inch (0.203 mm) thick.
b.	A thermoplastic or thermoset coil form not less than 0.028 (0.71 mm) inch thick.
c.	A material having a thickness less than 0.028 inch (0.71mm) is used only when it is equivalent to note a or b and the material has a minimum dielectric breakdown strength of 5000 volts for the thickness used as determined by the test described in Tests on Transformer Insulating Materials in the Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202.
d.	Using spacings specified in Table 18.2 in place of the specified insulation, is allowed.
e.	Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.013 inch (0.33 mm) when used in conjunction with an air spacing of one-half that specified in note d.
f.	Electrical grade paper, waxed or otherwise treated to resist the absorption of moisture, having a total thickness of not less than 0.028 inch (0.71 mm) where the insulation is in contact with the enclosure.
g.	A material having a thickness less than that specified in notes e and f is not prohibited where it is equivalent to notes e and f and the material has a minimum dielectric breakdown strength of 2500 volts for the thickness used for note e and 5000 volts for the thickness used for note f as determined by the Tests on Transformer Insulating Materials in the Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202.
h.	Any type and thickness of insulation in addition to the magnet wire coating, or a through air spacing less than that specified in Table 18.2 may be used between a crossover lead and the winding to which it is connected when the construction complies with the applicable dielectric withstand potential described in Section 32. The potential is to be applied between the coil leads with the crossover lead cut at the point where it enters the inner layer.

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Clause	Requirement + Test	Result - Remark	Verdict

Table 18.2 Spacings within a transformer

Minimum spacing through air and over surface, inch (mm)	
Potential involved, volts	Between any uninsulated live part and an uninsulated live part of opposite polarity, or the core[a]
0 – 50	3/64 (1.2)
Greater than 50 to 125	1/16 (1.6)
Greater than 125 to 250	3/32 (2.4)
Greater than 250 to 600	1/4 (6.4)

NOTE – This table applies only to transformers that are treated with an insulating varnish and baked or otherwise impregnated.

[a] Includes turns of a coil having a magnet wire coating.

P

18.2.2	Insulating material, such as outer-wrap and crossover-lead insulation, employed to reduce the risk of live parts from becoming accessible through openings in the outer enclosure shall comply with note (a) or (c) of Table 18.1.		P
18.2.3	A flanged bobbin-wound transformer shall be constructed so as to maintain physical separation between the primary and secondary windings. Physical separation accomplished by employing a 3-flange bobbin for winding the primary and secondary windings adjacent to each other is allowed. As an alternative, a telescoping bobbin construction, with each section containing an individual winding, is to be used where the primary winding is wound over the secondary winding or the secondary winding over the primary winding. The bobbin insulation shall comply with note (a), (b), (c), or (d) of Table 18.1. Exception No. 1: A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of the requirement when:		P
	a) The tape insulation complies with note (a) or (c) of Table 18.1;		P
	b) The tape insulation provides a continuous overlap on the bobbin flanges; and		P
	c) The transformer complies with the tests described in the Flanged Bobbin Transformer Abnormal Test, Section 35.4.		P
	Exception No. 2: A 2-flange bobbin having the primary winding wound over the secondary winding or the secondary winding wound over the primary with the primary winding insulated from the secondary winding by means of tape insulation meets the intent of the requirement when:		P
	a) The tape insulation complies with note (a) or (c) of Table 18.2;		P
	b) The coils are layer wound; and		P
	c) All windings have end turns that are retained by a positive means and the spacing between end margins of the primary and secondary windings comply with item (d) of Table 18.1.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 3: A transformer complying with the requirements in either both the Standard for Low Voltage Transformers, Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers, Part 3: Class 2 and Class 3 Transformers, UL 5085-3, the Standard for Class 2 Power Units, UL 1310, or the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television Type Appliances, UL 1411, complies with this requirement		P
18.2.4	With reference to note (c) in Exception No. 1 to 18.2.3, the Flanged Bobbin Transformer Abnormal Test, Section 35.4, is not required when the transformer is supplied from a LVLE circuit or a limited energy circuit.		P
19	**Fuses**		—
19.1	Fuses shall be acceptable for the current and voltage of the circuit they are protecting.		P
19.2	Fuses provided for protection of circuits or outputs shall comply with the applicable parts of the Standard for Low Voltage Fuses, UL 248 series. Fuseholders used with these fuses shall comply with the corresponding parts of the Standard for Fuseholders, UL 4248 series.		P
19.3	For user replaceable fuses, a fuse replacement marking in accordance with 46.4 shall be 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 user replaceable fuses with special fusing characteristics such as time delay or breaking capacity are necessary, the type shall also be indicated. Information on proper fuse replacement of user replaceable fuses shall also be included in the instructions. See Section 51.		P
20	**Capacitors**		—
20.1	The materials and construction of a capacitor, its case, or both shall be such that emission of flame from the enclosure of the unit during malfunction of the capacitor does not occur. See 20.3.		P
20.2	The materials and construction of a capacitor or its case within a unit shall be such that pressures capable of causing injury to persons do not develop in the capacitor in the event of malfunction of the capacitor or the circuit in which it is connected. See 20.3.		P
20.3	Compliance with the requirements described in 20.1 and 20.2 shall be determined by the abnormal tests specified in 35.5 and 35.6.		P
20.4	Under both normal and abnormal conditions of use, including internal shorting of the capacitor, a capacitor containing oil that is more combustible than askarel shall not result in a risk of fire or electric shock and shall be constructed to reduce the risk of expelling dielectric medium from the enclosure of the unit. See 20.5 and 20.6.		P

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Clause	Requirement + Test	Result - Remark	Verdict
20.5	With reference to the requirement in 20.4, a capacitor complying with the requirements for protected oil-filled capacitors in the Standard for Capacitors, UL 810, is to be constructed to reduce the risk of expelling the dielectric medium.		P
20.6	With reference to 20.4, a unit having a capacitor other than that described in 20.5 shall be provided with a complete noncombustible bottom panel below the capacitor.		P
20.7	Capacitors connected across an input ac circuit shall comply with the requirements for across-the-line capacitors in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414, or the Standard for Electromagnetic-Interference Filters, UL 1283.		P
21	**Strength of Enclosures**		—
21.1	Any hazardous live parts are required to be enclosed. The enclosure that is used shall be subjected to the Impact Test, Section 37, as applicable.		P
22	**Sharp Edges**		—
22.1	An enclosure, a frame, a guard, a handle, or similar device shall not have sharp edges that constitute a risk of injury to persons in normal maintenance and use.		P
23	**Battery Packs**		—
23.1	Battery packs shall be provided with an appropriate Battery Management System (BMS), and shall be designed to safely withstand anticipated abuse conditions for the vehicle involved. A battery pack used in vehicles covered by this Outline shall be in accordance with the Standard for Batteries for Use in Electric Vehicles, UL 2580, or the Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271.		P
24	**Operator Interface**		—
24.1	The operator interface shall be supplied by a limited power circuit and shall be completely enclosed.		P
24.2	Touchscreens with high voltage backlights shall be evaluated as Limited Current Circuits in accordance with the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1.		P
24.3	Emergency control of the motor shall not require multiple commands by the user and shall not require the user to remove their hold on the handle bars.		P
25	**Motors and Motor Controllers**		—
25.1	Electric motors shall comply with the Standard for Rotating Electrical Machines - General Requirements, UL 1004-1, and shall be thermally protected and shall comply with:		P
	a) The Standard for Impedance Protected Motors, UL 1004-2;		P

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	b) The Standard for Thermally Protected Motors, UL 1004-3; or		P
25.2	c) The Standard for Electronically Protected Motors, UL 1004-7.		P
	Controls associated with the motor shall be in accordance with the Standard of Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1. 25.3 In addition to the testing associated with the control of the motor in this Outline, hazards associated with the motor control shall be included in the analysis required in Safety Circuits and Safety Analysis, Section 11.		P
26	**Mounting**		—
26.1	Components of the electrical system shall be securely mounted to the vehicle such that they are not capable of moving and straining connections, allowing access to hazardous circuits, or increasing the risk of shock or fire. Parts shall not fall from their mounting means due to the normal vibration associated with the operation of the vehicle.		P
26.2	With respect to 26.1, the vehicle electrical system shall be subjected to the Vibration Test, Section 36.		P
	PERFORMANCE		—
27	**General**		—
27.1	The performance tests are to be conducted on representative units of the vehicle or vehicle electrical system as appropriate.		P
27.2	Testing is to be conducted at any ambient temperature between 5°C (41°F) and 35°C (95°F).	25°C	P
27.3	Unless indicated otherwise, batteries are to be fully charged to the maximum operating state of charge in accordance with the manufacturer's specifications. After charging and prior to testing, the batteries are to be allowed to rest for a maximum period of 8 hours at room ambient.		P
27.4	Tests may be conducted on a test track, a bench or a test stand, which keeps the driven wheel free of the ground.		P
27.5	If conducted on a test track, the wind speed is to not exceed 6.7 mph (3 m/s).		P
27.6	In all cases, worst case conditions of gear ratio and speed are to be selected.		P

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Clause	Requirement + Test	Result - Remark	Verdict
27.7	The tests contained in this Outline 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 surface of at least one cell/module within the DUT are to be monitored during the test for safety and information purposes. All personnel involved in the testing are to be instructed to never approach the test unit until temperatures are falling and have returned to within ambient temperatures.		P
27.8	Unless noted otherwise in the individual test methods, the tests shall be followed by a 1-h observation time prior to conclude the test and temperatures are to be monitored in accordance with 27.7.		P
27.9	Vehicles that are operational after tests associated with the battery shall be subjected to a minimum of one cycle of charging and discharging in accordance with the manufacturer's specifications to determine that there is no fire, explosion, rupture, electrolyte leakage, or shock hazard associated with the stressed battery. The tests that incorporate this one charge and discharge cycle are the Vibration Test, Section 36, Water Exposure Test, Section 38.1, and the Thermal Cycling Test, Section 38.2.		P
28	**Input Test**		—
28.1	The input current to a vehicle with an on board charging unit that is directly plugged into a NEMA 5-20R receptacle is to be measured with the unit operating while charging a fully discharged battery. The current input shall not be more than 110 percent of the rated value.		
29	**Leakage Current**		—
29.1	A cord-connected on board charging unit shall be tested in accordance with 29.2 – 29.8. Leakage current shall not be more than:		P
	a) 0.5 MIU for a two-wire cord- and plug-connected unit;		P
	b) 0.5 MIU for a three-wire (including grounding conductor) cord- and plug-connected portable unit; and		P
	c) 0.75 MIU for a three-wire (including grounding conductor) cord- and plug-connected fixed appliance.		P
29.2	All accessible conductive surfaces are to be tested for leakage currents to determine compliance with 29.1. Where surfaces are simultaneously accessible, they are to be tested:		P
	a) Individually;		P

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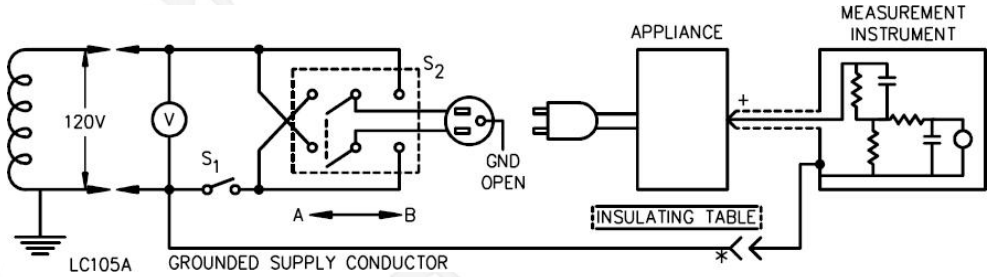
Clause	Requirement + Test	Result - Remark	Verdict
	b) Collectively (connected together) with the combined current measured to ground; and		P
	c) Point-to-point on the device for leakage current between the simultaneously accessible surfaces.		P
29.3	When a conductive part other than metal is used for an enclosure or part of an enclosure, leakage current is to be measured using a metal foil with an area of 4 by 8 inches (100 by 200 mm) in contact with the surface. Where the conductive surface has an area less than 4 by 8 inches the metal foil is to be the same size as the surface. The metal foil is to conform to the shape of the surface and is not to remain in place long enough to affect the temperature of the unit.		P
29.4	The typical measurement circuit for leakage current with the ground connection open is illustrated in Figure 29.1. The measurement instrument is defined in Figure 29.2. The meter that is used for a measurement need only indicate the same numerical value for a particular measurement as does the defined instrument; it need not have all the attributes of the defined instrument. Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:		P
	a) The measured ratio V1/I1 with sinusoidal voltages is to be as close as feasible to the ratio V1/I1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 29.2.		P
	b) The measured ratio V3/I1 with sinusoidal voltages is to be as close as feasible to the ratio V3/I1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 29.2. V3 is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts is converted to MIU by dividing the reading by 500 ohms and then multiplying the quotient by 1,000. The mathematic equivalent is to multiply the RMS voltage reading by 2.		P
	Figure 29.1 Leakage current measurement circuit used for devices intended for connection to 120 V circuits 		P

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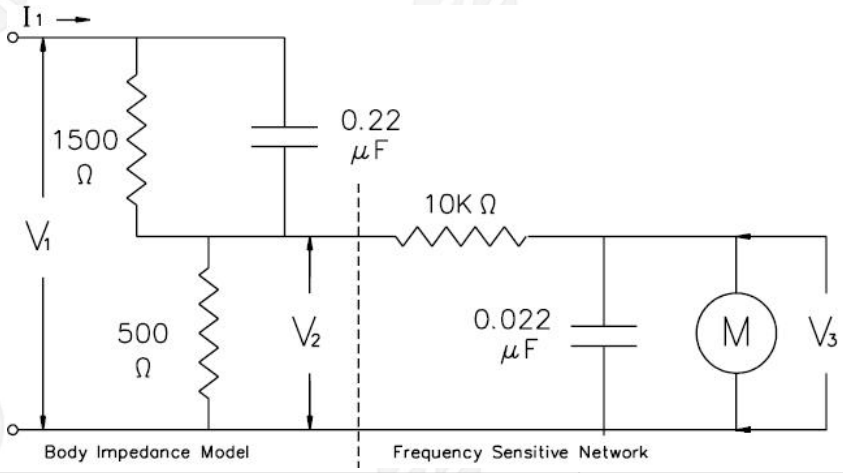
Clause	Requirement + Test	Result - Remark	Verdict

	Figure 29.2 Measurement instrument for reaction (leakage) current 		P
29.5	Unless the measurement instrument is being used to measure leakage current from one part of a unit to another, it is to be connected between accessible parts and the supply conductor connected to ground (the grounded or grounding conductor) that has the least extraneous voltages introduced from other equipment operated on the same supply. For products rated 120 volts, with one supply conductor grounded, this is likely to be the grounded supply conductor.		P
29.6	When there is no grounded conductor connected to the unit under test, then the instrument return lead is not prohibited from being connected to either the grounded or grounding conductor of the supply depending on the other electrical loads connected to the branch circuit and operating at the time the test is conducted. Use the conductor introducing the least extraneous voltage, as indicated by the lowest leakage current reading. In environments having significant extraneous voltage introduced, an isolating transformer reduces the effects of extraneous voltages.		P
29.7	A representative unit is to be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except that which occur as part of the production-line testing. The supply voltage is to be adjusted to rated voltage. The test sequence is to be as follows, with reference to Figure 29.1:		P
	a) With switch S1 open, the unit is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S2, and with the unit switching devices in all their normal operating positions.		P
	b) Switch S1 is then to be closed, energizing the product. Within 5 seconds, the leakage current is to be measured using both positions of switch S2 and with the product switching devices in all their normal operating positions.		P

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	c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the normal temperature test.		P
	d) The leakage current is also to be monitored with switch S1 open while the unit is at operating temperature and while cooling.		P
29.8	A representative unit is to be subjected to the entire leakage current test, as specified in 29.7, without interruption for other tests unless with the concurrence of those concerned, the tests are nondestructive tests.		P
30	**Capacitor Discharge Test**		—
30.1	A cord connected on board charging unit that is provided with filtering capacitors, or other primary capacitors, shall comply with this test.	Measured:U1=0,75V (peak) U2=0,80V (peak)	P
30.2	The device shall be connected to a supply source of rated voltage at 60 Hz. The output shall be connected to a suitable load such that rated current is drawn from the output of the device. A storage oscilloscope shall be connected across the point of disconnection of the supply.		P
30.3	The device shall be connected to the source of supply and energized with the output open circuit condition. The power shall then be removed and the resulting discharge curve for the stored charge on capacitors shall be measured and captured on the oscilloscope.		P
30.4	The test shall be repeated with all switches in all possible positions and combinations.		P
31	**Temperature Test**		—
31.1	The Temperature test shall be conducted to determine whether or not the temperature sensitive safety critical components and temperature sensitive materials in the vehicle components are being maintained within their temperature ratings and that temperatures on accessible surfaces, which may be contacted by the user are within acceptable limits. Additionally, this test is conducted to determine whether or not the component cells are being maintained within their specified operating limits during maximum charge and discharge conditions of the vehicle.		P
31.2	The test is to be performed under two methods. The battery charging circuit and battery are tested in accordance with 31.3 – 31.7, and the vehicle system and battery pack are tested in accordance with 31.8 and 31.9.		P

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Clause	Requirement + Test	Result - Remark	Verdict
31.3	First, a fully discharged battery pack is to be conditioned within a chamber set to the upper limit charging temperature specifications of the vehicle manufacturer. After thermal stabilization in the chamber, the battery pack is to be connected to a charging circuit input representative of anticipated maximum charging parameters provided by the specified charger. The battery pack shall then be subjected to maximum normal charging while monitoring voltages and currents on cells until it reaches the manufacturer's specified fully charged condition. Temperatures shall be monitored on temperature sensitive components including cells, enclosure, and all parts within the charging circuit that are temperature sensitive, including any user accessible surfaces.		P
31.4	While still in the conditioning chamber, and after allowing temperatures to stabilize, the fully charged battery pack shall then be discharged in accordance with the manufacturer's specifications representative of maximum weight and operating conditions for loading down to the manufacturer's specified end of discharge condition while monitoring voltage and current on cells until the battery pack reaches its specified end of discharge voltage (EODV). Temperatures shall be monitored on temperature sensitive safety critical components including cells, enclosure, and all parts within the charging circuit that are temperature sensitive, including any user accessible surfaces.		P
31.5	The charge and discharge cycles are then repeated for a total of 2 complete cycles of charge and discharge. The test is then repeated with the representative unit in a chamber set to the vehicle manufacturer's lowest specified operating ambient for 2 complete cycles of charge and discharge.		P
31.6	During the temperature test, the voltage and current during discharge and charging of the component cells is monitored to determine that they are not outside of the specified cell manufacturer's operating region.		P
31.7	The manufacturer's specified limits (voltage, current and temperatures measured) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications. See Tables 31.1 and 31.2 for surface and component temperature limits.		P
31.8	The vehicle shall be powered from a power source used to represent a battery pack. The vehicle system is then operated at the maximum load on the motor continuously until thermal stabilization. See 31.10.		P
31.9	Temperatures shall be monitored on all temperature sensitive components, enclosures, and user accessible surfaces. Temperatures measured on components shall not exceed their specifications. See Tables 31.1 and 31.2 for surface and component temperature limits.		P

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Clause	Requirement + Test	Result - Remark	Verdict

31.10	A temperature is determined to be stabilized when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no increase greater than 2°C (4°F).		P
	Table 31.1 Temperatures on components		P

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 casings	[b]
Motor Windings[c]:	
• Insulation Class A (open motor)	65
• Insulation Class A (totally enclosed motor)	70
• Insulation Class B (open motor)	85
• Insulation Class B (totally enclosed motor)	90
• Insulation Class F (open motor)	110
• Insulation Class F (totally enclosed motor)	115

[a] The temperatures measured on components and materials shall not exceed the maximum temperature rating for that component or material.
[b] The internal cell case temperature shall not exceed the manufacturer's recommended maximum temperature.
[c] The temperature limits are based upon thermocouple measurements.

	Table 31.2 Temperatures on user accessible surfaces		P

Accessible surfaces	Maximum surface temperatures		
	Metal °C (°F)	Glass, porcelain and vitreous materials °C (°F)	Plastic and rubber[a] °C (°F)
Handles, knobs, grips, etc., continuously held in normal use	55 (131)	65 (149)	75 (167)
Handles, knobs, grips, etc., held or touched for short periods only	60 (140)	70 (158)	85 (185)
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)

[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;

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

31.11	At the conclusion of this test, the battery pack tested under the battery method is placed back into the vehicle system. Any hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 33, (without humidity conditioning) or a Dielectric Strength Test, Section 32.		P
31.12	As a result of this test, in addition to temperatures remaining below the limits, there shall be no indication of fire, explosion, rupture, electrolyte leakage or electric shock.		P
32	**Dielectric Strength Test**		—
32.1	This test is an evaluation of the electrical spacings and insulation at hazardous voltage circuits within the vehicle system.		P

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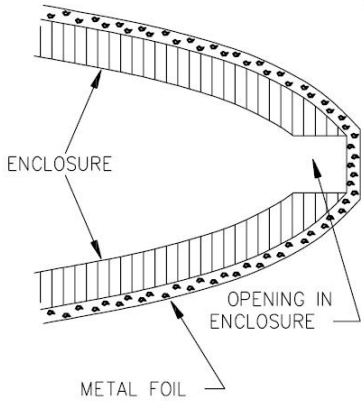
Clause	Requirement + Test	Result - Remark	Verdict
32.2	Circuits at 60 Vdc or higher shall be subjected to a dielectric withstand voltage consisting of a dc potential of twice the rated voltage times 1.414. Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.		P
32.3	The test voltage is to be applied between the hazardous voltage circuits of the vehicle system and non-current carrying conductive parts that may be accessible.		P
32.4	The test voltage is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the vehicle system.		P
32.5	If the accessible parts of the vehicle system are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts. The metal foil shall be wrapped tightly around and in intimate contact with the accessible part. The foil is to be drawn tightly across any opening in the enclosure or other accessible parts to form a flat plane across such opening. See Figure 32.1.		P
	Figure 32.1 Method of covering enclosures with foil for measurement and tests 		P
32.6	The test voltages shall be applied for a minimum of 1 min with the cells/modules disconnected to prevent charging during application of the voltage.		P
32.7	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 an ac test method and 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 may not be indicative of insulation breakdown.		P

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Clause	Requirement + Test	Result - Remark	Verdict
32.8	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 a dielectric breakdown (i.e. insulation breakdown).		P
33	**Isolation Resistance Test**		—
33.1	This test is intended to determine that insulation of the vehicle system provides adequate isolation of hazardous voltage circuits from accessible conductive parts of the vehicle system and that the insulation is non-hygroscopic.		P
33.2	A vehicle system with accessible parts shall be subjected to an insulation resistance test between the positive terminal and accessible dead metal parts of an vehicle system. If the accessible parts of the vehicle system are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts as shown in 32.5 and Figure 32.1.		P
33.3	The insulation resistance shall be measured after a 60-s application with a high resistance voltmeter using a 500 Vdc potential applied for at least 1 min to the locations under test.		P
33.4	The test shall be repeated on a representative unit subjected to humidity conditioning in accordance with the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1, Clause 2.9.2. Measurements shall be made with the unit still in the chamber.		P
33.5	The measured insulation resistance between the positive terminals and accessible parts of the DUT shall be at least 50,000 W.		P
34	**Humidity Conditioning**		—
34.1	An onboard electrical system shall comply with the requirements for leakage current in 29.1 if the system is provided with an on board charger that is cord connected, the Dielectric Strength Test, Section 32, and/or the Isolation Resistance Test, Section 33, following exposure to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F).	34°C, 90%, 48h	P
34.2	To determine whether a unit complies with the requirement in 34.1, a representative unit is to be heated to a temperature just above 34°C (93°F) to reduce the risk of condensation of moisture during conditioning. The heated unit is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 34.1. Immediately following the conditioning, the unit is to be removed from the humidity chamber and tested as described in 34.1.		P
35	**Abnormal Operations Tests**		—

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Clause	Requirement + Test	Result - Remark	Verdict

