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**Outline of Investigation for Electric Bicycles, Electrically Power Assisted
Cycles (EPAC Bicycles), Electric Scooters, and Electric Motorcycles**

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Summary of Topics

This third issue of the Outline of Investigation for Electric Bicycles, Electrically Power Assisted Cycles (EPAC Bicycles), Electric Scooters, and Electric Motorcycles, UL 2849, covers the expansion of the scope to cover electric bicycles that are not pedalec type, electric scooters, and electric motorcycles. Electric scooters and electric motorcycles refer to vehicles that are intended for use over road ways. Further, this new issue of the outline covers requirements for battery packs and chargers, including the correlation of the charger and battery combination.

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CONTENTS

INTRODUCTION

1 Scope	5
2 Components	5
3 Units of Measurement	6
4 Undated References	6
5 Glossary	6

CONSTRUCTION

6 General	7
7 Connection to Supply Source	8
7.1 General	8
7.2 Off board chargers	8
7.3 On board chargers	9
8 Personnel Protection Systems	9
9 Bonding of the Vehicle	10
9.1 General	10
9.2 Bonding connections	10
10 Double Insulation	11
11 Safety Circuits and Safety Analysis	12
12 Enclosures	14
13 Materials	14
13.1 Nonmetallic materials	14
13.2 Metallic materials	15
14 Flammability	16
15 Spacings and Separation of Circuits	16
16 Printed Wiring Boards	18
17 Internal Wiring and Terminals	18
18 Transformers	19
18.1 General	19
18.2 Coil insulation	20
19 Fuses	22
20 Capacitors	22
21 Strength of Enclosures	23
22 Sharp Edges	23
23 Battery Packs	23
24 Operator Interface	23
25 Motors and Motor Controllers	23
26 Mounting	24

PERFORMANCE

27 General	24
28 Input Test	25
29 Leakage Current	25
30 Capacitor Discharge Test	28
31 Temperature Test	28
32 Dielectric Strength Test	30
33 Isolation Resistance Test	32

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34	Humidity Conditioning	32
35	Abnormal Operations Tests	33
35.1	General	33
35.2	Transformer burnout test	34
35.3	Transformer overload test	36
35.4	Flanged bobbin transformer abnormal test	37
35.5	Capacitor faults	39
35.6	Electrolytic capacitor faults	39
35.7	Component fault tests	40
35.8	Forced ventilation/blocked ventilation	40
36	Vibration Test	40
37	Impact Test	41
38	Environmental Tests	41
38.1	Water exposure test	41
38.2	Thermal cycling	42
39	Motor Assistance Control - Pedalec	43
40	Startup Assistance Mode Test	43
41	Maximum Assistance Speed	43
42	Mold Stress	43
43	Permanence of Marking	44

MARKINGS

44	General	44
45	Nameplate and Identification	45
46	Cautionary Markings	45

INSTRUCTIONS

47	General	46
48	Instructions Pertaining to Risk of Fire, Electric Shock, or Injury To Persons	46
49	Installation Instructions	48
50	Operating Instructions	48
51	User Maintenance Instructions	49
52	Moving and Storage Instructions	49

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INTRODUCTION

1 Scope

1.1 This Outline covers the electrical systems of eBikes, electric scooters, and electric motorcycles. EBIkes are defined as both Pedalec (pedal assist) and non-Pedalec types. Electric scooters and electric motorcycles are intended for over the road use.

1.2 This Outline covers the on board electrical system, vehicle systems (which includes the combination of chargers and batteries) of eBikes, electric scooters, and electric motorcycles. When the battery is charged while integrated in the vehicle, the charging function is included in the scope of this Outline. If the battery is removed from the vehicle for charging, then the charging function is outside the scope of this Outline, however, the requirements for the charger still apply.

1.3 This Outline does not cover any other electrically powered vehicle other than eBikes, electric scooters, and electric motorcycles, as defined within this document. Electrically powered scooters that are not intended for road use and are intended for personal mobility are covered under the Standard for Electrical Systems for Personal E-Mobility Devices, UL 2272.

1.4 Requirements contained in 16 CFR Part 1512, Requirements for Bicycles, apply to eBikes. Verification of compliance with 16 CFR Part 1512 is outside the scope of this Outline.

1.5 Federal Motor Vehicle Safety Standards (FMVSS) outlined under 49 CFR, Chapter V, apply to electric scooters and electric motorcycles. Compliance with these FMVSS documents is outside the scope of this Outline.

2 Components

2.1 A component of a product covered by this Outline shall comply with the requirements for that component.

2.2 A component is not required to comply with a specific requirement that:

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this Outline; or
- b) Is superseded by a requirement in this Outline.

2.3 A component shall be used in accordance with its rating established for the intended conditions of use.

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

3 Units of Measurement

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

4 Undated References

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

5 Glossary

5.1 For the purpose of this Outline the following definitions apply.

5.2 CHARGER – An off board or on board device that converts grid power to DC power for charging the on board battery.

5.3 eBIKE – An electrical/mechanical vehicle provided with pedals that includes an electric motor to either assist the rider when pedaling (pedalec versions) or provide motive power to the wheels when the rider is not pedaling.

5.4 ELECTRICAL SYSTEM, ONBOARD – All electrical components located on the vehicle including, but not limited to, the motor, motor controller, interface/controls, battery pack and charging circuitry (which may include an on board charger).

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

5.6 END-OF-DISCHARGE VOLTAGE (EODV) – The voltage, under load, of the cell or battery at the end of discharge. The EODV may be specified, as in the case of a voltage terminated discharge, or simply measured in the case of a time-controlled discharge.