35.1	**General**		P
35.1.1	A unit shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons when subjected to the tests specified in 35.2 – 35.8. Separate representative units are to be used for conducting these tests, unless requested otherwise by the manufacturer.		P
35.1.2	Following each test, any hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 33, (without humidity conditioning) or a Dielectric Strength Test, Section 32.		P
35.1.3	A risk of fire, electric shock, or injury to persons exists when:		P
	a) Flame, burning oil, or molten metal is emitted from the enclosure of the unit as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper;		P
	b) The insulation breaks down when tested in accordance with 35.1.2 or live parts are made accessible to the probe in Figure 17.1;		P
	c) Cracking, rupturing, or bursting of the battery case or cover, where such damage results in user contact with battery electrolyte; or		P
	d) Explosion of the battery supply where such explosion results in a risk of injury to persons.		P
35.1.4	During these tests the unit is to be placed on a softwood surface covered with a white tissue paper and a single layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth running 14 - 15 yards per pound (26 - 28 m2/kg), and having, for any square inch, a count of 32 threads in one direction and 28 in the other direction.		P
35.1.5	The supply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20-ampere minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The test voltage and frequency are to be adjusted to the rated values.		P
35.1.6	The enclosure of the unit is to be connected directly to ground.		P
35.1.7	Each test is to be continued until further change as a result of the test condition is reduced significantly. When an automatically reset protector functions during a test, the test is to be continued for 7 hours. When a manual reset protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using the minimum resetting time, and not faster than 10 cycles of operation per minute. The following are examples of test terminations:		P

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Clause	Requirement + Test	Result - Remark	Verdict

	a) Opening or shorting of one or more components such as capacitors, diodes, resistors, solid state devices, printed wiring board traces, or similar devices;		P
	b) Opening of the intended branch circuit overcurrent protection device described in 35.1.5 – see 35.1.10; and		P
	c) Opening of an internal fuse.		P
35.1.8	When the manually reset protector is a circuit breaker that complies with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489, it is to be operated for 3 cycles using the minimum resetting time and not faster than 10 cycles of operation per minute.		P
35.1.9	A manual reset protector that becomes inoperative in the open condition shall be operated between 10 cycles and 3 cycles.		P
35.1.10	With reference to 35.1.7 (b), when the branch circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 48.3 (i).		P
35.2	**Transformer burnout test**		P
35.2.1	An adjustable resistive load is to be connected directly to the secondary winding of each transformer and adjusted to result in the load condition described in (a), (b), or (c) below. Opening of the intended branch circuit overcurrent protection device described in 35.1.5 or an internal overcurrent protection device connected in the primary-winding circuit is an example of when this test is terminated.		P
	a) For a transformer having a single isolated secondary winding, the load is to be adjusted to result in maximum volt-ampere output but not resulting in more than three times the maximum normal alternating current to flow in the primary winding.		P
	b) For a transformer having multiple isolated secondary windings, each secondary winding is to be tested separately; that is, with the winding under test loaded with an alternating current equal to three times the rms value of the secondary current flowing through that winding during maximum normal operation of the unit and the other isolated windings, each loaded with an alternating current equal to the rms value of the secondary current flowing through their respective windings during maximum normal operation of the unit.		P
	c) For an autotransformer, the conditions specified in (a) are to be used with the supply voltage connected to the outer input legs and the load resistor connected to the outer output legs. See Figure 35.1.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	Exception No. 1: A transformer supplied from either an inverter circuit or other means limiting the current to the transformer to less than three times rated current is to be loaded to a condition resulting in maximum obtainable input current without operation of overcurrent protection devices, where any are present.		P
	Exception No. 2: A transformer employed in a switch-mode inverter or converter circuit shall be subjected to the transformer overload test described in 35.3 in lieu of the transformer burnout test.		P
	Exception No. 3: Any transformer, including a control circuit transformer or a power transformer used for the transfer of either the input or output power of the unit, having overcurrent protection sized in accordance with Table 35.1 is not required to comply with this requirement.		P
	Exception No. 4: A transformer that is protected by the intended branch circuit protection device that is sized in accordance with the values in Table 35.1 and is provided in a unit marked in accordance with 48.3 (i) is not required to comply with this requirement.		P
	Exception No. 5: An isolating power transformer used for the transfer of either the input or output power of the unit and complying with the Standard for Low Voltage Transformers, Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers, Part 3: Class 2 and Class 3 Transformers, UL 5085-3; or the Standard for Dry-Type General Purpose and Power Transformers, UL 1561, or shall be subjected to the transformer overload in lieu of the transformer burnout test.		P
	Exception No. 6: A transformer subjected to the transformer overload in lieu of the transformer burnout test.		P
	Exception No. 7: An isolating power transformer used for the transfer of either the input or output power of the unit complying with the requirements in either of the following standards: a) Standard for Low Voltage Transformers, Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers, Part 3: Class 2 and Class 3 Transformers, UL 5085-3; or b) Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.		P
	Exception No. 8: A signal or gate-drive transformer that is rated 10 watts or less and having a secondary circuit that does not extend out of the unit is not required to comply with this requirement.		P

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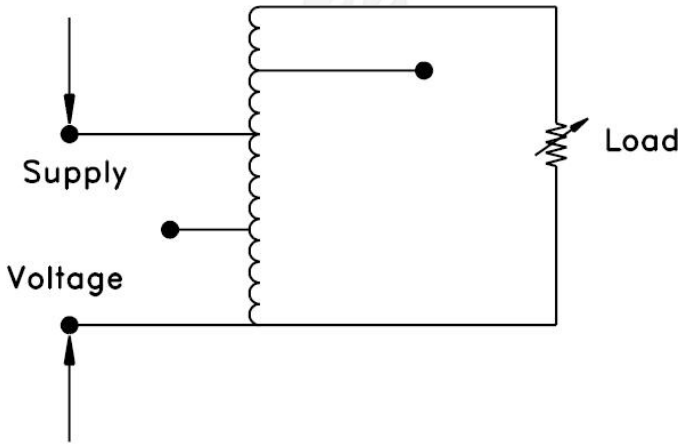
Clause	Requirement + Test	Result - Remark	Verdict

Figure 35.1 Autotransformer burnout test



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P

Clause	Requirement + Test	Result – Remark	Verdict
	Table 35.1 Primary overcurrent protection for control circuit transformers		P

Rated primary current, amperes	Maximum rating of overcurrent device, percent of transformer primary current rating
Less than 2	300
2 or more, less than 9	167
9 or more	125

35.2.2	A ferro-resonant transformer is to be tested in accordance with 35.2.1 with the secondary winding loaded to maximum input current. The transformer is to be operated continuously until ultimate conditions are observed.		P
35.2.3	During the tests described in 35.2.1 and 35.2.2, secondary circuit protective devices that are external to the transformer are to be bypassed. Primary circuit protective devices are to be left in the circuit.		P
35.3	**Transformer overload test**		P
35.3.1	When an isolating power transformer is to be tested in accordance with Exception No. 6 to 35.2.1, the tests described in 35.3.2 – 35.3.4 are to be conducted. When a transformer employed in a switch-mode inverter or converter circuit is to be tested in accordance with Exception No. 2 to 35.2.1, the test described in 35.3.5 is to be conducted.		P

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Clause	Requirement + Test	Result - Remark	Verdict
35.3.2	A resistive load is to be connected directly to each transformer secondary winding and adjusted to a value so each secondary winding carries 50 percent of rated load until temperatures of the transformer core become stabilized. The load is then to be increased to 200 percent of the rated value; no further adjustment of the overload current is to be made. The duration of the overload is to be as specified in Table 35.2. The short circuit method as described in the Test Code for Dry-Type Distribution and Power Transformers, ANSI/IEEE C57.12.91, is one method used to obtain the 200 percent of rated load current. Where the short-circuit test method is used, all secondary windings are to be shorted and the voltage applied to the primary windings is to be adjusted to result in rated current to flow in the secondary windings.		P
	Table 35.2 Overload test times Insulation class / Overload time, minutes 105 / 30 130 / 30 155 / 30 180 / 26 200 / 23 220 / 20		P
35.3.3	With reference to the requirement in 35.3.2, testing of a transformer rated more than 500 kilovolt-amperes is not required when the test has already been performed with results that meet the intent of the requirement on a smaller transformer rated not less than 500 kilovolt-amperes, when the smaller transformer has the same insulation system and same general construction as the larger transformer, and the temperatures recorded during the temperature test are no greater for the larger transformer than those recorded during the temperature test for the smaller transformer.		P
35.3.4	Within 1 hour following the overload test, the transformer shall perform as intended in a repeated dielectric voltage-withstand test except that the test value is to be at 65 percent of value specified in Dielectric Strength Test, Section 32.		P
35.3.5	For a unit tested in accordance with Exception No. 2 to 35.2.1, the power circuit supplied by the transformer is to be connected to a resistive load that draws maximum obtainable output power without causing operation of internal overcurrent protection devices or a protection circuit or resulting in opening of a circuit component such as a diode, resistor, sold state device, or similar device.		P
35.4	**Flanged bobbin transformer abnormal test**		N/A
35.4.1	A flanged bobbin transformer required to be tested as provided in (c) of Exception No. 1 to 18.2.3 – also see 18.2.4 – shall operate for 15 days with the secondary winding or windings loaded to the conditions described below in (a) – (c). A risk of fire or electric shock shall not result from:		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
	a) Short-circuiting the secondary winding;		N/A
	b) Loading the secondary winding to a current equal to maximum normal current plus X percent of the difference between the short-circuit current and the rated current - where X equals 75, 50, 25, 20, 15, 10, and 5, respectively; and		N/A
	c) Loading the secondary winding to maximum normal current.		N/A
	Exception No. 1: A flanged bobbin transformer used in a circuit where isolation is not required or where the secondary circuit does not extend out of the unit is not required to be subjected to this test.		N/A
	Exception No. 2: A transformer complies with this requirement when it complies with the requirements in either of the following: a) The Standard for Low Voltage Transformers, Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers, Part 3: Class 2 and Class 3 Transformers, UL 5085-3. b) The Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411.		N/A
35.4.2	The results of the test do not meet the intent of the requirement when the cheesecloth glows, or flames, is charred or a breakdown occurs when the test described in 35.4.4 is conducted.		N/A
35.4.3	Representative units for the 15-day abnormal operation tests are to be prepared as follows:		N/A
	a) The transformer is to be mounted either in the unit enclosure as intended under the conditions described in 35.1.4 or on a test bench with the cheesecloth mentioned in 35.1.4 draped over the transformer.		N/A
	b) All secondary windings are to be loaded to rated current before the abnormal condition is introduced; and the loads, other than that connected to the winding to be overloaded, are not to be readjusted thereafter.		N/A
35.4.4	While still in a heated condition from the tests described in 35.4.1, a transformer shall withstand the dielectric voltage-withstand test applied between the primary winding and the secondary winding. The dielectric voltage-withstand-test potential is to be applied to the transformer 1 minute after completion of the abnormal-operation test.		N/A
35.4.5	The abnormal tests are to be conducted with a protective device built into the transformer or with an external protective device used with the transformer in the unit connected in either the primary or secondary circuit, or in both. A protective device that is relied upon to open the circuit as a result of an abnormal test is to be one that has been investigated and found to meet the intent of the requirement.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

35.4.6	For the purpose of these requirements, each secondary winding tap and each primary winding tap that is used to supply power to a load in the unit are the equivalent of a secondary winding. 35.4.7 For the sequence of tests described in 35.4.1, when an abnormal-operation test continues for 15 days without a winding or a protective device opening, the remaining tests are not required to be conducted. For example, when the test described in 35.4.1 (a) continues for 15 days, the tests described in 35.4.1 (b) and (c) are not required to be conducted.		N/A
35.4.8	To determine whether a transformer complies with the requirement in 35.4.1, three separate representative units are to be subjected to each condition described in 35.4.1 (a) – (c). For a transformer that employs more than one secondary winding, each of the secondary windings is to be loaded for each condition specified in 35.4.1 with the other windings loaded to rated current. The test conditions are to be as described in 35.4.9 – 35.4.13.		N/A
35.4.9	To determine the short-circuit current value for conducting the tests described in 35.4.1 (b), the transformer is to be at room temperature at the beginning of the measurement, and the short-circuit current is to be measured 1 minute after the voltage is applied to the primary winding. A protective device outside the transformer, where provided by the manufacturer, is to be short-circuited during the measurement of the short-circuit current. When the line fuse or transformer winding opens within 1 minute after the application of the primary voltage, the short-circuit current is that value recorded just before the line fuse or winding opens. The short-circuit current of any one winding is to be measured with the other secondary windings open-circuited.		N/A
35.4.10	For the loading conditions, a variable resistor is to be connected across the secondary winding. Each test described in 35.4.1 (a) – (c) is to be continued until a risk of fire develops, the 3-ampere fuse opens, a winding of the transformer or a protective device opens or 15 days have passed. In conducting the tests described in 35.4.1 (a) – (c), the variable resistance load is to be adjusted to the required value as quickly as possible and readjusted, where required 1 minute after voltage is applied to the primary winding. For a switch-mode transformer, the load is to be connected to the output of the power supply connected to the transformer.		N/A
35.4.11	When short-circuiting the secondary winding causes one of the windings to open before 15 days, then the next test in the sequence described in 35.4.1 (b) and (c) that continues for 15 days is to have the variable load resistor reduced to zero impedance at the end of the 15 days to cause the transformer to burn out.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

35.4.12	For a transformer that is provided with a protective device built into the transformer or that is being tested in conjunction with an external protective device, a test described in 35.4.1 (a) – (c) is to be discontinued when the protective device opens the circuit and the next test in the sequence is to be started. The protective device mentioned above includes automatic recycling type, manual reset type, or a replaceable type.		N/A
35.4.13	When a protective device opens the circuit or a winding on any representative unit opens during the 15-day abnormal-operation tests while the units are unattended, the variable resistor load on the other units is to be increased, by reducing the resistance, until the protective device opens the circuit or the winding opens, so that the units are subjected to the dielectric voltage-withstand test described in 35.4.4 while in a heated condition. The next test in the sequence in 35.4.1 (b) and (c) that continues for 15 days is to be conducted.		N/A
35.5	**Capacitor faults**		P
35.5.1	Where required by Exception No. 2 to 20.6, a unit having a bottom-ventilated enclosure containing oil-filled capacitors shall be subjected to the performance tests specified for protected, oil-filled capacitors in the Standard for Capacitors, UL 810. These tests are to be conducted with the capacitors mounted in the unit enclosure as intended, and oil leakage from the capacitors passing through the enclosure, where present shall be extinguished – see 35.1.3 (a).		P
35.6	**Electrolytic capacitor faults**		P
35.6.1	For a unit having dc electrolytic storage capacitors operating above 60 vdc, the fault test described in 35.6.2 shall be conducted. Exception: This requirement does not apply to a capacitor that complies with the requirements in the Standard for Capacitors, UL 810. The capacitor shall have an available fault current rating of 10,000 amperes or a lower value where a circuit analysis indicates that because of a series impedance, the lower value is applicable.		P
35.6.2	With reference to the requirement in 35.6.1, a fault in one of the capacitors in the storage capacitor bank is to be simulated. This is to be accomplished by connecting the capacitor under test in reverse while the input ac supply to the unit is not energized. The unit is then to be energized and operated as in normal operation.		P
35.7	**Component fault tests**		P
35.7.1	A component, such as a capacitor, diode, solid state device, or similar device, connected in the input and output power circuits are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including start-up. This test is not required:		P

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Clause	Requirement + Test	Result - Remark	Verdict

	a) Where circuit analysis indicates that no other component or portion of the circuit is overloaded.		P
	b) For electromagnetic radio frequency interference capacitors subjected to the dielectric strength test across their terminals in accordance with Section 32, resistors, transformers, inductors, and optical isolators.		P
35.8	**Forced ventilation/blocked ventilation**		N/A
35.8.1	A unit having forced ventilation is to be operated with the rotor of a blower motor or fan locked. For a unit having more than one blower motor or fan, the test is to be conducted with the rotor of each blower motor or fan locked, one at a time, unless agreeable to all for which all blower motors or fans shall be locked at the same time.		N/A
35.8.2	A unit having filters over ventilation openings is to be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked 50 percent, then to be repeated under fully blocked condition.		N/A
36	**Vibration Test**		—
36.1	A vehicle system, or parts of the system, intended to be permanently mounted on a vehicle shall be subjected to a vibration test. After the unit is subjected to the vibration test described in 36.2: a) The vehicle system shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons; b) There shall be no loosening of parts; and c) The unit shall operate normally.		P
36.2	The vibration test shall consist of vibration for one hour at a frequency of 10 to 55 Hz and back to 10 Hz, with a linear sweep having a sweep time of two minutes per sweep cycle. The amplitude shall be 1.0 +0.1, –0 mm (0.040 +0.004, –0 inch) p-p displacement limit in a vertical plane.		P
36.3	After this test, the representative unit shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. After this charge/discharge cycle, the unit shall be subjected to an observation period per 27.8.		P
36.4	At the conclusion of the observation period, the unit shall be subjected to a Dielectric strength Test, Section 32, or an Isolation Resistance Test, Section 33, (without humidity conditioning).		P
36.5	As a result of the test, there shall be no indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		P
37	**Impact Test**		—

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Clause	Requirement + Test	Result - Remark	Verdict
37.1	A unit acting as an enclosure shall be subjected to this test. The enclosure is to be subjected to an impact of 5 foot-pounds (6.8 J) on any surface that is exposed to a blow during normal use. This impact is to be produced by dropping a steel sphere, 2 inches (50.8 mm) in diameter and weighing 1.18 pounds (535 g), from a height of 51 inches (1.29 m) to produce the 5 foot-pound impact. For surfaces other than the top, the steel sphere is to be suspended by a cord and swung as a pendulum, dropping through a vertical distance of 51 inches to strike the surface.		P
37.2	A unit is to be subjected to the impact test described in 37.1 with or without any attachment specified by the manufacturer so as to result in the most severe test.		P
37.3	When the part under test is made of polymeric material, the impact test is to be first conducted on a representative unit or units in the as-received condition. The test is then to be repeated on a different unit or units that have been cooled to room temperature after being conditioned for 7 hours in an air oven operating at 10°C (18°F) higher than the maximum operating temperature of the material, and not less than 70°C (158°F). While being conditioned, a part is to be supported in the same manner in which it is supported on the unit.		P
37.4	Upon being removed from the oven mentioned in 37.3 and before being subjected to the impact test, no units shall show signs of cracking or other deleterious effects from the oven conditioning, and no unit shall be distorted so as to result in a risk of injury to persons.		P
37.5	After the impact test, any openings resulting from the test shall be evaluated for access to hazardous live parts using the accessibility probe shown in Figure 17.1.		P
38	**Environmental Tests**		—
38.1	**Water exposure test**		P
38.1.1	This test is intended to evaluate the vehicle's ability to withstand potential water exposure in its intended use and is conducted in accordance with the test method outlined in 38.1.2.		P
38.1.2	A fully charged vehicle system, including any off board charging devices, shall be subjected to a water exposure test in accordance with the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, Tests for Protection Against Water Indicated by the Second Characteristic Numeral 4 (IPX4), unless the vehicle system is provided with a higher IP Code rating by the manufacturer, in which case the vehicle system shall be tested in accordance with its rating.		P
38.1.3	If the vehicle system is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 27.8.		P

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Clause	Requirement + Test	Result - Remark	Verdict

38.1.4	At the conclusion of the observation period, the units shall be subjected to a Dielectric Strength Test, Section 32, or an Isolation Resistance Test, Section 33, (without humidity conditioning).		P
38.1.5	As a result of the test, there shall be no indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		P
38.2	**Thermal cycling**		P
38.2.1	This test determines the vehicle's ability to withstand exposure to rapidly changing environments such as when the vehicle is entering or exiting a heated storage facility after being in a cold environment, changing temperatures during transport or storage outdoors, and the like, without evidence of damage that could lead to a hazardous event.		P
38.2.2	A fully charged vehicle system, including any off board charging devices, shall be subjected to the thermal cycling in accordance with 38.2.3.		P
38.2.3	For the test, the vehicle system shall be placed in a chamber with ambient air cycling at the temperature extremes of either 50 ±2°C (122 ±3.6°F) or -30 ±2°C (-22 ±3.6°F). The transition period between exposure temperatures is to be 15 min or less. This swing of temperature variations may be performed either through the use of a fast-response chamber, or by moving the vehicle system between two chambers at the two test temperatures. The vehicle system shall remain at each temperature extreme for as long as required for the vehicle system to reach a uniform temperature (±5°C) of the chamber temperature but no less than 6 hours. A total of five cycles (at the high and low temperature extremes) are to be performed.		P
38.2.4	If the vehicle system is operational after the test, it shall be allowed to return to room ambient and then subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period per 27.8.		P
38.2.5	At the conclusion of the observation period, the units shall be subjected to a Dielectric Strength Test, Section 32, or an Isolation Resistance Test, Section 33, (without humidity conditioning).		P
38.2.6	As a result of the test, there shall be no indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		P
39	**Motor Assistance Control - Pedalec**		—
39.1	The pedalec shall be tested to ensure that motor assistance is not provided while the operator is pedaling backwards.	Motor assistance were no provided	P
39.2	The test specified in Cycles - Electrically power assisted cycles - EPAC Bicycles, EN 15194, Section 4.2.4.2, shall be conducted.		P
40	**Startup Assistance Mode Test**		—

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Clause	Requirement + Test	Result - Remark	Verdict
40.1	For eBikes provided with a startup assistance mode, the test specified in 45.2 shall be conducted to ensure that startup assistance is only provided by the voluntary and maintained action of the operator either when riding or without pedaling and that the startup assistance velocity does not exceed 3.7 mph (6 km/h).	5.8 km/h	P
40.2	The test specified in Cycles - Electrically power assisted cycles - EPAC Bicycles, EN 15194, Section 4.2.4.3, shall be conducted.		P
41	**Maximum Assistance Speed**		—
41.1	The pedalec shall be tested to ascertain the maximum speed for which assistance is provided does not exceed 20 mph (32 kph).	31.5 kph	P
41.2	The test specified in Cycles - Electrically power assisted cycles - EPAC Bicycles, EN 15194, Section 4.2.6, shall be conducted.		P
42	**Mold Stress**		—
42.1	This test is intended to evaluate whether any shrinkage or distortion exists on a molded or formed thermoplastic enclosure due to release of internal stresses caused by the molding or forming operation and result in the exposure of hazardous parts or reduction of electrical spacings.		P
42.2	The representative units are to be placed in a full-draft circulating-air oven maintained at a uniform temperature of 70°C (158°F) or 10°C (18°F) higher than the maximum temperature observed on the part during the Temperature Test, Section 31. The units are to remain in the oven for 7 hours.		P
42.3	To inhibit hazards from overheating energized cells, units shall be fully discharged prior to conditioning.		P
42.4	After careful removal from the oven, the units shall be allowed to cool to room temperature and then examined. After the examination, the units shall be subjected to a Dielectric Strength Test, Section 32, or Isolation Resistance Test, Section 33, (without humidity conditioning).		P
42.5	There shall be no damage of the vehicle system enclosure that would allow hazardous voltage parts to be accessed by use of the test rod 2.5 mm diameter, 100 mm long, shown in Figure 1 of the Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271, and the articulate probe shown in Figure 17.1.		P
43	**Permanence of Marking**		—
43.1	The purpose of this test is to evaluate the permanence of an adhesive label that has not been subjected to a previous evaluation program.		P
43.2	An adhesive label secured to a surface representative of the end use application and is subjected to the following conditioning. The label is rubbed by hand for 15 s with a piece of cloth soaked with water. This is then repeated using petroleum spirit.		P

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Clause	Requirement + Test	Result - Remark	Verdict

43.3	The petroleum spirit to be used for the test is an aliphatic solvent hexane having:		P
	a) A maximum aromatics content of 0.1 percent by volume;		P
	b) A kauributenol value of 29; c) An initial boiling point of approximately 65°C (149°F);		P
	d) A dry point of approximately 69°C (156.2°F); and		P
	e) A mass per unit volume of approximately 0.7 kg/l. Exception: As an alternative, it is permitted to use a reagent grade hexane with a minimum of 85 percent as n-hexane .		P
43.4	After the conditioning outlined in 43.2, the unit is to be examined for signs of damage including curing and to determine if the marking is still legible. The unit is also examined to determine if it can be removed easily by hand from the adhered surface.		P
43.5	As a result of the conditioning, the representative label shall remain legible, show no evidence of damage including curling and shall not be able to be easily removed by hand from the adhered surface.		P
	MARKINGS		—
44	**General**		—
44.1	The markings required for compliance to this Outline shall be legible and permanent such as etched, adhesive labels, etc. An adhesive-backed label shall comply with the requirements in the Standard for Marking and Labeling Systems, UL 969, for the intended exposure conditions and surface adhered to. Alternatively, the label shall be subjected to the Permanence of Marking Test, Section 43.		P
45	**Nameplate and Identification**		—
45.1	Vehicle systems, or individual components of the system, are to be marked with the manufacturer's name, trade name, trademark or other descriptive marking which may identify the organization responsible for the product, part number or model number, and electrical ratings.		P
45.2	Vehicle systems, or components of the system, shall also be marked with the date of manufacture, which may be in the form of a code that does not repeat within 10 years.		P
45.3	Vehicle on board systems shall be marked with charging instructions. An example of such markings would be the following or equivalent ²Use Only (_) Charger."		P
45.4	All external terminals and connections shall be provided with identification and if applicable, polarity markings.		P
45.5	If a manufacturer produces or assembles vehicle systems at more than one factory location, the equipment shall have a distinctive marking – which may be in code – to identify it as the product of a particular factory.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

45.6	Equipment field wiring terminals shall be marked “Use Copper Conductors Only”.		P
45.7	A terminal for the connection of a grounded conductor shall be identified by means of a metallic plated coating white in color, and shall be readily distinguishable from the other terminals; or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as a marking on the unit, an indication on a wiring diagram attached to the unit, or information provided in the instruction manual. Where field wiring leads are provided, the lead intended to be grounded shall have a white or gray color and shall be readily distinguishable from other leads.		P
45.8	A unit containing a field-wiring lead that is connected to a wire binding screw located in the field-wiring compartment shall be marked with information clearly indicating the intended use of the lead.		P
46	**Cautionary Markings**		—
46.1	The words ²CAUTION², ²WARNING², OR ²DANGER² in a cautionary marking shall be in letters not less than 1/8 inch (3.2 mm) high. The remaining letters in a cautionary marking shall not be less than 1/16 inch (1.6 mm) high. The words ²WARNING² or ²DANGER² are alternatives for the word ²CAUTION”.		P
46.2	A cautionary marking shall be located on a part that is not removable; or if removable, on a part that impairs the operation of the unit when removed. The marking shall also be visible and legible to the operator during normal operation of the unit.		P
46.3	Off board charger units intended for indoor use only while charging vehicles in accordance with this Outline, shall be marked with the word “CAUTION” and the following or the equivalent: ²Risk of Electric Shock – Only use this charger indoors. Outdoor use is prohibited².		P
46.4	There shall be a replacement marking adjacent to a fuse or fuseholder if the fuse is used to reduce the risk of fire or electric shock and the fuse is user replaceable. The marking shall be located where it will be readily visible during replacement of the fuse, and shall consist of the word ²CAUTION² and the following or equivalent: ²For Continued Protection Against Risk Of Fire, Replace Only With Same Type__ A, __V fuse.² The blanks shall have the applicable current and voltage ratings.		P
47	**General**		—
47.1	A product shall be provided with legible installation instructions, operation instructions, and instructions pertaining to a risk of fire, electric shock, or injury to persons associated with the use of the product. Also, user maintenance instructions and moving and storage instructions associated with the use of the product by the end user shall be included.		P

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Clause	Requirement + Test	Result - Remark	Verdict
47.2	The instructions mentioned in 47.1 shall be in separate manuals or shall be combined in one or more manuals when the instructions pertaining to a risk of fire, electrical shock, or injury to persons are separated in format and emphasized to distinguish them from the rest of the text.		P
47.3	An illustration is allowed with a required instruction to clarify the intent but shall not replace the written instruction.		P
47.4	The following items shall be entirely in upper case letters or shall be emphasized to distinguish them from the rest of the text:		P
	a) The headings for the installation, operation, user maintenance, and moving and storage instructions;		P
	b) The heading for the instructions pertaining to a risk of fire, electric shock, or injury to persons; and		P
	c) The opening and closing statements of the instructions specified in 48.3 - “IMPORTANT SAFETY INSTRUCTIONS” and “SAVE THESE INSTRUCTIONS”, or the equivalent.		P
47.5	Unless otherwise indicated, the text of the instructions in 48.3 and 48.4 shall be in the words specified or words that are equivalent, clear, and understandable. Substitution of the signal word “DANGER” for “WARNING” is allowed when the risk associated with the product is such that a situation exists which, if not avoided, will result in death or serious injury.		P
48	**Instructions Pertaining to Risk of Fire, Electric Shock, or Injury To Persons**		—
48.1	Instructions pertaining to a risk of fire, electric shock, or injury to persons shall warn the user of reasonably foreseeable risks and state the precautions to be taken to reduce such risks. Such instructions shall be preceded by the heading “INSTRUCTIONS PERTAINING TO RISK OF FIRE, ELECTRIC SHOCK, OR INJURY TO PERSONS” or the equivalent.		P
48.2	Numbering of the items in the list in 48.3 and including other instructions pertaining to a risk of fire, electric shock, or injury to persons that the manufacturer determines to be necessary and that do not conflict with the intent of the instructions are acceptable.		P
48.3	The instructions pertaining to a risk of fire, electric shock, or injury to persons shall include those items in the following list that are applicable to the product. The statement “IMPORTANT SAFETY INSTRUCTIONS” or the equivalent shall precede the list, and the statement “SAVE THESE INSTRUCTIONS” or the equivalent shall either precede or follow the list. The word “WARNING” shall be entirely in upper case letters or shall be emphasized to distinguish it from the rest of the text.		P
	IMPORTANT SAFETY INSTRUCTIONS		P
	WARNING - When using this product, basic precautions should always be followed, including the following:		P

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Clause	Requirement + Test	Result - Remark	Verdict
	a) Read all the instructions before using the product.		P
	b) To reduce the risk of injury, close supervision is necessary when the product is used near children.		P
	c) Do not put fingers or hands into the product.		P
	d) Do not use this product if the flexible power cord or output cable is frayed, has broken insulation, or any other signs of damage.		P
	e) For an off board charger provided with a field wiring terminal or leads, the installation instructions shall state that the installation is intended to use copper wires only.		P
	f) For an off board charger, when a pressure terminal connector, or the fastening hardware, are not provided on the unit as shipped. The instruction manual shall indicate which pressure terminal or component terminal assemblies are for use with the unit.		P
	g) With reference to (f), the terminal assembly packages and the instruction manual shall include information identifying the wire size and the manufacturer's name, trade name, or other descriptive marking by which the organization responsible for the product is identified.		P
	h) When a pressure terminal connector provided on an off board charger, for a field installed conductor requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any required instructions for using the tool shall be included in the installation instructions.		P
	i) The instruction manual for a unit where the abnormal test is terminated by operation of the intended branch circuit over current protective device, shall include the word ²CAUTION² and the following or equivalent: ²To reduce the risk of fire, connect only to a circuit provided with_____amperes maximum branch circuit overcurrent protection in accordance with the National Electrical Code, ANSI/NFPA 70.² The blank space is to be filled in with the applicable ampere rating of branch circuit overcurrent protection.		P
	SAVE THESE INSTRUCTIONS		P
48.4	The instructions pertaining to a risk of fire, electric shock, or injury to persons, or the installation instructions shall include the following items if applicable. If the following instructions are included in the installation instructions, a reference to these instructions shall be included in the list mentioned in 48.3 as a separate item. The headings and the word "WARNING" shall be entirely in upper case letters or shall be emphasized to distinguish it from the rest of the text.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	GROUNDING INSTRUCTIONS This product must be grounded. If it should malfunction or breakdown, grounding provides a path of least resistance for electric current to reduce the risk of electric shock. This product is equipped with a cord having an equipment grounding conductor and a grounding plug. The plug must be plugged into an outlet that is properly installed and grounded in accordance with all local codes ordinances. WARNING - Improper connection of the equipment grounding conductor is able to result in a risk of electric shock. Check with a qualified electrician if you are in doubt as to whether the product is properly grounded. Do not modify the plug provided with the product - if it will not fit the outlet, have a proper outlet installed by a qualified electrician.		N/A
49	**Installation Instructions**		—
49.1	Installation instructions shall contain all the information needed to install the product for use as intended, and shall be preceded by the heading “INSTALLATION INSTRUCTIONS” or the equivalent.		P
50	**Operating Instructions**		—
50.1	Operating instructions shall contain all the information needed to operate the product as intended, and shall be preceded by the heading “OPERATING INSTRUCTIONS” or the equivalent.		P
50.2	Instructions in relation to operating that appear in the instructions pertaining to a risk of fire, electric shock, or injury to persons, are not required to be repeated here; but a reference to those instructions shall be included here.		P
50.3	The instruction manual shall contain the following information:		P
	a) Instructions regarding battery charging, temperature limits for appliance and battery use and storage, and the recommended temperature range for charging.		P
	b) A warning shall be provided against modifying or attempting to repair the vehicle system except as indicated in the instructions for use and care.		P
50.4	Instructions shall indicate that charging of the vehicle shall only be performed with the manufacturer’s recommended charger.		P
51	**User Maintenance Instructions**		—
51.1	Instructions for user maintenance shall include explicit instructions for all cleaning and servicing that are intended to be performed by the user, and shall be preceded by the heading “USER MAINTENANCE INSTRUCTIONS” or the equivalent.		P
51.2	For units with user replaceable fuses, the user maintenance instructions shall contain statements concerning fuse replacement instructions and reference to the correct fuse ratings that are to be used.		P

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Clause	Requirement + Test	Result - Remark	Verdict
52	**Moving and Storage Instructions**		—
52.1	If moving or storage of the product is able to result in damage to the product that could result in a risk of fire, electric shock, or injury to persons during subsequent use, the instructions shall describe the proper moving and storage procedure, and shall be preceded by the heading “MOVING AND STORAGE INSTRUCTIONS” or the equivalent.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

7	**General**		—
7.1	The information provided in Sections 7 through 10 is essential for the proper evaluation of the products covered by this Standard. The concepts in these Sections will outline and define the evaluation path based on what is provided in the system or vehicle.		P
7.2	The concepts in Sections 7 through 10 are general in nature and could result in different methods of evaluation for each different product type. This would be discussed in the specific requirements for the product type.		P
7.3	EBikes consist of both pedalec and non-pedalec types, but in all cases functional pedals shall be provided. For pedalec type eBikes, the motor shall disengage its assist function when the eBike achieves a maximum speed of 32 kph (20 mph), or if the user stops pedaling, or when the user applies the brakes (if the brakes are provided with cutoff functions) whichever occurs first. For non-pedalec versions of eBikes, the motor is not required to disengage when the user stops pedaling, but the maximum assistance speed is still limited to 32 kph. The maximum speed shall be controlled in either case. A non-pedalec type eBike may be provided with a pedalec mode. Additionally, the motor shall not exceed 750 W (1 hp).		P
7.4	Electric scooters and electric motorcycles shall not be provided with pedals, functional or otherwise, and are provided with a seat for the rider to sit on during operation. There is no maximum speed regulated for these vehicles. Operation is controlled through the throttle and the user is not required to act in any other manner to propel the vehicle other than manipulation of the throttle control.		N/A
7.5	For portions of the electrical system located on the vehicle, all equipment shall be evaluated as outdoor use equipment. Outdoor use equipment shall comply with all the requirements in this standard as applicable to outdoor use equipment at a maximum altitude of 2000 m (6562 feet) and over an ambient temperature range of 0°C to 40 °C (32°F to 104°F) and be subjected to ingress protection tests. For equipment located off board the vehicle, such as chargers or supply equipment, the equipment may be for indoor or outdoor use. Outdoor use is assumed unless the equipment is marked in accordance with 63.3. Indoor use only equipment shall comply with all the requirements in this standard as applicable to indoor use equipment operating at a maximum altitude of 2000 m and over an ambient temperature range of 0°C to 40°C (32°F to 104°F) but ingress protection for water is not applicable.		P

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Clause	Requirement + Test	Result - Remark	Verdict

7.6	For off board equipment connected to a source of supply, the equipment may be permanently connected or cord connected to the supply source. Permanently connected equipment is fixed in place and subjected to the applicable indoor or outdoor use requirements indicated in this standard. Cord connected equipment is considered movable, but shall be designated as indoor use only, or shall be evaluated to the outdoor use requirements in this standard.		N/A
8	**Power Levels**		—
8.1	**General**		P
8.1.1	Regardless of product type, a specific power level will be associated with the device. This will require rated voltage and current levels to be assigned, but can also include voltages or currents that are available within the device being evaluated. Different approaches can be used based on the potential hazards associated with a given power level.		P
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 are 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.		P
8.2	**Hazardous Voltage and Hazardous Energy**		P
8.2.1	Any accessible circuit or accessible part 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. 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.		P
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 must be protected against contact with the part or circuit by the use of an enclosure or proper 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.		P
8.3	**Low Voltage Limited Energy Circuits**		P

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Clause	Requirement + Test	Result - Remark	Verdict

8.3.1	A Low-Voltage Limited Energy Circuit is considered to be a circuit involving an alternating current voltage of not more than 30 volts rms (42.4 volts peak) or a direct current voltage of not more than 60 volts and supplied by:		P
	a) Class 2 transformer or Class 2 Power Unit,		P
	b) A combination of a battery source or an isolated transformer secondary winding and one or more resistors, or a regulating network complying with 8.3.3, 8.3.4, and 8.3.6, or		P
	c) A battery with output current limited by overcurrent protection complying with Section 19 in accordance with 8.3.5 and Table 8.1.		P
	Table 8.1 Rating for secondary fuse or circuit protector Circuit voltage (volts, rms) / Current (amperes) 20 or less / 5 More than 20 but not greater than 60 / 100/V[a] [a]V is the maximum output voltage, regardless of the load, with the primary energized.		P
8.3.2	A part or device, other than the battery pack, located in or supplied by an LVLE circuit need not be investigated. 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.		P
8.3.3	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 seconds after the application of the load. The resistor is to be continuously readjusted during this 1 minute period to maintain maximum load current. The measured load current shall not exceed the value listed in Table 8.1.		P
8.3.4	With reference to the voltage limit specified in 8.3.1, measurement is to be made with the product connected to the intended source of supply and with all loading circuits disconnected.		P
8.3.5	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.		P
8.3.6	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.		P
9	**Combination of Battery/BMS and Charger**		—

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Clause	Requirement + Test	Result - Remark	Verdict
9.1	The battery/BMS is used to control battery charging and is reliant on specific reactions of the charger to maintain safe operation during charging. Tests in this standard may have different outcomes using different chargers with the battery/BMS. Therefore, the combination of the charger and the battery/BMS is critical to the safety of the system and that combination shall be evaluated together.		P
9.2	All testing of the system shall be performed with the actual battery/BMS and charger combination that is recommended by the manufacturer. Any protection circuits or systems can remain in place provided those circuits or systems are proven to be reliable in accordance with Section 12.		P
10	**User Protection While Charging**		—
10.1	**General**		P
10.1.1	Charging of the battery may occur while the battery is installed on the vehicle, with the battery removed from the vehicle, or both options may apply based on user preference. If the battery is only intended to be charged when it is removed from the vehicle, then an inherent means shall be provided to insure that this option is the only option for charging the battery. If no inherent means are provided, and it is possible to charge the battery while on the vehicle, the battery shall be considered to be charged both on board and off board the vehicle.		P
10.1.2	If the battery is intended to be charged while on the vehicle whether by inherent construction or user preference, then the requirements in 10.2 apply. If the battery is only intended to be charged when removed from the vehicle, then the requirements in 10.2 do not apply.		P
10.1.3	The requirements in 10.1.1 and 10.1.2 are to be used in conjunction with the requirements in Section 8. If energy levels are such that no hazard exists, then protection means may be reduced.		P
10.2	**Charging batteries that are on the vehicle**		P
10.2.1	Charging of the battery on a vehicle 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 vehicle are protected and monitored during charging to prevent a shock hazard due to the charging energy supplied to the vehicle. The personnel protection system supplied shall be as indicated in 10.2.2 or 10.2.3.		P

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Clause	Requirement + Test	Result - Remark	Verdict
10.2.2	For vehicle charging system equipment where the specifics of the installation of the on board electrical system is unknown, or is not part of the evaluation, the vehicle charging system shall be provided with a system of protection in accordance with the requirements in the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements, UL 2231-1/CSA C22.2 No. 281.1 and the Standard for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protective Devices for Use in Charging Systems, UL 2231-2/CSA C22.2 No. 281.2.		P
10.2.3	For vehicle charging system equipment where the specifics of the installation of the on board electrical system is part of the evaluation, the vehicle shall be provided with a system of protection that is considered suitable to protect the user. This may be a system in accordance with 10.2.2, or may include other suitable means such as double insulation systems onboard the vehicle. The suitability of the protection system shall be judged based on the requirements in this standard.		P
10.2.4	With reference to 10.2.3, products utilizing a system of protection based on protective grounding shall comply with the requirements in 10.2.5 and products utilizing a system of protection based on double insulation shall comply with the requirements in 10.2.6.		P
10.2.5	Protection systems relying on protective grounding for user protection shall comply with the applicable requirements for grounding and bonding in Section 22. The requirements shall be applied to all points where protective grounding is used a means to protect the user.		P
10.2.6	A system of double insulation provided to protect the user shall be in accordance with the requirements in the Reference Standard for Double Insulation Systems for Use in Electronic Equipment, UL 2097.		P
11	**Battery Packs**		—
11.1	Battery packs shall be provided with an appropriate Battery Management System (BMS), and shall be designed to safely withstand anticipated abuse conditions for the vehicle involved. A battery pack used in vehicles covered by this Standard shall be in accordance with the Standard for Batteries for Use in Electric Vehicles, UL 2580/CAN/ULC-S2580, or the Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271/CAN/ULC-S2271. The battery management system shall comply with Section 12 as applicable.		P
12	**Safety Circuits and Safety Analysis**		—

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Clause	Requirement + Test	Result - Remark	Verdict
	12.1 The system's protective circuits shall undergo a safety analysis to verify that all potential hazards associated with the design are addressed in this evaluation. A circuit is defined as a protective circuit if it contains a circuit or a component that is considered critical for mitigating a fire, shock, or explosion hazard in accordance with this Standard.		P
12.2	For battery management systems, the protective circuit shall maintain the cells within their normal operating region for charging and, if normal limits are exceeded, the protective circuit shall limit or shut down the charging or discharging to prevent excursions beyond normal operating limits. Compliance is determined through a review of the battery system data including the safety analysis of 12.4 and through the tests in this Standard.		P
12.3	Protection circuits used to monitor operational parameters, such as maximum assist speed, cutoff assistance due to braking, and the like, shall also be evaluated based on the requirements in this section as applicable. Compliance is determined through a review of the design and overall system, including the safety analysis of 12.4 and through the tests in this Standard.		P
12.4	An analysis of potential hazards (including an FMEA) shall be conducted on the vehicle's electrical system, including the charger and other safety circuits, to determine that events that could lead to a hazardous condition have been identified and addressed through design or other means. Documents that can be used as guidance for the safety analysis include:		P
	a) The Standard for Analysis Techniques for System Reliability - Procedure for Failure Mode and Effects Analysis (FMEA), IEC 60812;		P
	b) The Standard for Fault Tree Analysis (FTA), IEC 61025;		P
	c) The Potential Failure Mode and Effects Analysis in Design (Design FMEA), Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA), SAE J1739; and		P
	d) The Procedures for Performing a Failure Mode, Effects, and Criticality Analysis, MIL-STD- 1629A.		P
12.5	The analysis in 12.4 is utilized to identify anticipated faults in the system which could lead to a hazardous condition and the types and levels of protection provided to mitigate the anticipated faults. The analysis shall consider single fault conditions in the protection circuit/scheme as part of the anticipated faults.		P
12.6	When conducting the analysis of 12.4, active devices shall not be relied upon for critical safety unless:		P
	a) They are provided with a redundant passive protection device;		P

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Clause	Requirement + Test	Result - Remark	Verdict
	b) They are provided with redundant active protection that remains functional and energized upon loss of power/failure of the first level active protection;		P
	c) They are determined to fail safe upon loss of power to the active circuit; or		P
	d) They are part of a protective circuit that has been shown to comply with an appropriate Functional Safety standard listed in 12.7, with a safety level defined by a corresponding hazard and risk analysis.		P
12.7	Devices relied upon for critical safety as noted in 12.4 shall be tested for functionality in the relevant configuration and environment, in accordance with appropriate functional safety requirements unless already evaluated through the other tests of this Standard. Functional safety criteria can be found in one of the following standards as appropriate to the design of the electronic and software protection scheme:		P
	a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, and the Standard for Software in Programmable Components, UL 1998, and Safety functions incorporating electronic technology, CSA C22.2 No. 0.8;		P
	b) The Standard for Automatic Electrical Controls for Household and Similar Use - Part 1: General Requirements, UL 60730-1 and Automatic Electric Controls – Part 1: General Requirements, CSA C22.2 E60730-1;		P
	c) The Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety- Related Systems - Part 1: General Requirements, IEC 61508-1, and all parts; and		P
	d) The Standard for Safety of Machinery – Safety Related Parts of Control Systems – Part 1: General Principles for Design, ISO 13849-1, and the Standard for Safety of Machinery – Safety Related Parts of Control Systems – Part 2: Validation, ISO 13849-2.		P
12.8	Any product containing hazardous voltage shall have a manual disconnect to prevent inadvertent access to hazardous voltage parts during servicing. The manual disconnect shall:		P
	a) Disconnect both poles of the hazardous voltage circuit;		P
	b) Be accessible and able to be operated without the use of a tool in the event of a collision or during servicing;		P
	c) Require manual action to break the electrical connection;		P
	d) Ensure disconnection is physically verifiable and can include actual removal of the battery system from the vehicle or unplugging the battery system connector/plug; and		P

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Clause	Requirement + Test	Result - Remark	Verdict
	e) When engaged (i.e. under disconnection), it does not create exposed conductors capable of becoming energized and is insulated to inhibit a shock hazard during actuation.		P
12.9	If a hazardous voltage automatic disconnect device is provided to isolate accessible conductive parts from the hazardous voltage circuit of the battery system, it shall:		N/A
	a) Not be able to be reset automatically although it may be able to be reset deliberately upon clearing of the fault;		N/A
	b) Disconnect both poles of the hazardous voltage circuit;		N/A
	c) Be capable of handling full load disconnects of the hazardous voltage circuit that it is isolating; and		N/A
	d) Not result in a hazardous condition upon automatic actuation.		N/A
13	**Enclosing and Insulating Hazardous Parts**		—
13.1	**General**		P
13.1.1	The enclosure shall have the strength and rigidity required to resist the possible physical abuses that it will be exposed to during its intended use, in order to reduce the risk of fire or injury to persons.		P
13.1.2	A device shall be provided with one or more enclosures that house all live parts that are considered hazardous. The enclosure shall protect the various parts of the device against mechanical damage from external forces. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, injury to persons, and electrical energy - high current levels shall comply with the applicable enclosure requirements specified in this Standard.		P
13.2	**Materials**		P
13.2.1	**Nonmetallic materials**		P
13.2.1.1	The materials employed for enclosures shall comply with the applicable enclosure requirements outlined in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, Path III, and Evaluation of Properties of Polymeric Materials, CSA C22.2 No. 0.17, except as modified by this Standard.		P
13.2.1.2	Polymeric materials employed for enclosures shall have a minimum flame rating of V-1 in accordance with Flammability, Section 17, or the enclosure may alternatively be evaluated to the 20 mm end product flame test in accordance with the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CSA C22.2 No. 0.17.		P

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Clause	Requirement + Test	Result - Remark	Verdict
13.2.1.3	The following factors in (a) - (e) shall be taken into consideration when an enclosure employing nonmetallic materials is being evaluated. For a nonmetallic enclosure all of these factors shall be considered with respect to thermal aging. Dimensional stability of a polymeric enclosure is addressed by compliance to the mold stress relief test. Suitability to factors (a) - (e) below may be determined by the tests of this Standard. a) Resistance to Impact; b) Crush Resistance; c) Abnormal Operations; d) Severe Conditions; and e) Mold Stress Relief Distortion.		P
13.2.1.4	The polymeric materials employed for enclosures and insulation shall be suitable for anticipated temperatures encountered in the intended application. Enclosures shall have a Relative Thermal Index (RTI) with impact suitable for temperatures encountered in the application but no less than 80°C (176°F), as determined in accordance with the Standard for Polymeric Materials - Long Term Property Evaluations, UL 746B, and Evaluation of Properties of Polymeric Materials, CSA C22.2 No. 0.17.		N/A
13.2.1.5	Materials employed as electrical insulation in the assembly shall be resistant to deterioration that would result in a risk of electrical shock, fire or other safety hazard. Compliance is determined by the tests of this standard. Materials employed for direct support of live parts at hazardous voltage, shall additionally meet the direct support insulation criteria outlined in the Material Property Considerations in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CSA C22.2 No. 0.17, unless employed as part of a component that has been evaluated to a suitable component standard. Insulated wiring is subjected to the requirements outlined in Section 18, Internal Wiring and Terminals.		P
13.2.1.6	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.		P
13.2.1.7	The outdoor use enclosure materials intended to be directly exposed to sunlight and rain in the end use application shall comply with the UV Resistance and the Water Exposure and Immersion tests in accordance with the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CSA C22.2 No. 0.17.		P
13.2.2	**Metallic materials**		P

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Clause	Requirement + Test	Result - Remark	Verdict
13.2.2.1	Metal enclosures shall be corrosion resistant. A suitable plating or coating process can achieve corrosion resistance. Additional guidance on methods to achieve corrosion protection can be found in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E/CSA C22.2 No. 94.2.		P
13.2.2.2	Metal enclosures may be provided with an insulating liner to prevent shorting of live parts to the enclosure. If using an insulating liner for this purpose, the insulating liner shall consist of non-moisture absorbent materials that have a temperature rating suitable for temperatures during operation including charging.		P
13.2.2.3	Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action.		P
13.3	**Strength of Enclosures**		P
13.3.1	Any hazardous live parts are required to be enclosed. The enclosure that is used shall be subjected to the Impact Test, Section 46, as applicable.		P
13.4	**Sharp Edges**		P
13.4.1	An enclosure, a frame, a guard, a handle, or similar device shall not have sharp edges that constitute a risk of injury to persons in normal maintenance and use.		P
13.5	**Ingress Protection**		P
13.5.1	Openings in the enclosure shall be designed to inhibit inadvertent access to hazardous parts. Compliance is determined by the Tests for Protection Against Access to Hazardous Parts Indicated by the First Characteristic Numeral, of the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, for a minimum IP rating of IP3X. Evaluation per IEC 60529, consists of the use of the Test Rod 2.5 mm, 100 mm long, shown in Figure 1 of the Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications, UL 2271/CAN/ULC-S2271, applied with a force of 10 N 10 percent.		P
13.5.2	Openings in an outdoor use enclosure shall be designed to prevent ingress of water as installed in the intended application in accordance with intended use and IP rating in accordance with the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, with a minimum rating of IPX4 and resistant to hazards associated with partial immersion. Compliance is determined by the Ingress Protection Tests in Section 49.		P
14	**Mounting**		—

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Clause	Requirement + Test	Result - Remark	Verdict
	14.1 Components that are intended to be mounted on a vehicle shall be securely mounted to the vehicle such that they are not capable of moving and straining connections, allowing access to hazardous circuits, or increasing the risk of shock or fire. Parts shall not fall from their mounting means due to the normal vibration associated with the operation of the vehicle.		P
14.2	Components mounted on the vehicle shall be subjected to the Vibration Test, Section 53.		P
15	**Printed Wiring Boards**		—
15.1	A printed-circuit board shall comply with the requirements in the Standard for Electrical Printed-Wiring Boards, UL 796, and shall have a flammability rating as indicated in Section 17.		P
15.2	A resistor, capacitor, inductor, or other part that is mounted on a printed-circuit board to form a printed-circuit assembly shall be secured so that it does not become displaced and cause a risk of electric shock or fire by a force that is capable of being exerted on it during assembly, intended operation, or servicing of the power supply.		P
16	**Spacings and Separation of Circuits**		—
16.1	Electrical circuits within the vehicle electrical system at opposite polarity shall be provided with reliable physical spacing to prevent inadvertent short circuits (i.e. electrical spacings on printed wiring boards, physical securing of uninsulated leads and parts). Insulation suitable for the anticipated temperatures and voltages shall be used where spacings cannot be controlled by reliable physical separation.		P
16.2	Electrical spacings in circuits shall have the following minimum over surface and through air spacings as outlined in Table 16.1 or the spacings requirements outlined in the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1/CSA C22.2 No. 60950-1, in Clearances, Creepage Distances and Distances Through Insulation.		P
16.3	As an alternative to the spacing requirements in 16.2, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment, UL 840, and Insulation Coordination, CSA C22.2 No. 0.2, may be used. For determination of clearances, the overvoltage category is considered Overvoltage Category II; and the pollution degree would be Pollution Degree 3 unless reduced by design in accordance with UL 840and CSA C22.2 No. 0.2.		P

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Clause	Requirement + Test	Result - Remark	Verdict

16.4	As an alternative to the clearance values outlined in the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1/CSA C22.2 No. 60950-1in Clearances, Creepage Distances and Distances Through Insulation, the alternative method for determining minimum clearances in the Annex for Alternative Method for Determining Minimum Clearances, Annex G, of the UL 60950-1/CSA C22.2 No. 60950-1 may be applied.		P
	Table 16.1 Electrical spacings		P

	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] 51 – 130 131– 300	1.6 (1/16) 3.2 (1/8) 6.4 (1/4)	1.6 (1/16) 4.8 (3/16) 9.5 (3/8)
Accessible dead metal parts and dead metal parts separated from live parts by basic insulation only – this ordinarily is a spacing resulting from supplementary insulation	0 – 50[a] 51 – 130 131– 300	1.6 (1/16) 3.2 (1/8) 6.4 (1/4)	1.6 (1/16) 4.8 (3/16) 9.5 (3/8)
Live parts and accessible dead metal parts separated by double insulation or by reinforced insulation	0 – 50[a] 51 – 130 131– 300	3.2 (1/8) 4.8 (3/16) 12.7(1/2)	3.2 (1/8) 6.4(1/4) 12.7(1/2)
[a] Spacings at these voltages may be decreased from those indicated in the table if it can be determined through test or analysis that there is no hazard (i.e. circuits supplied by limited power sources as defined in the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1).			

16.5	There are no minimum spacings applicable to parts where insulating compound completely fills the casing of a component 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 inch) thick for supplementary or reinforced insulation, and the device passes the Dielectric Strength Test, Section 41, and the Isolation Resistance Test, Section40. 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.		P
16.6	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.		P
17	**Flammability**		—

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Clause	Requirement + Test	Result - Remark	Verdict
17.1	Nonmetallic materials used for enclosures shall have a minimum flammability rating of V-1 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17. As an alternative, finished enclosures may be tested in accordance with the 20 mm end-product flame test in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17. Metallic materials used for enclosures are considered to comply without further evaluation, except magnesium shall not be used for enclosure materials.		P
17.2	Nonmetallic materials used for internal parts within the overall enclosure shall be rated V-2 minimum.		P
17.3	Internal parts of components shall comply with the flammability requirements of the component standard in accordance with Components, Section 2.		P
17.4	Small parts, and gaskets, that are not located near live parts, and are located in a manner such that they cannot propagate flame from one area to another within the equipment, are not required to have a specific flame rating.		P
17.5	Nonmetallic materials located outside the enclosure, and not used to complete the enclosure, are considered decorative parts. These parts shall be rated HB minimum.		P
17.6	Printed wiring board materials shall be rated V-1 minimum.		P
17.7	For the requirements outlined in 17.2 – 17.6, the flammability rating of the material shall be provided as part of the material rating or the flammability rating may be determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and Evaluation of Properties of Polymeric Materials, CAN/CSA C22.2 No. 0.17.		P
18	**Internal Wiring and Terminals**		—
18.1	Wiring shall be insulated and acceptable for the purpose, when considered with respect to temperature, voltage, and the conditions of service to which the wiring is likely to be subjected within the equipment.		P

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Clause	Requirement + Test	Result - Remark	Verdict
18.2	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.		P
18.3	An external terminal shall be designed to prevent inadvertent shorting. An external terminal shall be designed to prevent inadvertent misalignment or disconnection when the vehicle is in use.		P
18.4	An external terminal for charging shall be designed to prevent an inadvertent shorting and misalignment and a reverse polarity connection when connected to the charger.		P
18.5	Any other external terminals with hazardous voltage shall be designed to prevent access by the user. Compliance is determined by use of the articulate probe shown in Figure 18.1.		P
18.6	A hole by which insulated wires pass through a metal wall shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, upon which the wires may bear, to prevent abrasion of the insulation.		P
18.7	Wiring for hazardous voltage on board the vehicle shall be enclosed in junction boxes with hazardous voltage warning labels such as ISO 7010, No. W012 (i.e. lightning bolt within triangle), or shall be protected by suitable enclosures that are not accessible to the user.		P
18.8	Wires that are subjected to flexing during normal operation or due to user accessibility shall be subjected to the Flexing Test, Section 48.		P
19	**Overcurrent Protection**		—
19.1	Power, control and auxiliary circuits shall have overcurrent protection that is sized to prevent overheating of the smallest size conductor.	Use fuse for overcurrent protection	P

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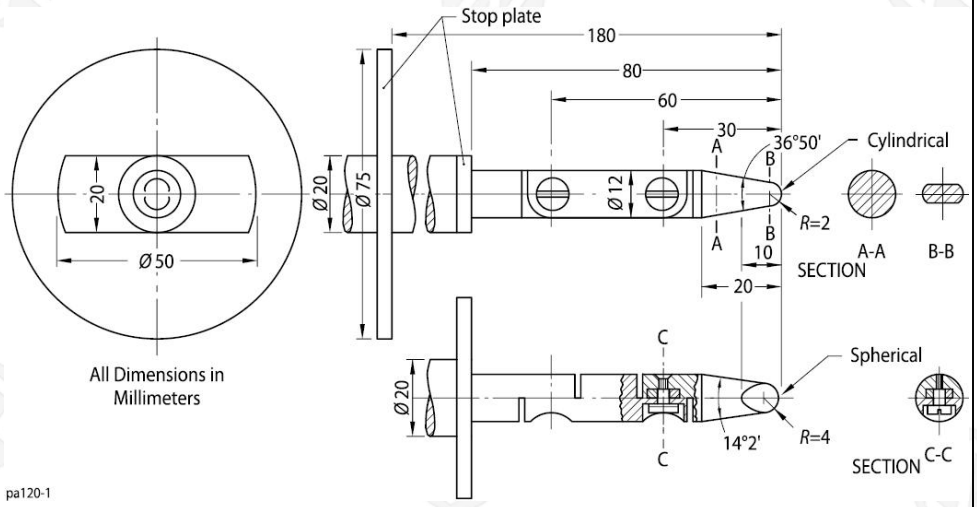
Clause	Requirement + Test	Result - Remark	Verdict

	Figure 18.1 Articulate probe  		P
18.6	A hole by which insulated wires pass through a metal wall shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, upon which the wires may bear, to prevent abrasion of the insulation.		P
18.7	Wiring for hazardous voltage on board the vehicle shall be enclosed in junction boxes with hazardous voltage warning labels such as ISO 7010, No. W012 (i.e. lightning bolt within triangle), or shall be protected by suitable enclosures that are not accessible to the user.		P
18.8	Wires that are subjected to flexing during normal operation or due to user accessibility shall be subjected to the Flexing Test, Section 48.		P
19	**Overcurrent Protection**		—
19.1	Power, control and auxiliary circuits shall have overcurrent protection that is sized to prevent overheating of the smallest size conductor.		P
19.2	The need for overcurrent protection in the power circuit to the vehicle motor is to be determined on the basis of the locked rotor and running overload tests described in Section 45.		P
19.3	Overcurrent devices in the control and power circuit shall be as close as practicable to the power supply or battery.		P
19.4	The need for overcurrent protection in the LVLE circuits is to be determined on the basis of the requirements described in Low-Voltage Limited Energy Circuit, 8.3.		P
19.5	The overcurrent protective device specified in 19.4 shall be a circuit breaker, fuse or positive temperature coefficient device.		P
19.6	A fuse or circuit breaker shall be either: a) Acceptable for branch circuit use; or b) A supplementary type.		P

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Clause	Requirement + Test	Result - Remark	Verdict
19.7	A positive temperature coefficient device shall comply with Manufacturing Deviation and Drift, Clause 15; Endurance, Clause 17; and Requirements for Controls Using Thermistors, Annex J, in the Standard for Automatic Electric Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1/CSA C22.2 E60730-1. The positive temperature coefficient device shall be tested and determined to comply in the actual battery configuration and environment.		P
19.8	Fuses shall be acceptable for the current and voltage of the circuit they are protecting and shall comply with 19.9 and 19.10. Fuses shall be tested and determined to comply in the actual battery configuration and environment.		P
19.9	Fuses provided for protection of circuits or outputs shall comply with the applicable parts of the Standard for Low Voltage Fuses, UL 248/CSA C22.2 No. 248series. Fuseholders used with these fuses shall comply with the corresponding parts of the Standard for Fuseholders, UL 4248/CSA C22.2 No. 4248 series.		P
19.10	For user replaceable fuses, a fuse replacement marking in accordance with 63.4 shall be 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 user replaceable fuses with special fusing characteristics such as time delay or breaking capacity are necessary, the type shall also be indicated. Information on proper fuse replacement of user replaceable fuses shall also be included in the instructions. See Section 65.		P
20	**Motors and Motor Controllers**		—
20.1	Electric motors shall comply with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, and Motors and Generators, CSA C22.2 No. 100, and shall be thermally protected and shall comply with:		P
	a) The Standard for Impedance Protected Motors, UL 1004-2, and Motors With Inherent Overheating Protection, CSA C22.2 No. 77;		P
	b) The Standard for Thermally Protected Motors, UL 1004-3, and Motors With Inherent Overheating Protection, CSA C22.2 No. 77; or		P
	c) The Standard for Electronically Protected Motors, UL 1004-7, and Motors With Inherent Overheating Protection, CSA C22.2 No. 77.		P

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Clause	Requirement + Test	Result - Remark	Verdict
20.2	Controls associated with the motor shall be in accordance with the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1/CSA C22.2 E60730-1. For e-Bikes and EPACs provided with a startup assistance function, the control for providing startup assistance shall require a voluntary and continuous action by the user to allow startup assistance, such as the use of a dead man switch.		P
20.3	In addition to the testing associated with the control of the motor in this standard, hazards associated with the motor control shall be included in the analysis required in Safety Circuits and Safety Analysis, Section 12.		P
21	**Operator Interface**		—
21.1	The operator interface shall be constructed such that the user will not have access to hazardous parts. If hazardous parts exist in the operator interface, then the operator interface shall comply with the requirements for enclosing hazardous parts in Section 13. Also, the interface shall comply with 21.2 and 21.3.		P
21.2	Touchscreens with high voltage backlights shall be evaluated as Limited Current Circuits in accordance with the Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1/CSA C22.2 60950-1.		P
21.3	Emergency control of the motor shall not require multiple commands by the user and shall not require the user to remove their hold on the handle bars.		P
22	**Grounding and Bonding**		—
22.1	**General**		N/A
22.1.1	For vehicles that are using a grounded system of protection to mitigate hazards associated with electric shock or electrical energy while charging, a means of extending the ground to the vehicle through a bonding conductor shall be provided.		N/A
22.1.2	The requirement in 22.1.1 applies for both on board chargers and off board chargers.		N/A
22.2	**Bonding connections**		N/A
22.2.1	For grounded systems, there shall be provision for bonding all dead metal parts of a vehicle to the main ground connection. This requirement applies to all dead metal parts that are exposed or that possess a risk of being contacted by a person during intended operation or adjustment and that are capable of becoming energized as a result of electrical malfunction.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
22.2.2	The bonding shall be by a positive means, such as by clamps, rivets, bolted or screwed connections, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455°C (850°F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.		N/A
22.2.3	An equipment-bonding terminal, or lead-bonding point, shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection. To reduce the risk of inadvertent loosening, the head of the screw or bolt shall not be accessible from outside of the enclosure.		N/A
22.2.4	An equipment-bonding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.		N/A
22.2.5	An equipment-bonding point shall be located so that the risk of inadvertently removing the bonding means during servicing is reduced.		N/A
22.2.6	An equipment-bonding lead shall be the same size as the grounding lead associated with the AC power source. The surface of the insulation shall be green.		N/A
22.2.7	For eBikes that are connected to NEMA 5-20R receptacles directly, the equipment-grounding conductor of a power-supply cord shall be connected to dead metal parts within the frame or enclosure by means of a screw, or stud and nut combination, or other equivalent means, not to be removed during ordinary servicing not involving the power-supply cord. The surface of any insulation on the grounding conductor shall be green with or without one or more yellow stripes and no other conductor shall be so identified. This connection can be part of a non-detachable cord that is part of the vehicle, or in the case of detachable cords, from the ground blade on the vehicle side connector.		N/A
22.2.8	An equipment-grounding conductor or equipment-bonding conductor shall not be spliced, nor shall it involve a trace on a printed wiring board.		N/A
22.2.9	A soldering lug, a connection means that depends on solder only, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used for equipment-grounding or equipment-bonding.		N/A
22.2.10	The equipment-grounding terminal or equipment-bonding terminal shall be capable of securing a conductor of a size intended for the application.		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
22.2.11	A terminal intended for the connection of an equipment-bonding conductor shall be identified by: a) Being marked "G", "GR", "GND", "Ground", "Grounding", or the like; or b) The grounding symbol illustrated in Figure 22.1 on or adjacent to the terminal or on a wiring diagram provided on the product.		N/A
	Figure 22.1 Symbol for equipment bonding connection 		N/A
23	**Chargers**		—
23.1	For eBikes and EPACs intended to be charged by an off board device, the off board device shall comply with one of the following:		P
	a) The Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202, and Power Supplies, CSA C22.2 No. 107.1;		P
	b) The Standard for Power Units Other Than Class 2, UL 1012, and Power Supplies, CSA C22.2 No. 107.1;		P
	c) The Standard for Class 2 Power Units, UL 1310, and Power Supplies With Extra Low Voltage Class 2 Outputs - General Instruction No. 1, CSA C22.2 No. 223;		P
	d) The Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1/CSA C22.2 No. 60950-1, along with the relevant Part 2 Standard as applicable; or		P
	e) The Standard for Electric Vehicle Supply Equipment, UL 2594/CSA C22.2 No. 280.		P
23.2	For off board chargers that comply with 23.1(c), no hazard exists at the output of the charger and requirements to mitigate a shock hazard or an energy hazard may be reduced as described in 8.3. Personnel protection in accordance with Section 10 is not required.		N/A
23.3	Off board chargers that comply with 23.1(a), (b), (d) or (e) are not necessarily limited at the output and the requirements for hazard mitigation apply. Personnel protection in accordance with Section 9 shall be provided. Further, off board devices that comply with 23.1(e) are required to be used with an onboard charger that converts the voltage from AC to DC to charge the battery. The on board charging circuits shall be evaluated for compliance with this Standard.		N/A
23.4	Chargers for lithium-ion battery systems shall have voltage, current, and temperature monitoring.		P
24	**Electrical Cables and Connectors Between the Vehicle and the Equipment**		—

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Clause	Requirement + Test	Result - Remark	Verdict
24.1	Cables that are used to connect the off board equipment to the eBike or EPAC shall be permanently connected to the charger or connected to the charger with a connector that complies with 24.2. The cable shall comply with the Standard for Flexible Cords and Cables, UL 62/CSA C22.2 No. 49, or with the Standard for Cord Sets and Power Supply Cords, UL 817, and Cord Sets and Power Supply Cords CSA C22.2 No. 21, and shall be suitably rated for the voltage and temperature it will be subjected to in the end use application and shall be sufficiently sized to conduct the anticipated current.		P
24.2	Connectors used to connect the off board equipment to the eBike or EPAC shall comply with the Standard for Plugs, Receptacles, and Couplers for Electric Vehicles, UL 2251/CSA C22.2 No. 282, or the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977, and Special Use Attachment Plugs, Receptacles and Connectors, CSA C22.2 No. 182.3. The connectors shall be suitably rated for the application.		P
25	**Supply Connections for E-Bikes and EPACs Connected Directly to the Source**		—
25.1	**General**		P
25.1.1	AC power shall be delivered to eBikes and EPACs that are connected directly to the source by connection to a NEMA 5-20R receptacle using a suitable power supply cord in accordance with 25.2.		P
25.1.2	The connection of the power supply cord to the eBike or EPAC shall be permanent and comply with the requirements in 25.2 – 25.4 or shall be made through the use of a connector that complies with the Standard for Plugs, Receptacles and Couplers for Electric Vehicles, UL 2251/CSA C22.2 No. 282, or through a connector that complies with the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977, and Special Use Attachment Plugs, Receptacles and Connectors, CSA C22.2 No. 182.3.		P
25.2	**Cord Connections**		P
25.2.1	For cord connected vehicles, flexible cords and attachment plugs shall be used for connection to the alternating current input circuit. The flexible cord shall comply with the Standard for Cord Sets and Power Supply Cords, UL 817, and Cord Sets and Power Supply Cords CSA C22.2 No. 21.		P

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Clause	Requirement + Test	Result - Remark	Verdict
25.2.2	The cord shall be type G, SEO, SO, STO, SJEO, SJO, SJTO, or W, or a cord that is equally serviceable. The flexible power cord shall terminate at the enclosure of the eBike or EPAC. The overall length of the power cord shall be measured from the face of the attachment plug to the point where it enters the enclosure and shall be a minimum of 1.8 meters (6 feet) and shall be no greater than 4.6 meters (15 feet).		P
25.2.3	A flexible power cord shall be rated for a voltage not less than the rated voltage of the equipment, and shall have a current rating not less than the current rating of the equipment.		P
25.2.4	The attachment plug of a supply cord shall have a current rating in accordance with 25.2.5 and have a voltage rating corresponding to the voltage rating of the equipment.		P
25.2.5	The current rating of an attachment plug for the alternating current input circuit shall not be less than 125 percent of the rated input current of the device.		P
25.2.6	The attachment plug shall be a grounding type attachment plug.		P
25.3	**Strain relief**	Use appliance inlet	P
25.3.1	Strain relief shall be provided on the flexible power cord to reduce the risk of mechanical stress being transmitted to terminals, splices, or interior wiring. See Pull Strain Relief Test in Section 57.2. A knot in the flexible power cord is not considered an acceptable form of strain relief.		P
25.3.2	A metal strain relief clamp or band provided in accordance with 25.3.1 shall be provided with auxiliary insulation over the cord if damage to the cord insulation results when the strain relief tests are conducted without auxiliary insulation.		P
25.3.3	Means shall be provided to prevent a flexible power cord from being pushed into the equipment through the cord entry hole if such displacement would:		P
	a) Result in mechanical damage to the cord		P
	b) Expose the cord to a temperature higher than that for which it is rated; or		P
	c) Reduce spacings below the acceptable minimum values.		P
	To determine compliance, the flexible power cord shall be tested in accordance with the Push-Back Strain Relief Test in Section 57.3.		P
25.3.4	Strain relief bushings shall comply with the Standard for Insulating Bushings, UL 635.		N/A
25.4	**Bushings**		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
25.4.1	At the point where the flexible power cord passes through an opening in a wall, barrier, or the enclosure, there shall be a bushing or the equivalent that is secured in place and that has a smooth, well-rounded surface against which the cord may bear. An insulating bushing shall be provided, if the wall or barrier is of metal, or if the construction is such that the cord may be subjected to strain or motion. The bushing shall comply with the requirements in the Standard for Insulating Bushings, UL 635, or shall meet the requirements for insulating materials in this Standard.		N/A
25.4.2	A hole in porcelain, phenolic composition, or other non-conducting material, having a smooth, rounded surface, is considered to be equivalent to a bushing.		N/A
25.4.3	A bushing of the same material as, and molded integrally with, a flexible power cord, is acceptable if the built up section is not less than 1.6 mm (1/16 inch) thick at the point where the cord passes through the enclosure.		N/A
25.4.4	At a point of flexure, no additional wires or cables shall be routed through a bushing or opening with the flexible power cord.		N/A
26	**Chargers**		—
26.1	For eScooters and eMotorcycles intended to be charged by an off board device, the off board device shall comply with one of the following:		P
	a) The Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202, and Power Supplies, CSA C22.2 No. 107.1.		P
	b) The Standard for Electric Vehicle Supply Equipment, UL 2594/CSA C22.2 No. 280.		P
27	**Electrical Cables and Connectors Between the Vehicle and the Equipment**		—
27.1	Cables that are used to connect the off board equipment to the eScooter or eMotorcycle shall be permanently connected to the off board device or connected to the charger with a connector that complies the Standard for Plugs, Receptacles, and Couplers for Electric Vehicles, UL 2251/CSA C22.2 No. 282. The cable shall comply with the Standard for Flexible Cords and Cables, UL 62/CSA C22.2 No. 49, and shall be suitably rated for the voltage and temperature it will be subjected to in the end use application and shall be sufficiently sized to conduct the anticipated current. SWAP SYSTEMS		P
28	**General**		—

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Clause	Requirement + Test	Result - Remark	Verdict
28.1	A swap system consists of a unit that houses batteries while they are recharged and allows the user to remove charged batteries from the swap station and install them on the vehicle while placing the discharged batteries from the vehicle back into the swap station. The swap station may be provided with a control panel, or interactive kiosk, for allowing the user to identify which battery to take, allowing the user to enter account information or provide payment, providing instructions to the user, and the like.		P
28.2	Swap stations are required to insure that hazardous parts are not accessible to the user in accordance with this standard and that batteries are not placed into or removed from the swap station while charging. This means that no make and break under load is intended at the swap station.		P
29	**Interactive Kiosks**		—
29.1	Any interactive kiosk provided as part of the swap system shall comply with the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1/CSA C22.2 No. 60950-1, along with the relevant part 2 standard as applicable.		N/A
30	**Chargers**		—
30.1	The off board device shall comply with one of the following:		N/A
	a) The Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202, and CSA C22.2 No. 107.1.		N/A
	b) The Standard for Power Units Other Than Class 2, UL 1012, and Power Supplies, CSA C22.2 No. 107.1.		N/A
	c) The Standard for Class 2 Power Units, UL 1310, and Power Supplies With Extra Low Voltage Class 2 Outputs - General Instruction No. 1, CSA C22.2 No. 223.		N/A
	d) The Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1/ CSA C22.2 No. 60950-1, along with the relevant Part 2 Standard as applicable.		N/A
31	**Supply Connections**		—
31.1	**General**		P
31.1.1	Except as indicated in 31.1.1.1, a permanently connected device shall have provision for connection of a wiring system. This provision shall consist of either wiring terminals as specified in 31.1.3 and 31.2 or wiring leads as specified in 31.1.3 and 31.3 and a means for connection of cable or conduit as specified in 31.5.		P

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Clause	Requirement + Test	Result - Remark	Verdict
31.1.1.1	The requirements described in 31.1.3 and 31.3.6 do not apply to the means for connection to accessible signal circuits.		P
31.1.2	The requirement in 31.1.3 and 31.1.1 applies to the wiring connection means for alternating current and direct current power circuits of a device. These connections are intended to be made in the field when the device is installed.		P
31.1.3	A wiring terminal or lead shall be used for the connection of a conductor having an ampacity based on Table 310.16 of the National Electrical Code, ANSI/NFPA 70.		P
31.2	**Wiring terminals**		P
31.2.1	A wiring terminal shall comply with the requirements in the Standard for Wire Connectors, UL 486A-486B/ CSA C22.2 No. 65, for wire of each metal that is intended to be used. For field wiring terminals, both copper and aluminum are considered to be intended unless the terminals are marked in accordance with 31.1.3 and 62.6.		P
31.2.2	Except as indicated in 31.2.2.1 and 31.2.2.2, a wiring terminal shall be provided with a pressure terminal connector of other than the crimping type and the terminal shall be securely fastened in place - for example, firmly bolted or held by a screw.		P
31.2.2.1	A pressure terminal connector, including a crimping type, may be field installed in accordance with 31.2.4.		P
31.2.2.2	A wire binding screw may be employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor where upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position.		P
31.2.3	Except as indicated in 31.2.3.1, a wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This shall be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method.		P
31.2.3.1	A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 31.2.4 may turn when the least spacing between adjacent terminals and also between terminals and dead metal parts complies with Spacings and Separation of Circuits, Section 16, for when connectors are oriented in such a position that results in these spacings.		P
31.2.4	As allowed per 31.2.2 and 31.2.3, a pressure terminal connector is not required to be provided when the conditions in (a) – (e) are complied with:		P

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Clause	Requirement + Test	Result - Remark	Verdict

	a) One or more component terminal assemblies shall be available from the device manufacturer or others, and they shall be specified in the instruction manual. See 65.3(f).		P
	b) The fastening hardware such as a stud, nut, bolt, spring, or flat washer, or similar part is mounted on or separately packaged with the device, or specified in the instruction manual.		P
	c) The installation of the terminal assembly shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.		P
	d) Where the pressure terminal connector provided in a terminal assembly requires the use of other than an ordinary tool for securing the conductor, the tool and any required instructions for using the tool shall be included with the device. See 65.3(h).		P
	e) Installation of the pressure terminal connector in the intended manner shall result in a device complying with the requirements of this Standard.		P
31.2.5	An insulating base for support of a pressure terminal connector shall be subjected to the Strength of Terminal Insulating Base and Support Test, 50.		P
31.2.6	Except as indicated in 31.2.6.1, a wire binding screw at a field wiring terminal shall not be smaller than No. 10 (4.8 mm diameter).		P
31.2.6.1	A No. 8 (4.2 mm diameter) screw being used at a terminal intended only for the connection of a 14 AWG (2.1 mm2) conductor, or a No. 8 or 6 (4.2 mm or 3.5 mm diameter) screw being used at a terminal intended for connection of a 16 or 18 AWG (1.3 or 0.82 mm2) control circuit conductor, is allowed.		P
31.2.7	A wire binding screw shall thread into metal.		P
31.2.8	Except as indicated in 31.2.8.1, a terminal plate tapped for a wire binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick.		P
31.2.8.1	A terminal plate less than 1.27 mm (0.050 inch) thick may be used in a low voltage, limited energy circuit when the tapped threads withstand the tightening torque specified in Table 31.1 without stripping.		P
	Table 31.1 Tightening torque for wire-binding screws		P

Size of terminal screw, number	Wire sizes to be tested [a]		Tightening torque	
	mm^2	AWG	Newton meters	(Pound-inches)
6	1.31 – 0.824 (ST)	16 – 18 (ST)	1.4	(12)
8	2.08 (S) and 1.31 – 0.824 (ST)	14 (S) and 16 – 18 (ST)	1.8	(16)
10	5.26 – 2.08 (S) and 1.31 – 0.824 (ST)	10 – 14 (S) and 16 – 18 (ST)	2.3	(20)

[a] ST – stranded wire; S – solid wire.

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Clause	Requirement + Test	Result - Remark	Verdict
31.2.9	There shall be two or more full threads in the metal of a terminal plate. When the metal is extruded at the tapped hole, at least two full threads shall be provided.		P
31.2.10	A terminal for connection of a grounded conductor of an alternating current power circuit shall be identified as described in 62.7.		P
31.3	**Field wiring leads**		P
31.3.1	Except as indicated in 31.3.1.1, a field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is connected, and shall not be smaller than 18 AWG (0.82 mm^2), for example, a 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a 6 AWG (13.3 mm^2) field-provided conductor. A field-wiring lead shall not be less than 152.4 mm (6 inches) long.		P
	31.3.1.1 An 18 AWG (0.82 mm^2) size field wiring lead may be used for connection to a 12 AWG (3.3 mm^2) size branch circuit conductor.		P
31.3.2	A field wiring lead shall consist of general building wire, or other wiring where it has an insulation of:		P
	a) At least 0.8 mm (1/32 inch) thick thermoplastic material;		P
	b) At least 0.4 mm (1/64 inch) thick rubber plus a braid cover for applications of 300 V or less; or		P
	c) At least 0.8 mm (1/32 inch) thick rubber plus a braid cover for applications between 301 and 600 volts.		P
31.3.3	A field wiring lead shall be subjected to the test specified in 57.2.		P
31.3.4	A field wiring lead provided for connection to an external line voltage circuit shall not be connected to a wire binding screw or pressure terminal connector located in the same compartment as the free end of the wiring lead unless the screw or connector is rendered unusable for field wiring connection or the lead is insulated at the unconnected end, and a marking is provided on the device in accordance with 62.8.		P
31.3.5	The free end of a field wiring terminal that is not used in every installation, such as a tap for a multivoltage transformer, shall be insulated.		P
31.3.6	A field wiring lead for connection of a grounded conductor shall be identified as described in 62.7.		P
31.4	**Wiring compartments**		P
31.4.1	A wiring compartment on a fixed device shall be located so that wire connections therein are accessible for inspection, without disturbing either factory or field connected wiring, after the device is installed in the intended manner.		P
31.4.2	Wiring compartments, raceways, or similar devices for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that are capable of damaging conductor insulation.		P

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Clause	Requirement + Test	Result - Remark	Verdict
31.5	**Openings for conduit or cable connection**		P
31.5.1	For a permanently connected device, openings for wiring and conduit shall comply with the requirements specified in 31.5.2 – 31.5.10.		P
31.5.2	Enclosures shall be designed for use with appropriate conductor entry provisions to maintain the specified environmental capability of the particular enclosure type being evaluated.		P
31.5.3	When threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or when an equivalent construction is employed, there shall not be less than three nor more than five threads in the metal, and the construction of the enclosure shall be such that a conduit bushing is capable of being attached as intended. When threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or similar material there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors equivalent to that provided by a standard conduit bushing with an internal diameter the same as that of the corresponding trade size of rigid conduit.		P
31.5.4	Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and similar material that are supplied as a part of an enclosure shall comply with the Standard for Metallic Outlet Boxes, UL 514A/CSA C22.2 No. 18.1, and the Standard for Conduit, Tubing and Cable Fittings, UL 514B/CSA C22.2 No. 18.3.		P
31.5.5	A knockout in a sheet-metal enclosure shall be secured and shall be removable without undue deformation of the enclosure.		P
31.5.6	A knockout shall be provided with a flat surrounding surface so that the conduit bushing is capable of being seated as intended, and shall be located so that installation of a bushing at any knockout to be used during installation does not result in spacing between an uninsulated live part and the bushing to be less than that specified in Spacings and Separation of Circuits, Section 16.		P
31.5.7	In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 31.5.6, it shall be assumed that a bushing having the dimensions specified in Table 31.2 is in place, in conjunction with a single locknut installed on the outside of the enclosure.		P

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Clause	Requirement + Test	Result - Remark	Verdict

Table 31.2 Knockout or hole sizes and dimensions of bushings

Metric designator (Trade size)	Knockout or hole diameter		Bushing dimensions			
			Overall diameter		Height	
mm (inches)	mm	(inches)	mm	(inches)	mm	(inches)
16 (1/2)	22.2	(7/8)	25.4	(1)	9.5	(3/8)
21 (3/4)	27.8	(1-3/32)	31.4	(1-15/64)	10.7	(27/64)
27 (1)	34.5	(1-23/64)	40.5	(1-19/32)	13.1	(33/64)
35 (1-1/4)	43.7	(1-23/32)	49.2	(1-15/16)	14.3	(9/16)
41 (1-1/2)	50.0	(1-31/32)	56.0	(2-13/64)	15.10	(19/32)
53 (2)	62.7	(2-15/32)	68.7	(2-45/64)	15.9	(5/8)
63 (2-1/2)	76.2	(3)	81.8	(3-7/32)	19.1	(3/4)
78 (3)	92.1	(3-5/8)	98.4	(3-7/8)	20.6	(13/16)

P

	31.5.8 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings and Separation of Circuits, Section 16, shall be provided between uninsulated live parts and a conduit bushing installed at any location that shall be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the device are ways to specify such a location. The specified location of the openings shall be such that damage to internal parts does not result when openings are made.		P
31.5.9	With respect to the requirement in 31.5.8, means shall be provided so that an opening for conduit is capable of being made without subjecting internal parts to contamination resulting from the presence of metallic particles. Compliance with this requirement is possible by the use of a removable, bolted plate.		P
31.5.10	A polymeric- or metal-closure plug for an unused conduit opening shall comply with the requirements in the Standard for Metallic Outlet Boxes, UL 514A/CSA C22.2 No. 18.1, and shall maintain the specified environmental capability of the enclosure in accordance with 31.5.2.		P
31.6	**Wire bending space**		P
31.6.1	A permanently connected device employing pressure terminal connectors for field connection of circuits described in 31.1.2 shall be provided with space within the enclosure as specified in 31.6.3 – 31.6.7 for the installation of conductors, including grounding conductors that are employed in the installation.		P
31.6.2	The conductor size used in judging the wiring space shall be based on the use of a conductor sized in accordance with 31.1.3.		P
31.6.3	Wire bending space for field installed conductors shall be provided opposite any pressure wire connector as specified in 31.6.4 or 31.6.5 and opening or knockout for a wireway or conduit in a gutter as specified in 31.6.9.		P

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Clause	Requirement + Test	Result - Remark	Verdict

31.6.4	When a conductor is capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 31.3. A wire is capable of entering or leaving a top, back, bottom, or side surface when there is an opening for conduit or a wireway.		P

Table 31.3 Minimum wire-bending space for conductors through a wall opposite terminals in mm (inches)

Wire size AWG or kcmil	Wire size mm²	Wires per terminal (pole)[a] 1		2			3			4 or more		
14 –10 AWG	2.1 – 5.3	Not Specified		–			–			–		
8	8.4	38.1	(1-1/2)	–			–			–		
6	13.3	50.8	(2)	–			–			–		
4	21.1	76.2	(3)	–			–			–		
3	26.7	76.2	(3)	–			–			–		
2	33.6	88.9	(3-1/2)	–			–			–		
1	42.4	114	(4-1/2)	–			–			–		
0	53.5	140	(5-1/2)	140			179		(7)	–		
2/0	67.4	152	(6)	152			191		(7-1/2)	–		
3/0	85.0	165	(6-1/2)	165	12.7	(6-1/2)	203		(8)	–		
4/0	107	179	(7)	191	38.1	(7-1/2)	216	12.7	(8-1/2)	–		
250 kcmil	127	216	(8-1/2)	216	50.8	(8-1/2)	229	25.4	(9)	254		(10)
300	152	254	(10)	254	50.8	(10)	279	25.4	(11)	305		(12)
350	177	305	(12)	305	76.2	(12)	330	76.2	(13)	355	50.8	(14)
400	203	330	(13)	330	76.2	(13)	355	76.2	(14)	381	76.2	(15)
500	253	355	(14)	355	76.2	(14)	381	76.2	(15)	406	76.2	(16)
600	304	381	(15)	406	76.2	(16)	457	76.2	(18)	483	76.2	(19)
700	355	406	(16)	457	76.2	(18)	508	76.2	(20)	559	76.2	(22)
750	380	432	(17)	483	76.2	(19)	559	76.2	(22)	610	76.2	(24)
800	405	457	(18)	508		(20)	559		(22)	610		(24)
900	456	483	(19)	559		(22)	610		(24)	610		(24)
1000	507	508	(20)	–			–			–		
1250	633	559	(22)	–			–			–		
1500	760	610	(24)	–			–			–		
1750	886	610	(24)	–			–			–		
2000	1013	610	(24)	–			–			–		

Note – The table includes only those multiple-conductor combinations that are used. Combinations not specified shall be further evaluated.

[a] Wire bending space is not prohibited from being reduced by the number of inches shown in brackets under the following conditions:

1) Only removable or lay-in wire connectors receiving one wire each are used (more than one removable wire connector per terminal is possible) and

2) The removable wire connectors are removed from their intended location without disturbing structural or electrical parts other than a cover, and are installed with the conductor in place.

P

31.6.5	Where a conductor is not capable of entering or leaving the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 31.4. The wire bending space is in accordance with Table 31.4 when a barrier is provided between the connector and the opening, or drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector. See illustrations A, B, and C of Figure 31.1.		P

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Clause	Requirement + Test	Result - Remark	Verdict

Table 31.4 Minimum width of gutter and wire-bending space for conductors through a wall not opposite terminals in mm (inches)

Wire size		Wires per terminal (pole)									
AWG or kcmil	mm²	1		2		3		4		5	
14 – 10 AWG	2.1 – 5.3	Not Specified	–	–		–		–		–	
8 – 6	8.4 – 13.3	38.1	(1-1/2)	–		–		–		–	
4 – 3	21.1 – 26.7	50.8	(2)	–		–		–		–	
2	33.6	63.5	(2-1/2)	–		–		–		–	
1	42.4	76.2	(3)	–		–		–		–	
1/0 – 2/0	53.5 – 7.4	88.9	(3-1/2)	127	(5)	178	(7)	–		–	
3/0 – 4/0	85.0 – 107	102	(4)	152	(6)	203	(8)	–		–	
250 kcmil	127	114	(4-1/2)	152	(6)	203	(8)	254	(10)	–	
300 – 350	152 – 177	127	(5)	203	(8)	254	(10)	305	(12)	–	
400 – 500	203 – 253	152	(6)	203	(8)	254	(10)	305	(12)	356	(14)
600 – 700	304 – 355	203	(8)	254	(10)	305	(12)	356	(14)	406	(16)
750 – 900	380 – 456	203	(8)	305	(12)	356	(14)	406	(16)	457	(18)
1000 – 1250	507 – 633	254	(10)	–		–		–		–	
1500 – 2000	760 – 1010	305	(12)	–		–		–		–	

NOTE – The table includes only those multiple-conductor combinations that are frequently used. Combinations not specified shall be further evaluated.

P

31.6.6	When a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance shall be measured from the end of the barrier. See illustration D of Figure 31.1.		P
31.6.7	For a device not provided with a conduit opening or knockout, the minimum wiring bending space mentioned in 31.6.4 – 31.6.6 shall be based on any enclosure wall capable of being used for installation of the conduit, or only specific walls that are to be used as determined by a marking, drawing, or template furnished with the device.		P
31.6.8	The distance mentioned in 31.6.3 – 31.6.5 shall be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. See illustrations A - C of Figure 31.1. The wire terminal shall be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it is capable of assuming without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or similar part. A barrier, shoulder, or similar part shall be disregarded where the measurement is being made when it does not reduce the radius to which the wire must be bent. Where a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance shall be measured from the wire opening closest to the wall of the enclosure. As an alternate, the requirements of 31.6.6 may be used.		P

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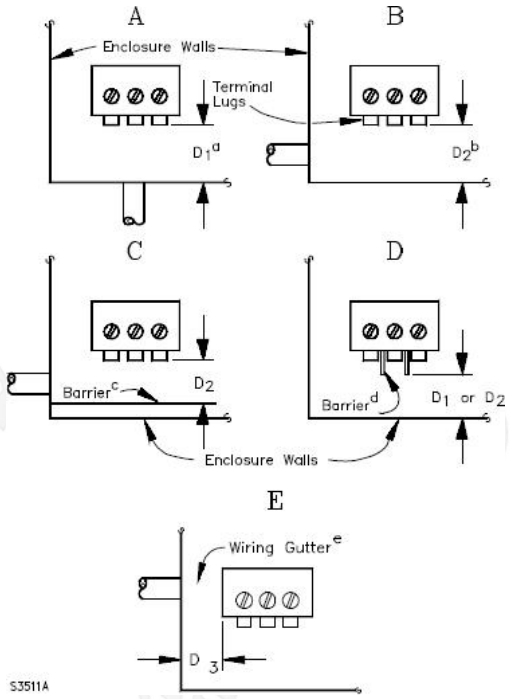
Clause	Requirement + Test	Result - Remark	Verdict
31.6.9	Except as indicated in 31.6.9.1, the width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to bending) conductors of the maximum size that are used at that knockout. The values of the minimum required width of a wiring gutter, with respect to conductors entering a knockout, are the same as the values of minimum required bending space given in Table 31.3. See illustration E of Figure 31.1.		P
	Figure 31.1 Wire bending space 		P
31.6.9.1	The wiring space is not required to be of this width when knockouts are provided elsewhere that are in compliance with these requirements, the wiring space at such other point or points is of a width that accommodates the conductors in question, and the knockout or knockouts at such other points are used in the intended wiring of the device. CHARGING RACKS		P
32	**General**		—
32.1	Charging racks shall meet the requirements of this Standard for all products. Additionally, charging racks shall be subjected to the requirements of Sections 33 through 36.		N/A
33	**Interactive Kiosks**		—
33.1	Any interactive kiosk provided as part of a charging rack system shall comply with the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1/CSA C22.2 No. 60950-1, along with the relevant part 2 standard as applicable.		N/A
34	**Chargers**		—

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
34.1	The off board device shall comply with one of the following:		P
	a) The Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202, and Power Supplies, CSA C.22.2 No. 107.1.		P
	b) The Standard for Power Units Other Than Class 2, UL 1012, and Power Supplies, CSA C.22.2 No. 107.1.		P
	c) The Standard for Class 2 Power Units, UL 1310, and Power Supplies With Extra Low Voltage Class 2 Outputs - General Instruction No. 1, CSA C22.2 No. 223.		P
	d) The Standard for Information Technology Equipment - Safety - Part 1: General Requirements, UL 60950-1/CSA C22.2 No. 60950-1, along with the relevant Part 2 Standard as applicable.		P
35	**Electrical Cables and Connectors Between the Vehicle and the Equipment**		—
35.1	Cables that are used to connect the off board equipment to the eBike or EPAC shall be permanently connected to the charger or connected to the charger with a connector that complies with 35.2. The cable shall comply with the Standard for Flexible Cord and Cable, UL 62/CSA C22.2 No. 49, or with the Standard for Cord Sets and Power Supply Cords, UL 817, and Cord Sets and Power Supply Cords, CSA C22.2 No. 21, and shall be suitably rated for the voltage and temperature it will be subjected to in the end use application and shall be sufficiently sized to conduct the anticipated current.		P
35.2	Connectors used to connect the off board equipment to the eBike or EPAC shall comply with theStandard for Plugs, Receptacles, and Couplers for Electric Vehicles, UL 2251/CSA C22.2 No. 282, or the Standard for Component Connectors for Use in Data, Signal, Control and Power Applications, UL 1977, and Special Use Attachment Plugs, Receptacles and Connectors, CSA C22.2 No. 182.3. The connectors shall be suitably rated for the application. Connectors operated within LVLE circuits do not require evaluation.		P
36	**Supply Connections**		—
36.1	Supply connections shall be in accordance with Section 31.		P
	PERFORMANCE ALL PRODUCTS		P
37	**General**		—
37.1	The performance tests are to be conducted on representative samples of the product as appropriate.		P
37.2	Testing is to be conducted at any ambient temperature between 5°C (41°F) and 35°C (95°F).		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
37.3	Unless indicated otherwise, batteries are to be fully charged to the maximum operating state of charge in accordance with the manufacturer's specifications. After charging and prior to testing, the batteries are to be allowed to rest for a maximum period of 8 hours at room ambient.		P
37.4	Tests may be conducted on a test track, a bench or a test stand, which keeps the driven wheel free of the ground.		P
37.5	If conducted on a test track, the wind speed is to not exceed 3 m/s (6.7 mph).		P
37.6	In all cases, worst case conditions of gear ratio and speed are to be selected.		P
37.7	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 surface of at least one cell/module within the device are to be monitored during the test for safety and information purposes. All personnel involved in the testing are to be instructed to never approach the test unit until temperatures are falling and have returned to within ambient temperatures.		P
37.8	Unless noted otherwise in the individual test methods, the tests shall be followed by a 1-h observation time prior to concluding the test and temperatures are to be monitored.		P
37.9	Products that are operational after tests associated with the battery shall be subjected to a minimum of one cycle of charging and discharging in accordance with the manufacturer's specifications to determine that there is no fire, explosion, rupture, electrolyte leakage, or shock hazard associated with the stressed battery.		P
38	**Input Test**		—
38.1	The input current to a product is to be measured with the unit operating while charging a fully discharged battery. The current input shall not be more than 110 percent of the rated current value for the vehicle as assigned by the manufacturer.		P
39	**Temperature Test**		—

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Clause	Requirement + Test	Result - Remark	Verdict
39.1	The Temperature test shall be conducted to determine whether or not the temperature sensitive safety critical components and temperature sensitive materials in the vehicle components are being maintained within their temperature ratings and that temperatures on accessible surfaces, which may be contacted by the user are within acceptable limits. Additionally, this test is conducted to determine whether or not the component cells are being maintained within their specified operating limits during maximum charge and discharge conditions of the vehicle.		P
39.2	The test is to be performed using two methods. The battery charging circuit and battery are tested in accordance with 39.3 – 39.7, and the vehicle system is tested in accordance with 39.8.		P
39.3	First, a fully discharged battery pack is to be conditioned within a chamber set to the upper limit charging temperature specifications of the vehicle manufacturer. After thermal stabilization in the chamber, the battery pack is to be connected to a charging circuit input representative of anticipated maximum charging parameters provided by the specified charger. The battery pack shall then be subjected to maximum normal charging while monitoring voltages and currents on cells until it reaches the manufacturer's specified fully charged condition. Temperatures shall be monitored on temperature sensitive components including cells, enclosure, and all parts within the charging circuit that are temperature sensitive, including any user accessible surfaces.		P
39.4	While still in the conditioning chamber, and after allowing temperatures to stabilize, the fully charged battery pack shall then be discharged in accordance with the manufacturer's specifications representative of maximum weight and operating conditions for loading down to the manufacturer's specified end of discharge condition while monitoring voltage and current on cells until the battery pack reaches its specified end of discharge voltage (EODV). Temperatures shall be monitored on temperature sensitive safety critical components including cells, enclosure, and all parts within the charging circuit that are temperature sensitive, including any user accessible surfaces.		P
39.5	The charge and discharge cycles are then repeated for a total of 2 complete cycles of charge and discharge. The test is then repeated with the representative unit in a chamber set to the vehicle manufacturer's lowest specified operating ambient for 2 complete cycles of charge and discharge.		P

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Clause	Requirement + Test	Result - Remark	Verdict

39.6	During the temperature test, the voltage and current during discharge and charging of the component cells is monitored to determine that they are not outside of the specified cell manufacturer's operating region.		P
39.7	The manufacturer's specified limits (voltage, current and temperatures measured) shall not be exceeded during the charging and discharging cycles. Temperatures measured on components shall not exceed their specifications. See Tables 39.1 and 39.2 for surface and component temperature limits.		P
39.8	The vehicle shall be powered from a power source used to represent a battery pack. The vehicle system is then operated at the maximum load on the motor continuously until thermal stabilization. See 39.10.		P
39.9	Temperatures shall be monitored on all temperature sensitive components, enclosures, and user accessible surfaces. Temperatures measured on components shall not exceed their specifications. See Tables 39.1 and 39.2 for surface and component temperature limits.		P

Table 39.1 Temperatures on components — P

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 casings	[b]
Motor Windings[c]:	
• Insulation Class A (open motor)	65 (149)
• Insulation Class A (totally enclosed motor)	70 (158)
• Insulation Class B (open motor)	85 (185)
• Insulation Class B (totally enclosed motor)	90 (194)
• Insulation Class F (open motor)	110 (230)
• Insulation Class F (totally enclosed motor)	115 (239)

[a] The temperatures measured on components and materials shall not exceed the maximum temperature rating for that component or material.
[b] The internal cell case temperature shall not exceed the manufacturer's recommended maximum temperature.
[c] The temperature limits are based upon thermocouple measurements.

Table 39.2 Temperatures on user accessible surfaces — P

Accessible surfaces	Maximum surface temperatures		
	Metal °C (°F)	Glass, porcelain and vitreous materials °C (°F)	Plastic and rubber[a] °C (°F)
Handles, knobs, grips, etc., continuously held in normal use	55 (131)	65 (149)	75 (167)
Handles, knobs, grips, etc., held or touched for short periods only	60 (140)	70 (158)	85 (185)
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)

[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;

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

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Clause	Requirement + Test	Result - Remark	Verdict
39.10	A temperature is determined to be stabilized when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no increase greater than 2°C (4°F).		P
39.11	At the conclusion of this test, the battery pack tested under the battery method is placed back into the vehicle system. Any hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 40, (without humidity conditioning) or a Dielectric Strength Test, Section 41.		P
39.12	As a result of this test, in addition to temperatures remaining below the limits, there shall be no indication of fire, explosion, rupture, electrolyte leakage or electric shock.		P
40	**Isolation Resistance Test**		—
40.1	This test is intended to determine that insulation of the vehicle system provides adequate isolation of hazardous voltage circuits from accessible conductive parts of the vehicle system and that the insulation is non-hygroscopic. The measured insulation resistance between the positive terminals and accessible parts of the vehicle shall be at least 50,000 Ω.		P
40.2	A vehicle system with accessible parts shall be subjected to an insulation resistance test between the positive terminal and accessible dead metal parts of an vehicle system. If the accessible parts of the vehicle system are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts as shown in 41.5 and Figure 41.1.		P
40.3	The insulation resistance shall be measured after a 60-s application with a high resistance voltmeter using a 500 V dc potential applied for at least 1 minute to the locations under test.		P
40.4	The test shall be repeated on a representative unit subjected to humidity conditioning in accordance with Section 42. Measurements shall be made with the unit still in the chamber.		P
41	**Dielectric Strength Test**		—
41.1	This test is an evaluation of the electrical spacings and insulation at hazardous voltage circuits within the vehicle system. 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 a dielectric breakdown (i.e. insulation breakdown).		P

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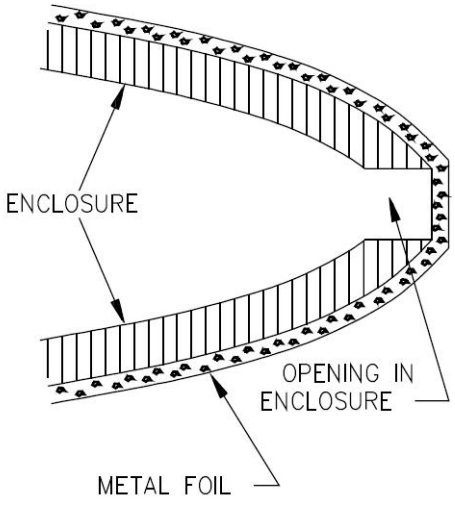
Clause	Requirement + Test	Result - Remark	Verdict
41.2	Circuits at 60 Vdc or higher shall be subjected to a dielectric withstand voltage consisting of a dc potential of twice the rated voltage times 1.414. Semiconductors or similar electronic components liable to be damaged by application of the test voltage may be bypassed or disconnected.		P
41.3	The test voltage is to be applied between the hazardous voltage circuits of the vehicle system and non-current carrying conductive parts that may be accessible.		P
41.4	The test voltage is also to be applied between the hazardous voltage charging circuit and the enclosure/accessible non-current carrying conductive parts of the vehicle system.		P
41.5	If the accessible parts of the vehicle system are covered with insulating material that may become live in the event of an insulation fault, then the test voltages are applied between each of the live parts and metal foil in contact with the accessible parts. The metal foil shall be wrapped tightly around and in intimate contact with the accessible part. The foil is to be drawn tightly across any opening in the enclosure or other accessible parts to form a flat plane across such opening. See Figure 41.1.		N/A
41.6	The test voltages shall be applied for a minimum of 1 minute with the cells/modules disconnected to prevent charging during application of the voltage.		P
	Figure 41.1 Method of covering enclosures with foil for measurement and tests  		P

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Clause	Requirement + Test	Result - Remark	Verdict
41.7	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 an ac test method and 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 may not be indicative of insulation breakdown.		P
42	**Humidity Conditioning**		—
42.1	A product shall comply with the requirements for the Dielectric Strength Test, Section 41, and/or the Isolation Resistance Test, Section 40, following exposure to air having a relative humidity of 88 ±2 percent at a temperature of 32 ±2°C (90 ±4°F).		P
42.2	To determine whether a unit complies with the requirement in 42.1, a representative unit is to be heated to a temperature just above 34°C (93°F) to reduce the risk of condensation of moisture during conditioning. The heated unit is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 42.1. Immediately following the conditioning, the unit is to be removed from the humidity chamber and tested as described in 42.1.		P
43	**Normal Charging Test**		—
43.1	Charging a lithium-ion battery under normal conditions shall not exceed the specified operating region for charging of the cell.		P
43.2	Compliance with 43.1 is checked by the following tests in 43.3 – 43.7.		P
43.3	The battery is charged in accordance with the charging system instructions starting with a fully discharged battery. Testing is carried out at an ambient temperature of 20 ±5°C (68 ±9°F) and:		P
	a) If the product is recommended to be operated at a minimum temperature lower than 0°C (32°F), the test is also conducted at that minimum temperature plus 0/minus 5 °C (plus 0/minus 9 °F); or		N/A
	b) If the product is recommended to be operated at a maximum temperature greater than 40°C (104°F), the test is also conducted at that maximum temperature plus 5/minus 0 °C (plus 9/minus 0 °F).		N/A

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Clause	Requirement + Test	Result - Remark	Verdict
43.4	All individual cell voltages, temperatures and the charging current (or multiple current measurements as in the case of parallel configurations unless analysis makes this unnecessary) are monitored. Cells shall not experience conditions outside their specified operating region for charging (e.g. limits of voltage and current). Below is an example result of such analyses. The charging current for each branch of a parallel connection would not need to be monitored, if the maximum deliverable current of the charger did not exceed the maximum charging current of a single cell.		P
43.5	For batteries employing series configurations, the test is repeated with a deliberately imbalanced battery. The imbalance is introduced into a fully discharged battery by charging one cell to approximately 50 percent of full charge.		P
43.6	With reference to 43.5, if it can be demonstrated through testing and/or design evaluation that an imbalance less than 50 percent would actually occur in normal use, then this lower imbalance may be used. See examples of testing and design in items (a) and (b) below.		P
	a) An example for testing is repeated charging and discharging a battery in accordance with the manufacturer's instructions until its capacity has decreased to 80 percent of the rated capacity, using the imbalance at the end of the test.		P
	b) Those designs that employ circuitry intended for maintaining balance between cells in the battery pack. Systems with a small number of cells in series may be shown to exhibit limited imbalance in practice, if the product ceases to operate with a battery prepared with a smaller initial imbalance.		P
43.7	Battery systems intended for use with power packs which may be left on, such as flashlights and fans shall additionally be tested with their battery discharged by allowing the appliance to remain on for at least 12 hours prior to recharging.		P
44	**Lithium Charging System Test**		—
44.1	A sample of the product subjected to this test shall be considered to comply with this test provided none of the following has occurred: a) There has been no explosion during this test; or b) No charring or burning of the medical gauze, cheesecloth or tissue paper has resulted; or		P
	c) The cells shall not have exceeded the upper limit charging voltage by more than 150 mV or, if they have, then the charging system shall be permanently disabled from recharging the battery.		P

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Clause	Requirement + Test	Result - Remark	Verdict
44.2	With reference to 44.1(b), charring is defined as a blackening of the medical gauze or cheesecloth caused by combustion. Discoloration of the medical gauze or cheesecloth caused by smoke is acceptable. Charring or igniting of the tissue paper, cheesecloth, or medical gauze from the shorting means in not considered a failure.		P
44.3	With reference to 44.1(c), to determine if recharging is disabled, the battery shall be discharged by using the product to approximately a 50 percent charge, followed by an attempt to recharge the battery normally. There shall be no charging current after 10 minutes or after 25 percent of the nominal capacity has been delivered, whichever occurs first.		P
44.4	A sample of the product is placed on a soft wood surface covered by two layers of tissue paper; the sample is covered by one layer of untreated 100 percent cotton medical gauze or cheesecloth. The sample is operated as specified in the operating instructions with all of the categories of abnormal conditions listed below in (a) - (d). The cumulative stress resulting from successive tests on electronic circuits or the battery is to be avoided. Additional samples may be used as necessary. There shall be no evidence of damage to the cell vent.		P
	a) Components in the charging circuit are faulted as described in 44.6, one at a time, if the outcome of such a fault is uncertain based upon analysis. For each fault condition introduced, the state of the battery before charging is as follows: 1) A series configured battery shall have a deliberate imbalance. The imbalance is introduced into a fully discharged battery by charging one cell to approximately 50 percent of full charge; 2) If the test of Normal Charging of Lithium-ion Systems, Section 43 is conducted with an imbalance of less than 50 percent, a series configured battery shall have a deliberate imbalance as established in 44.6; or 3) A single cell or parallel only configuration battery shall be fully discharged.		P
	b) If the test of Normal Charging of Lithium-ion Systems, Section 43 is conducted with an imbalance of less than 50 percent due to the function of circuit(s), and if a single fault of any component within that circuit(s) is shown to result in the loss of that function, then a series configured battery shall be charged with a deliberate imbalance. The imbalance is introduced into a fully discharged battery by charging one cell to approximately 50 percent of full charge.		P
	c) For a battery with a series configuration, all cells are at approximately 50 percent charge except for one which is shorted. The battery is then charged.		P

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Clause	Requirement + Test	Result - Remark	Verdict
	d) With a fully charged battery connected to the charger, a short is introduced to the charging system across a component or between adjacent PCB tracks at a location expected to produce the most unfavorable results to evaluate the effect of back-feed from the battery. For a charger with a cord that connects to the battery, the short shall be introduced at the point likely to produce the most adverse effects. The resistance of the short shall not exceed 10 mΩ.		P
44.5	During the tests of 44.4, each cell voltage is continuously monitored to determine if it has exceeded the limit conditions. Venting of the cells is permitted. The test is continued until the sample under test experiences a failure as described in 44.1, returns to room temperature or, if neither of these, until at least 7 hours or twice the normal charging period has elapsed, whichever is longer.		P
44.6	Fault conditions for components as required by 44.4 are as follows:		P
	a) Open-circuit at the terminal of any component;		P
	b) Short-circuit of capacitors, unless they are certified EMI capacitors;		P
	c) Short-circuit of any two terminals of an electronic component, other than a monolithic integrated circuit. This fault is not applied between the two circuits of an optocoupler;		P
	d) Failure of triacs in the diode mode; and		P
	e) Failure of a monolithic integrated circuit or other circuits that cannot be assessed by the fault conditions (a) - (d). All possible output signals are considered under fault conditions within the integrated circuit. Components such as thyristors and triacs are not subjected to this fault condition.		P
45	**Abnormal Operations Tests**		—
45.1	**General**		P
45.1.1	A unit shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons when subjected to the tests specified in 45.2 – 45.6. Separate representative units are to be used for conducting these tests, unless requested otherwise by the manufacturer.		P
45.1.2	Following each test, any hazardous voltage circuits shall be subjected to an Isolation Resistance Test, Section 40, (without humidity conditioning) or a Dielectric Strength Test, Section 41.		P
45.1.3	A risk of fire, electric shock, or injury to persons exists when:		P
	a) Flame, burning oil, or molten metal is emitted from the enclosure of the unit as evidenced by ignition, glowing, or charring of the cheesecloth or tissue paper;		P

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Clause	Requirement + Test	Result - Remark	Verdict
	b) The insulation breaks down when tested in accordance with Section 41 or live parts are made accessible to the probe in Figure 18.1;		P
	c) Cracking, rupturing, or bursting of the battery case or cover, where such damage results in user contact with battery electrolyte; or		P
	d) Explosion of the battery supply where such explosion results in a risk of injury to persons.		P
45.1.4	During these tests the unit is to be placed on a softwood surface covered with a white tissue paper and a single layer of cheesecloth is to be draped loosely over the entire enclosure. The cheesecloth is to be untreated cotton cloth running 14 - 15 yards per pound (26 - 28 m2/kg), and having, for any square inch, a count of 32 threads in one direction and 28 in the other direction.		P
45.1.5	The supply circuit is to have branch circuit overcurrent protection, the size of which equals 125 percent of the input current rating (20-ampere minimum), except where this value does not correspond with the standard rating of a fuse or circuit breaker, the next higher standard device rating shall be used. The test voltage and frequency are to be adjusted to the rated values.		P
45.1.6	The enclosure of the unit is to be connected directly to ground.		P
45.1.7	Each test is to be continued until further change as a result of the test condition is reduced significantly. When an automatically reset protector functions during a test, the test is to be continued for 7 hours. When a manual reset protector functions during a test, the test is to be continued until the protector is operated for 10 cycles using the minimum resetting time, and not faster than 10 cycles of operation per minute. The following are examples of test terminations:		P
	a) Opening or shorting of one or more components such as capacitors, diodes, resistors, solid state devices, printed wiring board traces, or similar devices;		P
	b) Opening of the intended branch circuit overcurrent protection device described in 45.1.5 – see 45.1.10; and		P
	c) Opening of an internal fuse.		P
45.1.8	When the manually reset protector is a circuit breaker that complies with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489/CSA C22.2 No. 5, it is to be operated for 3 cycles using the minimum resetting time and not faster than 10 cycles of operation per minute.		P
45.1.9	A manual reset protector that becomes inoperative in the open condition shall be operated between 10 cycles and 3 cycles.		P

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Clause	Requirement + Test	Result - Remark	Verdict
45.1.10	With reference to 45.1.7(b), when the branch circuit overcurrent protection device terminates the test, the instruction manual shall contain the information specified in 65.3(i).		P
45.2	**Overcharging test**		P
45.2.1	Products shall withstand abusive overcharging without risk of fire or explosion when tested in accordance with 45.2.2.		P
45.2.2	The battery is placed on a soft wood surface covered by two layers of tissue paper and the sample is covered by one layer of untreated 100 percent cotton medical gauze and charged at a rate of 10 times the manufacturer's recommended rate for the battery for 1.25 hours or at the maximum output that is available from an external source provided with the pack. There shall be no explosion and no charring or burning of the gauze or tissue paper. Charring is defined as a blackening of the gauze caused by combustion. Discoloration of the gauze caused by smoke is acceptable. Venting of the cells is acceptable.		P
45.3	**Component fault tests**		P
45.3.1	A component, such as a capacitor, diode, solid state device, or similar device, connected in the input and output power circuits are to be short- or open-circuited, any two terminals one at a time, during any condition of operation including start-up. This test is not required:		P
	a) Where circuit analysis indicates that no other component or portion of the circuit is overloaded;		P
	b) For electromagnetic radio frequency interference capacitors subjected to the dielectric strength test across their terminals in accordance with Section 41; and		P
	c) For resistors, transformers, inductors, and optical isolators.		P
45.4	**Forced ventilation/blocked ventilation**		P
45.4.1	A unit having forced ventilation is to be operated with the rotor of a blower motor or fan locked. For a unit having more than one blower motor or fan, the test is to be conducted with the rotor of each blower motor or fan locked, one at a time, unless agreeable to all for which all blower motors or fans shall be locked at the same time.		P
45.4.2	A unit having filters over ventilation openings is to be operated with the openings blocked to represent clogged filters. The test is to be conducted initially with the ventilation openings blocked 50 percent, then to be repeated under fully blocked condition.		P
45.5	**Locked Rotor Motor Test**		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
45.5.1	This test is intended to evaluate a motor's ability to safely withstand a locked rotor condition, which may occur in the end use application. This test is waived if the motor and its locked rotor protection has already been evaluated as part of a motor and motor protector combination evaluation, per the Standard for Rotating Electrical Machines - Thermally Protected Motors, UL 1004-3, and Motors With Inherent Overheating Protection, CSA C22.2 No. 77, or the Standard for Rotating Electrical Machines - Electronically Protected Motors, UL 1004-7, and CSA C22.2 No. 77, or if relying on impedance protection per the Standard for Rotating Electrical Machines - Impedance Protected Motors, UL 1004-2, and CSA C22.2 No. 77, as applicable.		P
45.5.2	The motor is operated at the voltage used in the vehicle application and with its rotor locked for 7 h or until steady conditions are established. The motor is to be tested while in the personal e-mobility device and temperatures on windings are to be monitored. As an alternative, the motor can be tested outside the personal e-mobility device.		P
45.5.3	If the design or size of the motor prevents the measuring of temperature windings, the test may be conducted with the motor removed from the vehicle and instead of monitoring temperatures, the motor is to be supported on a surface covered with a single layer of tissue paper with the motor covered with a single layer of cheesecloth.		P
45.5.4	If the motor contains a hazardous voltage circuit, the motor shall be subjected to a Dielectric Voltage Withstand Test, Section 41, or Isolation Resistance Test, Section 40, (without humidity conditioning).		P
45.5.5	If monitoring temperatures on windings during the locked rotor test, the temperatures on the windings shall not exceed the values noted in Table 45.1. If not monitoring temperatures on windings during the test, there shall be no sign of ignition of the tissue or cheesecloth at the conclusion of the test.		P
	Table 45.1 Motor winding temperature limits during locked rotor		P

	Temperature Limits, °C (°F)			
Thermal Class	**Class A (105)**	**Class E (120)**	**Class B (130)**	**Class F (155)**
Type of Protection:				
Protection by inherent or external impedance	150 (302)	165 (329)	175 (347)	200 (392)
Protection by any protective device that operates during the first hour	200 (392)	215 (419)	225 (437)	250 (482)
Protection by protective device:				
• maximum after first hour (automatic)	175 (347)	190 (374)	200 (392)	225 (437)
• maximum after first hour (thermal cutoff)	150 (302)	165 (329)	175 (347)	200 (392)
• arithmetic average during the 2nd hour and during the 72nd hour (automatic)	150 (302)	165 (329)	175 (347)	200 (392)

45.6	**Running Overload Test**		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
45.6.1	This test is intended to evaluate a motor's ability to safely withstand an overload condition, which may occur in the end use application. This test is waived if the motor and its overload protection has already been evaluated as part of a motor and motor protector combination evaluation per the Standard for Rotating Electrical Machines - Thermally Protected Motors, UL 1004-3, and Motors With Inherent Overheating Protection, CSA C22.2 No. 7, or the Standard for Rotating Electrical Machines – Electronically Protected Motors, UL 1004-7, and CSA C22.2 No. 7, as applicable to the method of thermal protection.		P
45.6.2	The motor is to be tested while in the vehicle and temperatures on windings are to be monitored. As an alternative, the motor can be tested outside the vehicle.		P
45.6.3	The motor is first operated under maximum normal load conditions. The load is then increased so that the current is increased in appropriate gradual steps with the motor supply voltage being maintained at its original value. When steady state temperature conditions are established the load is again increased. The load is thus progressively increased in appropriate steps until either the overload protection device operates or the motor winding becomes an open circuit.		P
45.6.4	The motor winding temperatures are determined during each steady period and the maximum temperature recorded shall not exceed the value in Table 45.2.		P
	Table 45.2 Motor winding temperature limits during overload Thermal Class: Class A (105) / Class E (120) / Class B (130) / Class F (155) Temperature Limit, °C (°F): 140 (284) / 155 (311) / 165 (329) / 190 (374)		P
45.6.5	If the design or size of the motor prevents the measuring of temperature windings, the test may be conducted with the motor removed from the vehicle and instead of monitoring temperatures, the motor is to be supported on a surface covered with a single layer of tissue paper with the motor is covered with a single layer of cheesecloth.		P
45.6.6	If the motor contains a hazardous voltage circuit, the motor shall be subjected to a Dielectric Voltage Withstand Test, Section 41, or Isolation Resistance Test, Section 40, (without humidity conditioning).		P
45.6.7	If monitoring temperatures on windings during the overload test, the temperatures on the windings shall not exceed the values noted in Table 45.2. If not monitoring temperatures on windings during the test, there shall be no sign of ignition of the tissue or cheesecloth at the conclusion of the test.		P
46	**Impact Test**		—

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
46.1	A unit acting as an enclosure shall be subjected to this test. The enclosure is to be subjected to an impact of 5 foot-pounds (6.8 J) on any surface that is exposed to a blow during normal use. This impact is to be produced by dropping a steel sphere, 2 inches (50.8 mm) in diameter and weighing 1.18 pounds (535 g), from a height of 51 inches (1.29 m) to produce the 5 foot-pound impact. For surfaces other than the top, the steel sphere is to be suspended by a cord and swung as a pendulum, dropping through a vertical distance of 51 inches to strike the surface.		P
46.2	A unit is to be subjected to the impact test described in 46.1 with or without any attachment specified by the manufacturer so as to result in the most severe test.		P
46.3	When the part under test is made of polymeric material, the impact test is to be first conducted on a representative unit or units in the as-received condition. The test is then to be repeated on a different unit or units that have been cooled to room temperature after being conditioned for 7 hours in an air oven operating at 10°C (18°F) higher than the maximum operating temperature of the material, and not less than 70°C (158°F). While being conditioned, a part is to be supported in the same manner in which it is supported on the unit.		P
46.4	Upon being removed from the oven mentioned in 46.3 and before being subjected to the impact test, no units shall show signs of cracking or other deleterious effects from the oven conditioning, and no unit shall be distorted so as to result in a risk of injury to persons.		P
46.5	After the impact test, any openings resulting from the test shall be evaluated for access to hazardous live parts using the accessibility probe shown in Figure 18.1.		P
47	**Mold Stress**		—
47.1	This test is intended to evaluate whether any shrinkage or distortion exists on a molded or formed thermoplastic enclosure due to release of internal stresses caused by the molding or forming operation and result in the exposure of hazardous parts or reduction of electrical spacings.		P
47.2	The representative units are to be placed in a full-draft circulating-air oven maintained at a uniform temperature of 70°C (158°F) or 10°C (18°F) higher than the maximum temperature observed on the part during the Temperature Test, Section 39. The units are to remain in the oven for 7 hours.		P
47.3	To inhibit hazards from overheating energized cells, units shall be fully discharged prior to conditioning.		P

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Clause	Requirement + Test	Result - Remark	Verdict
47.4	After careful removal from the oven, the units shall be allowed to cool to room temperature and then examined. After the examination, the units shall be subjected to a Dielectric Strength Test, Section 41, or Isolation Resistance Test, Section 40, (without humidity conditioning).		P
47.5	There shall be no damage of the vehicle system enclosure that would allow hazardous voltage parts to be accessed by use of the test rod 2.5 mm diameter, 100 mm long, shown in Figure 1 of the Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271/CAN/ULC-S2271, and the articulate probe shown in Figure 18.1.		P
48	**Flexing Test**		—
48.1	After wiring has been subjected to flexing as described in 48.2, the unit shall be subjected to the Dielectric Voltage-Withstand Test in Section 41 and the wiring is to be examined for damage to determine where any conductors are broken or where individual strands have penetrated the insulation.		N/A
48.2	Wiring that is subjected to movement at times other than installation and servicing is to be tested by cycling the moving part through the maximum travel intended for the construction. The duration of the test is to be 500 cycles.		N/A
49	**Ingress Protection Tests**		—
49.1	This test is intended to evaluate the vehicle's ability to withstand potential water exposure in its intended use and is conducted in accordance with the test method outlined in 49.2.		P
49.2	A fully charged vehicle system, including any off board charging devices, shall be subjected to a water exposure test in accordance with the Standard for Degrees of Protection Provided by Enclosures (IP Code), IEC 60529, Tests for Protection Against Water Indicated by the Second Characteristic Numeral 4 (IPX4), unless the vehicle system is provided with a higher IP Code rating by the manufacturer, in which case the vehicle system shall be tested in accordance with its rating.		P
49.3	If the vehicle system is operational after the test, it shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. The test shall be followed by an observation period in accordance with 37.8.	IP65	P
49.4	At the conclusion of the observation period, the units shall be subjected to a Dielectric Strength Test, Section 41, or an Isolation Resistance Test, Section 40, (without humidity conditioning).		P
49.5	As a result of the test, there shall be no indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		P

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Clause	Requirement + Test	Result - Remark	Verdict

50	**Strength of Terminal Insulating Base and Support Test**		—
50.1	An insulating base or support is considered to comply with the test described in 50.2 when there are no cracks in insulating base materials, no rotation of the insulating base, bosses or recesses or other means to prevent turning perform their intended function, or the like. Minor deformation or deterioration is allowed as long as the performance of the connection is not affected		P
50.2	An insulating base or support shall be subjected to the force created when the connectors, securing short lengths of conductors sized as described in 31.1.3, are torqued to 110 percent of the value marked on the device.		P
51	**Permanence of Marking**		—
51.1	The purpose of this test is to evaluate the permanence of an adhesive label that has not been subjected to a previous evaluation program.		P
51.2	An adhesive label secured to a surface representative of the end use application and is subjected to the following conditioning. The label is rubbed by hand for 15 s with a piece of cloth soaked with water. This is then repeated using petroleum spirit.		P
51.3	The petroleum spirit to be used for the test is an aliphatic solvent hexane having:		P
	a) A maximum aromatics content of 0.1 percent by volume;		P
	b) A kauributenol value of 29;		P
	c) An initial boiling point of approximately 65°C (149°F);		P
	d) A dry point of approximately 69°C (156.2°F); and		P
	e) A mass per unit volume of approximately 0.7 kg/l (5.8 lb/gal). *Exception: As an alternative, it is permitted to use a reagent grade hexane with a minimum of 85 percent as n-hexane.*		P
51.4	After the conditioning outlined in 51.2, the unit is to be examined for signs of damage including curing and to determine if the marking is still legible. The unit is also examined to determine if it can be removed easily by hand from the adhered surface.		P
51.5	As a result of the conditioning, the representative label shall remain legible, show no evidence of damage including curling and shall not be able to be easily removed by hand from the adhered surface.		P
52	**General**		—
52.1	The performance tests are to be conducted on representative samples of the product as appropriate.		P
52.2	Testing is to be conducted at any ambient temperature between 5°C (41°F) and 35°C (95°F).		P

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Clause	Requirement + Test	Result - Remark	Verdict
52.3	Unless indicated otherwise, batteries are to be fully charged to the maximum operating state of charge in accordance with the manufacturer's specifications. After charging and prior to testing, the batteries are to be allowed to rest for a maximum period of 8 hours at room ambient.		P
52.4	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 surface of at least one cell/module within the device are to be monitored during the test for safety and information purposes. All personnel involved in the testing are to be instructed to never approach the test unit until temperatures are falling and have returned to within ambient temperatures.		P
52.5	Unless noted otherwise in the individual test methods, the tests shall be followed by a 1-h observation time prior to concluding the test and temperatures are to be monitored.		P
52.6	Products that are operational after tests associated with the battery shall be subjected to a minimum of one cycle of charging and discharging in accordance with the manufacturer's specifications to determine that there is no fire, explosion, rupture, electrolyte leakage, or shock hazard associated with the stressed battery.		P
53	**Vibration Test**		—
53.1	A vehicle system, or parts of the system, intended to be permanently mounted on a vehicle shall be subjected to a vibration test. After the unit is subjected to the vibration test described in 53.2:		P
	a) The vehicle system shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons;		P
	b) There shall be no loosening of parts; and		P
	c) The unit shall operate normally.		P
53.2	The vibration test shall consist of vibration for one hour at a frequency of 10 to 55 Hz and back to 10 Hz, with a linear sweep having a sweep time of two minutes per sweep cycle. The amplitude shall be 1.0 +0.1, - 0 mm (0.040 +0.004, - 0 inch) p-p displacement limit in a vertical plane.		P

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Clause	Requirement + Test	Result - Remark	Verdict
53.3	After this test, the representative unit shall be subjected to a minimum of one charge/discharge cycle at the manufacturer's maximum specified values. After this charge/discharge cycle, the unit shall be subjected to an observation period per 52.5.		P
53.4	At the conclusion of the observation period, the unit shall be subjected to a Dielectric strength Test, Section 41, or an Isolation Resistance Test, Section 40, (without humidity conditioning).		P
53.5	As a result of the test, there shall be no indication of fire, explosion, rupture, electrolyte leakage, or shock hazard. CORD CONNECTED VEHICLES		P
54	**General**		—
54.1	The performance tests are to be conducted on representative samples of the product as appropriate.		P
54.2	Testing is to be conducted at any ambient temperature between 5°C (41°F) and 35°C (95°F).		P
54.3	Unless indicated otherwise, batteries are to be fully charged to the maximum operating state of charge in accordance with the manufacturer's specifications. After charging and prior to testing, the batteries are to be allowed to rest for a maximum period of 8 hours at room ambient.		P
54.4	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 surface of at least one cell/module within the device are to be monitored during the test for safety and information purposes. All personnel involved in the testing are to be instructed to never approach the test unit until temperatures are falling and have returned to within ambient temperatures.		P
55	**Leakage Current**		—
55.1	A cord-connected on board charging unit shall be tested in accordance with 55.2 – 55.8. Leakage current shall not be more than: a) 0.5 MIU for a two-wire cord- and plug-connected unit; b) 0.5 MIU for a three-wire (including grounding conductor) cord- and plug-connected portable unit; and c) 0.75 MIU for a three-wire (including grounding conductor) cord- and plug-connected fixed appliance.		P

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Clause	Requirement + Test	Result - Remark	Verdict
55.2	All accessible conductive surfaces are to be tested for leakage currents to determine compliance with 55.1. Where surfaces are simultaneously accessible, they are to be tested: a) Individually; b) Collectively (connected together) with the combined current measured to ground; and c) Point-to-point on the device for leakage current between the simultaneously accessible surfaces.		P
55.3	When a conductive part other than metal is used for an enclosure or part of an enclosure, leakage current is to be measured using a metal foil with an area of 100 by 200 mm (4 by 8 inches) in contact with the surface. Where the conductive surface has an area less than 100 by 200 mm (4 by 8 inches), the metal foil is to be the same size as the surface. The metal foil is to conform to the shape of the surface and is not to remain in place long enough to affect the temperature of the unit.		P
55.4	The typical measurement circuit for leakage current with the ground connection open is illustrated in Figure 55.1. The measurement instrument is defined in Figure 55.2. The meter that is used for a measurement need only indicate the same numerical value for a particular measurement as does the defined instrument; it need not have all the attributes of the defined instrument. Over the frequency range 20 Hz to 1 MHz with sinusoidal currents, the performance of the instrument is to be as follows:		P
	a) The measured ratio V1/I1 with sinusoidal voltages is to be as close as feasible to the ratio V1/I1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 55.2.		P
	b) The measured ratio V3/I1 with sinusoidal voltages is to be as close as feasible to the ratio V3/I1 calculated with the resistance and capacitance values of the measurement instrument shown in Figure 55.2. V3 is to be measured by the meter M in the measuring instrument. The reading of meter M in RMS volts is converted to MIU by dividing the reading by 500 ohms and then multiplying the quotient by 1,000. The mathematical equivalent is to multiply the RMS voltage reading by 2.		P

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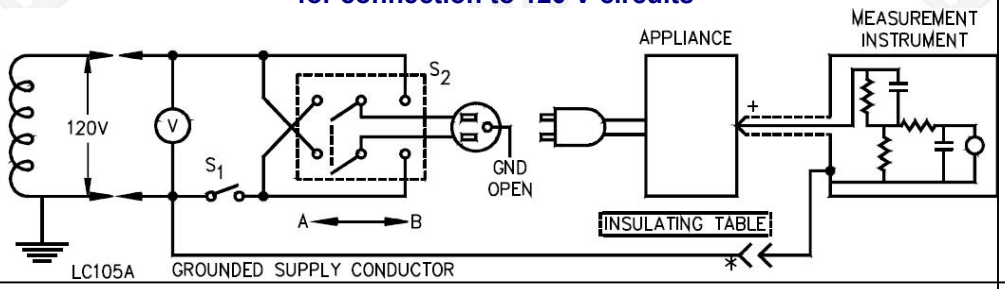
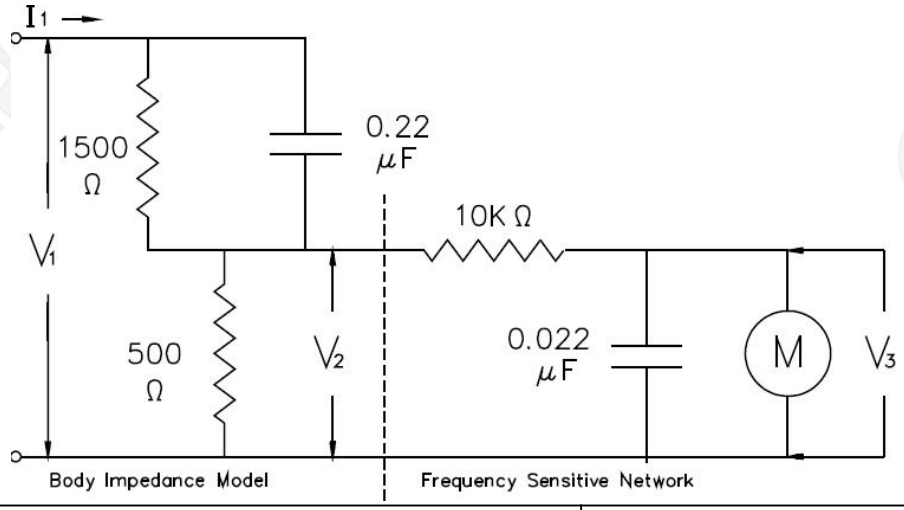
Clause	Requirement + Test	Result - Remark	Verdict

	Figure 55.1 Leakage current measurement circuit used for devices intended for connection to 120 V circuits 		P
	Figure 55.2 Measurement instrument for reaction (leakage) current 		P
55.5	Unless the measurement instrument is being used to measure leakage current from one part of a unit to another, it is to be connected between accessible parts and the supply conductor connected to ground (the grounded or grounding conductor) that has the least extraneous voltages introduced from other equipment operated on the same supply. For products rated 120 volts, with one supply conductor grounded, this is likely to be the grounded supply conductor.		P
55.6	When there is no grounded conductor connected to the unit under test, then the instrument return lead is not prohibited from being connected to either the grounded or grounding conductor of the supply depending on the other electrical loads connected to the branch circuit and operating at the time the test is conducted. Use the conductor introducing the least extraneous voltage, as indicated by the lowest leakage current reading. In environments having significant extraneous voltage introduced, an isolating transformer reduces the effects of extraneous voltages.		P

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Clause	Requirement + Test	Result - Remark	Verdict
55.7	A representative unit is to be tested for leakage current starting with the as received condition – the as received condition being without prior energization, except that which occur as part of the production-line testing. The supply voltage is to be adjusted to rated voltage. The test sequence is to be as follows, with reference to Figure 55.1:		P
	a) With switch S1 open, the unit is to be connected to the measurement circuit. Leakage current is to be measured using both positions of switch S2, and with the unit switching devices in all their normal operating positions.		P
	b) Switch S1 is then to be closed, energizing the product. Within 5 seconds, the leakage current is to be measured using both positions of switch S2 and with the product switching devices in all their normal operating positions.		P
	c) Leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the normal temperature test.		P
	d) The leakage current is also to be monitored with switch S1 open while the unit is at operating temperature and while cooling.		P
55.8	A representative unit is to be subjected to the entire leakage current test, as specified in 55.7, without interruption for other tests unless with the concurrence of those concerned, the tests are nondestructive tests.		P
56	**Capacitor Discharge Test**		—
56.1	A cord connected on board charging unit that is provided with filtering capacitors, or other primary capacitors, shall comply with this test.		P
56.2	The device shall be connected to a supply source of rated voltage at 60 Hz. The output shall be connected to a suitable load such that rated current is drawn from the output of the device. A storage oscilloscope shall be connected across the point of disconnection of the supply.		P
56.3	The device shall be connected to the source of supply and energized with the output open circuit condition. The power shall then be removed and the resulting discharge curve for the stored charge on capacitors shall be measured and captured on the oscilloscope. The value of the stored charge shall decay to less than 37 percent of its initial value within 1 second.		P
56.4	The test shall be repeated with all switches in all possible positions and combinations.		P
57	**Strain Relief**		—
57.1	**General**		P

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Clause	Requirement + Test	Result - Remark	Verdict
57.1.1	The tests in 57.2 and 57.3 apply to the flexible cord connections, field wiring connections, and the EV cable connections.		P
57.1.2	Both the Strain Relief - Pull Test and the Strain Relief - Push Back Test are required for each cord or cable connection mentioned in 57.1.1. Field wiring connections are only required to be subjected to the Strain Relief - Pull Test.		P
57.1.3	All of the tests can be performed on one sample, but each test is to be performed individually.		P
57.1.4	The internal connections are to be disconnected or cut prior to the tests in 57.2 and 57.3.		P
57.2	**Strain relief - pull test**		N/A
57.2.1	The strain relief means provided for a flexible cord or EV cable connection, other than output cords of Class 2 Transformers, shall withstand a direct pull of 156 N (35 pounds) applied to the cord for one minute without displacement. The strain relief does not comply when at the point of disconnection of the conductors, there is such movement as to indicate that stress on the connections results.		N/A
57.2.2	The strain relief means provided for the output cord of a Class 2 transformer shall be tested as indicated in 57.2.1, except the weight shall be 89 N (20 pounds).		N/A
57.2.3	A wiring lead intended for field wiring connection shall be tested as indicated in 57.2.1, except in the case of a lead extending from the enclosure the weight is to be 89 N (20 pounds) and in the case of al lead within a wiring compartment, the weight is to be 44.5 N (10 pounds).		N/A
57.2.4	The weight is to be suspended from the cord, cable, or lead and supported by the unit so that the strain relief means is stressed from any angle of the unit.		N/A
57.3	**Strain relief - push back test**		N/A
57.3.1	The supply cord or EV cable shall be prevented from being pushed into the product through the cord entry hole where such displacement is likely to: a) Subject the cord or cable to mechanical damage or to exposure to a temperature higher than that for which the cord or cable is rated; b) Reduce spacings below the minimum intended values; or c) Damage internal connectors or components.		N/A
57.3.2	The supply cord is to be held 25.4 mm (1 inch) from the point where the cord emerges from the unit and is then to be pushed back into the unit. The cord is to be pushed back into the unit in 25.4 mm (1 inch) increments until the cord buckles or the force to push the cord into the unit exceeds 26.7 N (6 pounds force). The supply cord or cable, within the unit, is to be manipulated to the worst case position during the test to determine compliance with 57.3.1. E-BIKES AND EPACs		N/A

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Clause	Requirement + Test	Result - Remark	Verdict

58	**General**		—
58.1	The performance tests are to be conducted on representative samples of the product as appropriate.		P
58.2	Testing is to be conducted at any ambient temperature between 5°C (41°F) and 35°C (95°F).		P
58.3	Unless indicated otherwise, batteries are to be fully charged to the maximum operating state of charge in accordance with the manufacturer's specifications. After charging and prior to testing, the batteries are to be allowed to rest for a maximum period of 8 hours at room ambient.		P
58.4	Tests may be conducted on a test track, a bench or a test stand, which keeps the driven wheel free of the ground.		P
58.5	If conducted on a test track, the wind speed is to not exceed 3 m/s (6.7 mph).		P
58.6	In all cases, worst case conditions of gear ratio and speed are to be selected.		P
58.7	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 surface of at least one cell/module within the device are to be monitored during the test for safety and information purposes. All personnel involved in the testing are to be instructed to never approach the test unit until temperatures are falling and have returned to within ambient temperatures.		P
58.8	Unless noted otherwise in the individual test methods, the tests shall be followed by a 1-h observation time prior to concluding the test and temperatures are to be monitored.		P
58.9	Products that are operational after tests associated with the battery shall be subjected to a minimum of one cycle of charging and discharging in accordance with the manufacturer's specifications to determine that there is no fire, explosion, rupture, electrolyte leakage, or shock hazard associated with the stressed battery.		P
59	**Startup Assistance Mode Test**		—
59.1	E-Bikes or EPACs provided with a startup assistance mode are to be tested. The startup assistance mode shall have a maximum speed of 6 kph (3.7 mph) and that the assistance stops when the activation control is released.		P

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Clause	Requirement + Test	Result - Remark	Verdict
59.2	The sample unit shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test.		P
59.3	Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value.		P
59.4	The unit is to be operated for 5 minutes as a speed equal to 80 percent of its marked maximum assistance speed and then the sample is stopped. The startup assistance mode is activated and run for 1 minute. At the end of the 1 minute, the maximum speed is recorded.		P
59.5	At the end of the 1 minute duration in 60.4, the activation control is released and the motor current is observed. When the motor current returns to the non-assist current value, the test is ended.		P
60	**Motor Assistance Control**		—
60.1	**General**		P
60.1.1	The tests in 60.2, 60.3, and 60.5, are required for all EPACs and all e-Bikes with a pedalec mode. For e-Bikes without a pedalec mode, the tests in 60.2 and 60.3 would not apply. The test in 60.4 is only required on e-Bikes and EPACs that are provided with a cutoff feature when braking.		P
60.1.2	For all tests, the term “sample” is considered to apply to the on board electrical system or the complete vehicle with the on board electrical system installed. The term refers to all EPACs and to any e-Bike that is provided with a pedalec function.		P
60.2	**Reverse Pedaling Test**		P
60.2.1	The motor assistance shall not be activated when the pedals are operated in reverse. The motor current shall not increase above the non-assist current value when tested in accordance with 60.2.2 – 60.2.4.		P
60.2.2	The sample shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test.		P

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Clause	Requirement + Test	Result - Remark	Verdict
60.2.3	Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value.		P
60.2.4	The pedals are operated in reverse and the motor current value is observed. The motor current value is recorded during this operation and shall not exceed the non-assist current value.		P
60.3	**Pedal Cessation Test**		N/A
60.3.1	The motor assistance shall cutoff within 2 meters (6.6 feet) of travel distance when the user stops pedaling. The motor current shall decrease to or below the non-assist current value within those 2 meters.		N/A
60.3.2	The sample shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test.		N/A
60.3.3	Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value.		N/A
60.3.4	The sample is operated at 90 percent of the marked maximum assistance speed and then pedaling is ceased. The distance traveled is measured from the time pedaling ceases to the time the motor current is at or below the non-assist current level. No braking shall occur during this test.		N/A
60.3.5	With reference to 60.3.4, the distance traveled can be determined in the test bench by calculation using the number of rotations of a given wheel size.		N/A
60.4	**Cutoff When Braking Test**		P
60.4.1	The motor assistance shall cutoff when the brake device is actuated.		P
60.4.2	The sample shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test.		P
60.4.3	Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value.		P

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Clause	Requirement + Test	Result - Remark	Verdict
60.4.4	The sample is operated at any convenient speed for this test. While pedaling, the brake device is actuated and the motor current shall be interrupted and begin to decrease. This test is repeated for each brake device that is provided with cutoff functionality, one brake device for each test.		P
60.5	**Cutoff at Maximum Speed Test**		P
60.5.1	The motor assistance shall be cutoff on or before the sample obtains the marked maximum assistance speed when tested as indicated in 60.5.2 – 60.5.4.		P
60.5.2	The sample shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test.		P
60.5.3	Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value.		P
60.5.4	The sample is to be operated for 5 minutes as a speed equal to 80 percent of its marked maximum assistance speed. After this duration, the speed is increased to the maximum speed the motor will allow but not more than 125 percent of the marked maximum assistance speed. The motor current shall be reduced to the non-assist current value when, or before, the maximum speed of the sample reaches the marked maximum assistance speed.		P
61	**General**		—
61.1	The markings required for compliance to this Standard shall be legible and permanent such as etched, adhesive labels, etc. An adhesive-backed label shall comply with the requirements in the Standard for Marking and Labeling Systems, UL 969, and Adhesive Labels, CSA C22.2 No. 0.15, for the intended exposure conditions and surface adhered to. Alternatively, the label shall be subjected to the Permanence of Marking Test, Section 51.		P
62	**Nameplate and Identification**		—
62.1	Vehicle systems, the vehicle, or individual components of the system, are to be marked with the manufacturer's name, trade name, trademark or other descriptive marking which may identify the organization responsible for the product, part number or model number, and electrical ratings.		P
62.2	Vehicle systems, or components of the system, shall also be marked with the date of manufacture, which may be in the form of a code that does not repeat within 10 years.		P

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Clause	Requirement + Test	Result - Remark	Verdict
62.3	Vehicle on board systems shall be marked with charging instructions. An example of such markings would be the following or equivalent ″Use Only Charger (_____).” The blank would be filled in with identifying information for the charger.		P
62.4	All external terminals and connections shall be provided with identification and if applicable, polarity markings.		P
62.5	If a manufacturer produces or assembles vehicle systems at more than one factory location, the equipment shall have a distinctive marking - which may be in code - to identify it as the product of a particular factory.		P
62.6	Equipment field wiring terminals shall be marked “Use Copper Conductors Only”.		P
62.7	A terminal for the connection of a grounded conductor shall be identified by means of a metallic plated coating white in color, and shall be readily distinguishable from the other terminals; or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as a marking on the unit, an indication on a wiring diagram attached to the unit, or information provided in the instruction manual. Where field wiring leads are provided, the lead intended to be grounded shall have a white or gray color and shall be readily distinguishable from other leads.		P
62.8	A unit containing a field-wiring lead that is connected to a wire binding screw located in the field-wiring compartment shall be marked with information clearly indicating the intended use of the lead.		P
62.9	EPACs and e-Bikes with a pedalec function shall be marked with the maximum assistance speed or cutoff speed as applicable.		P
63	**Cautionary Markings**		—
63.1	The words, ″CAUTION″, ″WARNING″, OR ″DANGER″ in a cautionary marking shall be in letters not less than 3.2 mm (1/8 inch) high. The remaining letters in a cautionary marking shall not be less than 1.6 mm (1/16 inch) high. The words, ″WARNING″ or ″DANGER″ are alternatives for the word, ″CAUTION”.		P
63.2	A cautionary marking shall be located on a part that is not removable; or if removable, on a part that impairs the operation of the unit when removed. The marking shall also be visible and legible to the operator during normal operation of the unit.		P
63.3	Off board charger units intended for indoor use only while charging vehicles in accordance with this Standard, shall be marked with the word, “CAUTION” and the following or the equivalent: ″Risk of Electric Shock - Only use this charger indoors. Outdoor use is prohibited″.		N/A

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
63.4	There shall be a replacement marking adjacent to a fuse or fuseholder if the fuse is used to reduce the risk of fire or electric shock and the fuse is user replaceable. The marking shall be located where it will be readily visible during replacement of the fuse, and shall consist of the word, "WARNING" and the following or equivalent: "For Continued Protection Against Risk Of Fire, Replace Only With Same Type and ratings of fuse."		P
	INSTRUCTIONS		—
64	**General**		—
64.1	A product shall be provided with legible installation instructions, operation instructions, and instructions pertaining to a risk of fire, electric shock, or injury to persons associated with the use of the product. Also, user maintenance instructions and moving and storage instructions associated with the use of the product by the end user shall be included.		P
64.2	The instructions mentioned in 64.1 shall be in separate manuals or shall be combined in one or more manuals when the instructions pertaining to a risk of fire, electrical shock, or injury to persons are separated in format and emphasized to distinguish them from the rest of the text.		P
64.3	An illustration is allowed with a required instruction to clarify the intent but shall not replace the written instruction.		P
64.4	The following items shall be entirely in upper case letters or shall be emphasized to distinguish them from the rest of the text:		P
	a) The headings for the installation, operation, user maintenance, and moving and storage instructions;		P
	b) The heading for the instructions pertaining to a risk of fire, electric shock, or injury to persons; and		P
	c) The opening and closing statements of the instructions specified in 67.3 - “IMPORTANT SAFETY INSTRUCTIONS” and “SAVE THESE INSTRUCTIONS”, or the equivalent.		P
64.5	Unless otherwise indicated, the text of all instructions shall be in the words specified or words that are equivalent, clear, and understandable. Substitution of the signal word "DANGER" for "WARNING " is allowed, when the risk associated with the device is such that a situation exists which, if not avoided, will result in death or serious injury. For other than the signal words " DANGER" and "WARNING," if a specific conflict exists in the application of such wording to a device, modified wording is allowed.		P
65	**Instructions Pertaining to a Risk of Fire or Electric Shock**		—

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
65.1	Instructions pertaining to a risk of fire or electric shock shall warn the user of reasonably foreseeable risks and state the precautions to be taken to reduce such risks. Such instructions shall be preceded by the heading, “INSTRUCTIONS PERTAINING TO RISK OF FIRE or ELECTRIC SHOCK” or the equivalent.		P
65.2	Numbering of the items in the list in 65.3 and including other instructions pertaining to a risk of fire, electric shock, or injury to persons that the manufacturer determines to be necessary and that do not conflict with the intent of the instructions are acceptable.		P
65.3	The instructions pertaining to a risk of fire, electric shock, or injury to persons shall include those items in the following list that are applicable to the product. The statement “IMPORTANT SAFETY INSTRUCTIONS” or the equivalent shall precede the list, and the statement “SAVE THESE INSTRUCTIONS” or the equivalent shall either precede or follow the list. The word “WARNING” shall be entirely in upper case letters or shall be emphasized to distinguish it from the rest of the text.		P
	IMPORTANT SAFETY INSTRUCTIONS		—
	WARNING - When using this product, basic precautions should always be followed, including the following:		P
	a) Read all the instructions before using the product.		P
	b) To reduce the risk of injury, close supervision is necessary when the product is used near children.		P
	c) Do not put fingers or hands into the product.		P
	d) Do not use this product if the flexible power cord or output cable is frayed, has broken insulation, or any other signs of damage.		P
	e) For an off board charger provided with a field wiring terminal or leads, the installation instructions shall state that the installation is intended to use copper wires only.		P
	f) For an off board charger, when a pressure terminal connector, or the fastening hardware, are not provided on the unit as shipped. The instruction manual shall indicate which pressure terminal or component terminal assemblies are for use with the unit.		P
	g) With reference to (f), the terminal assembly packages and the instruction manual shall include information identifying the wire size and the manufacturer’s name, trade name, or other descriptive marking by which the organization responsible for the product is identified.		P

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
	h) When a pressure terminal connector provided on an off board charger, for a field installed conductor requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any required instructions for using the tool shall be included in the installation instructions.		P
	i) The instruction manual for a unit where the abnormal test is terminated by operation of the intended branch circuit over current protective device, shall include the word ″CAUTION″ and the following or equivalent: ″To reduce the risk of fire, connect only to a circuit provided with_____ amperes maximum branch circuit overcurrent protection in accordance with the National Electrical Code, ANSI/NFPA 70.″ The blank space is to be filled in with the applicable ampere rating of branch circuit overcurrent protection		P
	SAVE THESE INSTRUCTIONS		P
65.4	The instructions pertaining to a risk of fire, electric shock, or injury to persons, or the installation instructions shall include the following items if applicable. If the following instructions are included in the installation instructions, a reference to these instructions shall be included in the list mentioned in 65.3 as a separate item. The headings and the word “WARNING” shall be entirely in upper case letters or shall be emphasized to distinguish it from the rest of the text.		P
	GROUNDING INSTRUCTIONS		—
	This product must be grounded. If it should malfunction or breakdown, grounding provides a path of least resistance for electric current to reduce the risk of electric shock. This product is equipped with a cord having an equipment grounding conductor and a grounding plug. The plug must be plugged into an outlet that is properly installed and grounded in accordance with all local codes ordinances.		N/A
	WARNING - Improper connection of the equipment grounding conductor is able to result in a risk of electric shock. Check with a qualified electrician if you are in doubt as to whether the product is properly grounded. Do not modify the plug provided with the product - if it will not fit the outlet, have a proper outlet installed by a qualified electrician.		N/A
66	**Installation Instructions**		—
66.1	Installation instructions shall contain all the information needed to install the product for use as intended, and shall be preceded by the heading, “INSTALLATION INSTRUCTIONS” or the equivalent.		P
67	**Operating Instructions**		—

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict
67.1	Operating instructions shall contain all the information needed to operate the product as intended, and shall be preceded by the heading “OPERATING INSTRUCTIONS” or the equivalent.		P
	67.2 Instructions in relation to operating that appear in the instructions pertaining to a risk of fire, electric shock, or injury to persons, are not required to be repeated here; but a reference to those instructions shall be included here. 67.3 The instruction manual shall contain the following information: a) Instructions regarding battery charging, temperature limits for appliance and battery use and storage, and the recommended temperature range for charging. b) A warning shall be provided against modifying or attempting to repair the vehicle system except as indicated in the instructions for use and care.		P
67.4	Instructions shall indicate that charging of the vehicle shall only be performed with the manufacturer’s recommended charger.		P
68	**User Maintenance Instructions**		—
68.1	Instructions for user maintenance shall include explicit instructions for all cleaning and servicing that are intended to be performed by the user, and shall be preceded by the heading, “USER MAINTENANCE INSTRUCTIONS” or the equivalent.		P
68.2	For units with user replaceable fuses, the user maintenance instructions shall contain statements concerning fuse replacement instructions and reference to the correct fuse ratings that are to be used.		P
69	**Moving and Storage Instructions**		—
69.1	If moving or storage of the product is able to result in damage to the product that could result in a risk of fire, electric shock, or injury to persons during subsequent use, the instructions shall describe the proper moving and storage procedure, and shall be preceded by the heading, “MOVING AND STORAGE INSTRUCTIONS” or the equivalent.		N/A
Annex B	**– French Translations**		—
B1	**French Translations**		N/A

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict

Clause	English	French
62.3	Use Only Charger (_____)	Utiliser exclusivement le chargeur (_____)
62.6	Use Copper Conductors Only	Utiliser uniquement des conducteurs en cuivre
63.3	CAUTION – Risk of Electric Shock - Only use this charger indoors. Outdoor use is prohibited.	Risque de choc électrique – Utiliser seulement ce chargeur à l'intérieur. L'utilisation en extérieur est interdite.
63.4	WARNING – For Continued Protection Against Risk Of Fire, Replace Only With Same Type and ratings of fuse.	AVERTISSEMENT – Pour une protection continue contre le risque d'incendie, remplacer seulement par des fusibles du même type et calibre.
64.4(c) 65.3	IMPORTANT SAFETY INSTRUCTIONS SAVE THESE INSTRUCTIONS	INSTRUCTIONS IMPORTANTES CONCERNANT LA SÉCURITÉ CONSERVER CES INSTRUCTIONS
64.5	Unless otherwise indicated, the text of all instructions shall be in the words specified or words that are equivalent, clear, and understandable. Substitution of the signal word "DANGER" for "WARNING " is allowed, when the risk associated with the device is such that a situation exists which, if not avoided, will result in death or serious injury. For other than the signal words " DANGER" and "WARNING," if a specific conflict exists in the application of such wording to a device, modified wording is allowed.	À moins d'avis contraire, les instructions doivent être rédigées à l'aide du vocabulaire prescrit ou d'un vocabulaire équivalent, et aussi clair et aussi compréhensible. Il est permis de remplacer le mot indicateur «DANGER» par le mot «AVERTISSEMENT» si le risque associé au dispositif est tel que si la situation visée n'est pas évitée, elle entraînera la mort ou des blessures graves Dans le cas des mots autres que les mots indicateurs «DANGER» et «AVERTISSEMENT» si une possibilité de confusion résulte de l'utilisation du vocabulaire prescrit, il peut être modifié
65.1	INSTRUCTIONS PERTAINING TO A RISK OF FIRE OR ELECTRIC SHOCK	INSTRUCTIONS AYANT TRAIT À UN RISQUE D'INCENDIE OU DE CHOC ÉLECTRIQUE

N/A

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict

Clause	English	French	
65.3	WARNING - When using this product, basic precautions should always be followed, including the following: a) Read all the instructions before using the product. b) To reduce the risk of injury, close supervision is necessary when the product is used near children. c) Do not put fingers or hands into the product. d) Do not use this product if the flexible power cord or output cable is frayed, has broken insulation, or any other signs of damage. e) For an off board charging system provided with a field wiring terminal or leads, the installation instructions shall state that the installation is intended to use copper wires only. f) For an off board charging system, when a pressure terminal connector, or the fastening hardware, are not provided on the unit as shipped. The instruction manual shall indicate which pressure terminal or component terminal assemblies are for use with the unit. g) With reference to (f), the terminal assembly packages and the instruction manual shall include information identifying the wire size and the manufacturer's name, trade name, or other descriptive marking by which the organization responsible for the product is identified. h) When a pressure terminal connector provided on an off board charging system, for a field installed conductor requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any required instructions for using the tool shall be included in the installation instructions. i) The instruction manual for a unit where the abnormal test is terminated by operation of the intended branch circuit over current protective device, shall include the word "CAUTION" and the following or equivalent: "To reduce the risk of fire, connect only to a circuit provided with _____ amperes maximum branch circuit overcurrent protection in accordance with the National Electrical Code, ANSI/NFPA 70." The blank space is to be filled in with the applicable ampere rating of branch circuit overcurrent protection.	AVERTISSEMENT – Lors de l'utilisation de ce produit, il convient toujours de respecter des précautions élémentaires, notamment les suivantes: a) Lire toutes les directives avant d'utiliser le produit. b) Pour limiter les risques de blessure, exercer une surveillance étroite si le produit est utilisé à proximité d'enfants. c) Ne pas introduire les doigts ou les mains dans le produit. d) Ne pas utiliser ce produit si le cordon d'alimentation souple ou les câbles de sortie sont effilochés, si l'isolant est abîmé ou s'il y a d'autres signes de dommages. e) Lorsqu'un système de charge externe est fourni avec une borne pour connexion à pied d'œuvre ou des fils de raccordement, les directives d'installation préciseront que l'installation prévoit uniquement l'utilisation de fils de cuivre. f) Avec un système de charge externe, lorsque l'unité n'est pas livrée avec une borne de raccordement à pression ou le matériel de fixation, le manuel d'utilisation devra indiquer quels assemblages de bornes à pression ou de bornes de composant doivent être utilisés avec l'unité. g) En référence au point f), les boîtiers d'assemblage des bornes et le manuel d'utilisation doivent comprendre des renseignements indiquant la taille des fils et la raison sociale du fabricant, la marque de commerce ou toute autre inscription descriptive permettant d'identifier l'entreprise responsable de la fabrication du produit.	N/A

UL 2849-2016			
Clause	Requirement + Test	Result - Remark	Verdict

Clause	English	French
65.4	GROUNDING INSTRUCTIONS This product must be grounded. If it should malfunction or break down, grounding provides a path of least resistance for electric current to reduce the risk of electric shock. This product is equipped with a cord having an equipment grounding conductor and a grounding plug. The plug must be plugged into an appropriate outlet that is properly installed and grounded in accordance with all local codes and ordinances. WARNING - Improper connection of the equipment-grounding conductor is able to result in a risk of electric shock. Check with a qualified electrician or serviceman if you are in doubt as to whether the product is properly grounded. Do not modify the plug provided with the product - if it will not fit the outlet, have a proper outlet installed by a qualified electrician.	CONSIGNES DE MISE À LA TERRE Ce produit doit être mis à la terre. En cas de mauvais fonctionnement ou de rupture, la mise à la terre offre un trajet de moindre résistance au courant électrique ce qui réduit le risque de choc électrique. Ce produit est muni d'un cordon contenant un conducteur et une fiche de mise à la terre. La fiche doit être introduite dans une prise appropriée, installée correctement et mise à la terre conformément aux codes et règlements locaux. AVERTISSEMENT - Une mauvaise connexion du conducteur de mise à la terre peut présenter un risque de choc électrique. Consultez un électricien ou un technicien qualifié si vous avez des doutes quant à la qualité de la mise à la terre. Ne pas modifier la fiche qui équipe le produit - si elle ne convient pas à la prise, faire installer une prise appropriée par un électricien qualifié.
66.1	INSTALLATION INSTRUCTIONS	INSTRUCTIONS D'INSTALLATION
67.1	OPERATING INSTRUCTIONS	INSTRUCTIONS D'UTILISATION
68.1	USER MAINTENANCE INSTRUCTIONS	INSTRUCTIONS D'ENTRETIEN À L'INTENTION DE L'UTILISATEUR
69.1	MOVING AND STORAGE INSTRUCTIONS	INSTRUCTIONS VISANT LE DÉPLACEMENT ET L'ENTREPOSAGE

N/A

14	Flammability	P

Part	Test temperature (C)	Duration(s)	Observation
Adapter enclosure	650	30	No
PCB	850	30	No
Transformer bobbin	850	30	No
Motor bobbin	850	30	No

15/18	TABLE: Clearance and creepage distance measurements	P

Clearance (cl) and creepage distance (cr) at/of/between:	U peak (V)	U r.m.s. (V)	Required cl (mm)	cl (mm)	Required cr (mm)	cr (mm)
Between live part and enclosure	169.5	120	3.2	5.7	4.8	5.7
L-N (on PCB)	169.5	120	3.2	4.0	4.8	5.0
Between the primary and secondary windings of transformer	169.5	120	4.8	6.4	6.4	6.4
Between the primary and secondary windings of PCB	169.5	120	4.8	6.6	6.4	6.6

28	TABLE: Power input deviation	P

Input deviation of/at:	I rated (A)	I measured (A)	dI	Required dI	Remark
100V, 60Hz	2.0	1.986	99.3%	110%	P
240V~, 60Hz	2.0	0.827	41.4%	110%	P
100V, 50Hz	2.0	1.985	99.3%	110%	P
240V~, 50Hz	2.0	0.827	41.4%	110%	P

29	TABLE: Leakage current		P
	Test voltage.....:	120	

Leakage current between	I (mA)	Max. allowed I (mA)
L,N and basic insulation	0,05/0,05	0,5
L.N and reinforced insulation	0,01/0,01	0,5

31	Temperature Test (charge cycles)		P
	Test voltage (V)..... :	120	
	Ambient (C) ..... :	25.0	

Thermocouple locations	T (C)	Max. T (C)
Power supply cord	37.6	105

Connector	43.5	50
LI-ION BATTERY CHARGER	45.7	60
Battery	53.7	70
Motor	25.0	110
Handle	25.0	75
Knob	25.0	85

31	Temperature Test (discharge cycles)		P
	Test voltage (V)..... :	48	
	Ambient (C) ..... :	25.0	

Thermocouple locations	T (C)	T (C)
Battery	43.1	60
Enclosure inside	42.8	Ref
Enclosure Outside	44.2	Ref
Motor	47.9	85
Handle	25.7	75
Knob	27.5	85

32	TABLE: electric strength measurements	P
Test voltage applied between:	Test voltage (V)	Breakdown
Live parts to enclosure	678.8	NO
Live parts to output	678.7	NO

33	TABLE: Isolation Resistance Test	P
Insulation resistance R between:	R (M)	Required R ( )
Live parts to enclosure (for BS adapter)	1000	50000
Live parts to output (for BS adapter)	1000	50000

35	**TABLE: Abnormal Operations Tests**						P
Ambient temperature (C) .....:			25 C				
Component No.	Abnormal Condition	Supply voltage, (V)	current, (A)	I rated (A)	dI	Required	Remark
Adapter	**Transformer burnout test**	100	1.986	2.0	99.3%	167%	P

35	**Abnormal Operations Tests (Transformer overload test)**	P
Temperature rise of part/at:	T (C)	Remark
Adapter transformer	97.5	P

After 35	TABLE: electric strength measurements	P
Test voltage applied between:	Test voltage (V)	Breakdown
Live parts to enclosure	678.8	NO
Live parts to output	678.7	NO

35	**Abnormal Operations Tests**	P
Abnormal Condition	Observation	Remark
Capacitor faults	no hazard	P
Electrolytic capacitor faults	no hazard	P
Component fault tests	no hazard	P

36.Vibration Test			
Test Procedure	Requirements	Test Result	Verdict
The vibration test shall consist of vibration for one hour at a frequency of 10 to 55 Hz and back to 10 Hz, with a linear sweep having a sweep time of two minutes per sweep cycle. The amplitude shall be 1.0 +0.1, –0 mm (0.040 +0.004, –0 inch) p-p displacement limit in a vertical plane	a) The vehicle system shall not emit flame or molten metal or become a risk of fire, electric shock, or injury to persons; b) There shall be no loosening of parts; and c) The unit shall operate normally	The vehicle system no emit flame or molten metal or become a risk of fire, electric shock, or injury to persons; There no loosening of parts The unit operate normally	Pass
After this test, Dielectric strength Test were pass; There no indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.			

37	**TABLE: Impact Test**				P
Surface tested	Height	Impact energy (J)	Requirements	Test Result	Verdict
Battery metal enclosure	1.29 m)	6.8	After the impact test, any openings resulting from the test shall be evaluated for access to hazardous live parts using the accessibility probe shown in Figure 17.1.	No access to dangerous living parts	Pass
Handle	1.29 m)	6.8		No access to dangerous living parts	Pass
Knob	1.29 m)	6.8		No access to dangerous living parts	Pass

38.1			
Test Procedure	Requirements	Test Result	Verdict
After testing in according with appropriate requirements of EN 60529 14.1 and 14.2.5 the enclosure shall be inspected for ingress of water	IPX5	No ingress of water was found inside	Pass
Accordance with EN 60529 13.2 and 13.4, 13.6 test. The protection is satisfactory if the full diameter of the probe specified in table 7 does not pass through any opening	IP6X	There is no trace of dust inside	Pass

38.2	Temperature Test (charge cycles)		P
	Test voltage (V)..... :	120	
	Ambient (C) ..... :	50.0	

Thermocouple locations	T (C)	Max. T (C)
Power supply cord	62.6	Ref
Connector	67.5	Ref
LI-ION BATTERY CHARGER	70.7	Ref
Battery	78.7	Ref
Motor	50.0	Ref
Handle	50.0	Ref
Knob	50.0	Ref
No indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		

38.2	Temperature Test (discharge cycles)		P
	Test voltage (V)..... :	48	
	Ambient (C) ..... :	50.0	

Thermocouple locations	T (C)	T (C)
Battery	67.8	Ref
Enclosure inside	67.2	Ref
Enclosure Outside	68.4	Ref
Motor	72.4	Ref
Handle	50.6	Ref
Knob	52.4	Ref
No indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		

38.2	Temperature Test (charge cycles)		P
	Test voltage (V)..... :	120	
	Ambient (C) ..... :	-30	

Thermocouple locations	T	Max. T

	(C)	(C)
Power supply cord	-18.6	Ref
Connector	-11.5	Ref
LI-ION BATTERY CHARGER	-9.3	Ref
Battery	-1.3	Ref
Motor	-30.0	Ref
Handle	-30.0	Ref
Knob	-30.0	Ref
No indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		

38.2	Temperature Test (discharge cycles)		P
	Test voltage (V)..... :	48	
	Ambient (C) ..... :	-30.0	

Thermocouple locations	T (C)	T (C)
Battery	-12.2	Ref
Enclosure inside	-12.8	Ref
Enclosure Outside	-11.6	Ref
Motor	-7.6	Ref
Handle	-29.4	Ref
Knob	-27.6	Ref
No indication of fire, explosion, rupture, electrolyte leakage, or shock hazard.		

Batteries test			
Test Procedure	Requirements	Test Result	Verdict
The representative units are to be placed in a full-draft circulating-air oven maintained at a uniform temperature of 70°C (158°F) or 10°C (18°F) higher than the maximum temperature observed on the part during the Temperature Test, Section 31. The units are to remain in the oven for 7 hours. To inhibit hazards from overheating energized cells, units shall be fully discharged prior to conditioning.	After careful removal from the oven, the units shall be allowed to cool to room temperature and then examined. After the examination, the units shall be subjected to a Dielectric Strength Test, Section 32, or Isolation Resistance Test, Section 33, (without humidity conditioning). There shall be no damage of the vehicle system enclosure that would allow hazardous voltage parts to be accessed by use of the test rod 2.5 mm diameter, 100 mm long, shown in Figure 1 of the Standard for Batteries for Use in Light Electric Vehicle (LEV) Applications, UL 2271, and the articulate probe shown in Figure 17.1.	After the test, the units Dielectric Strength Test were pass, Isolation Resistance were pass There no damage of the vehicle system enclosure	Pass
45.2**Overcharging test**			
Test Procedure	Requirements	Test Result	Verdict

The battery is placed on a soft wood surface covered by two layers of tissue paper and the sample is covered by one layer of untreated 100 percent cotton medical gauze and charged at a rate of 10 times the manufacturer's recommended rate for the battery for 1.25 hours or at the maximum output that is available from an external source provided with the pack. There shall be no explosion and no charring or burning of the gauze or tissue paper. Charring is defined as a blackening of the gauze caused by combustion. Discoloration of the gauze caused by smoke is acceptable. Venting of the cells is acceptable	Products shall withstand abusive overcharging without risk of fire or explosion when tested	Products were withstand abusive overcharging without risk of fire or explosion	Pass

45.2	**Locked Rotor Motor Test**		P
Temperature rise of part/at:		T (C)	T (C)
Motor		116.8	175

45.6	**Running Overload Test**		P
Temperature rise of part/at:		T (C)	T (C)
Motor		90.7	165

60.2 Reverse Pedaling Test			
Test Procedure	Requirements	Test Result	Verdict
The sample shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test. Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value. The pedals are operated in reverse and the motor current value is observed. The motor current value is recorded during this operation and shall not exceed the non-assist current value.	The motor assistance shall not be activated when the pedals are operated in reverse. The motor current shall not increase above the non-assist current value when tested	The motor assistance no activated when the pedals are operated in reverse. The motor current l no increase above the non-assist current value	Pass

60.4 Cutoff When Braking Test			
Test Procedure	Requirements	Test Result	Verdict

The sample shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test. Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value. The sample is operated at any convenient speed for this test. While pedaling, the brake device is actuated and the motor current shall be interrupted and begin to decrease. This test is repeated for each brake device that is provided with cutoff functionality, one brake device for each test.	The motor assistance shall cutoff when the brake device is actuated.	The motor assistance were cutoff when the brake device is actuated.	Pass

60.5 Cutoff at Maximum Speed Test			
Test Procedure	Requirements	Test Result	Verdict
The sample shall be provided with a fully charged battery for this test. The test can be performed on a test track or on a test bench that keeps the assisted wheel free of the ground during the test. Motor current is to be monitored throughout the test. Prior to any start of pedaling (stand by condition), the motor current is measured and recorded. This is considered the non-assist current value. During the test, the current to the motor will increase due to motor assist. The test is terminated when the motor returns to this non-assist current value. The sample is to be operated for 5 minutes as a speed equal to 80 percent of its marked maximum assistance speed. After this duration, the speed is increased to the maximum speed the motor will allow but not more than 125 percent of the marked maximum assistance speed. The motor current shall be reduced to the non-assist current value when, or before, the maximum speed of the sample reaches the marked maximum assistance speed.	The motor assistance shall be cutoff on or before the sample obtains the marked maximum assistance speed when tested	The motor assistance were cutoff on or before the sample obtains the marked maximum assistance speed	Pass

TABLE: Components				P
Object / part No.	Manufacturer/ trademark	Type / model	Technical data	Mark(s) of conformity
Plug	Various	V-20	125V~, 7A	UL E468831
Power supply cord	Various	SVT	300V, VW-1, 105, 18AWG	UL E468831
Connector	Various	JT-872B	125V~, 10A	UL E306012
LI-ION BATTERY CHARGER	Wuxi Dpower Electronic Co., Ltd.	DPLC110V55	Input: 100-240V~, 50/60Hz, 2.0A; Output:54.6VDC, 2.0A	UL E494189
Battery	Various	---	48VDC, 20A, 13AH	UL
Motor	Various		48VDC, 2A	Test with appliance
Bobbin	Various	---	94V-0,130°C	UL
Tap	Various	---	130°C	UL
Insulated Winding Wire	Various	---	130°C, (Class B)	UL

Photos
Details of: GS9

Details of: LI-ION BATTERY CHARGER

Details of: LI-ION BATTERY CHARGER

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