5.7 LIVE PART – A conductive part, such as metal, within the unit that during intended use has a potential difference with respect to earth ground or any other conductive part.

5.8 MOTORCYCLE, ELECTRIC – A two or three wheeled electric vehicle that includes a seat for the rider. The rider is intended to straddle the vehicle while riding. No pedals are included and the throttle controls the propulsion action. These vehicle types are suitable for over the road use.

5.9 PEDALEC – A version of an eBike where the motor only operates when the pedals are being used by the rider. The motor stops when the rider stops pedaling or when the eBike reaches a maximum speed of 20 mph (32.2 kph).

5.10 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist at any exposed live part of a product or system if the available open-circuit potential is higher than 42.4 volts peak or 60 V dc and the available current through a 1500-ohm resistance is more than 5 milliamperes.

5.11 RISK OF ELECTRICAL ENERGY – HIGH CURRENT – The capability for damage to property or injury to persons, other than by electric shock, from available electrical energy exists when between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 volts or more and either an available continuous power level of 240 volt-amperes or more, or a reactive energy level of 20 joules or more. For example, a tool, or other metal short-circuiting a component causes a risk of a burn or a fire when enough energy is available at the component to vaporize, melt, or more than warm the metal.

5.12 SCOOTER, ELECTRIC – A two- or three-wheeled electric vehicle that includes a flat section or footrests for the riders feet, a seat for the rider, and a pass-through type design for the footrest portion which is located lower than the seat. No pedals are included and the throttle controls the propulsion action. These vehicle types are suitable for over the road use.

5.13 VEHICLE SYSTEM – The combination of the on board electrical system (without an on board charger) and an off board charger.

CONSTRUCTION

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).

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.

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.

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).

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.

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.

7 Connection to Supply Source

7.1 General

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.

7.2 Off board chargers

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:

- a) The Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202.
- b) The Standard for Power Units Other Than Class 2, UL 1012.
- c) The Standard for Class 2 Power Units, UL 1310.
- d) The Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1, along with the relevant Part 2 Standard as applicable.

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.

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.

7.3 On board chargers

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.

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:

- a) Electric Vehicle Supply Equipment in accordance with the Standard for Electric Vehicle Supply Equipment, UL 2594.
- b) Connection to a NEMA 5-20R receptacle using a suitable power supply cord.

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.

7.3.4 In all cases with an on board charger, a personnel protection system in accordance with Section 8 shall be provided.

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.

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.

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.

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.

9 Bonding of the Vehicle

9.1 General

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.

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.

9.1.3 The requirements in 9.1.1 and 9.1.2 apply for both on board chargers and off board chargers.

9.2 Bonding connections

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.

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.

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.

9.2.4 An equipment-bonding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel.

9.2.5 An equipment-bonding point shall be located so that the risk of inadvertently removing the bonding means during servicing is reduced.

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.

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.

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.

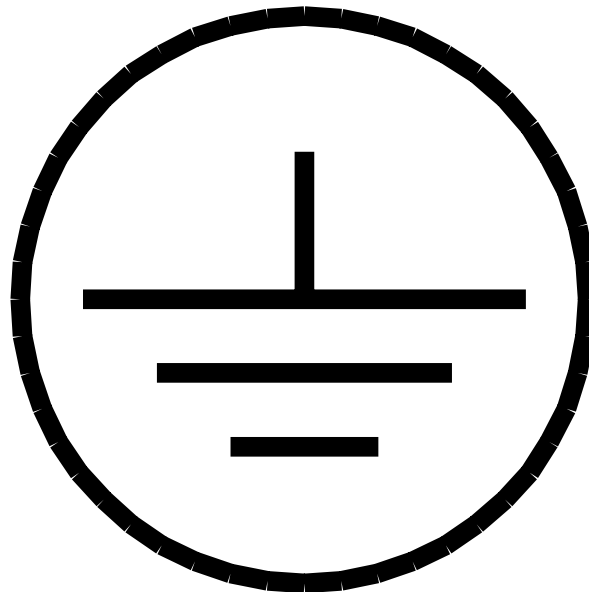
9.2.9 A soldering lug, a connection means that depends on solder, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used for equipment-grounding or equipment-bonding.

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.

9.2.11 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;
- b) The grounding symbol illustrated in Figure 9.1 on or adjacent to the terminal or on a wiring diagram provided on the product.

Figure 9.1
Symbol for equipment bonding connection



IEC Publication 60417, Symbol 5019

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.

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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.

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.

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.

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:

- a) The Standard for Analysis Techniques for System Reliability - Procedure for Failure Mode and Effects Analysis (FMEA), IEC 60812;
- b) The Standard for Fault Tree Analysis (FTA), IEC 61025;
- 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
- d) The Procedures for Performing a Failure Mode, Effects, and Criticality Analysis, MIL-STD-1629A.

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.

11.6 When conducting the analysis of 11.4, active devices shall not be relied upon for critical safety unless:

- a) They are provided with a redundant passive protection device; or
- 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
- c) They are determined to fail safe upon loss of power to the active circuit.

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:

- 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;
- b) The Standard for Automatic Electrical Controls for Household and Similar Use - Part 1: General Requirements, UL 60730-1; and
- c) The Standard for Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems - Part 1: General Requirements, IEC 61508-1, and all parts.

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:

- a) Disconnect both poles of the hazardous voltage circuit;
- b) Be accessible and able to be operated without the use of a tool in the event of a collision or during servicing;
- c) Require manual action to break the electrical connection;
- 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
- 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.

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:

- a) Not be able to be reset automatically although it may be able to be reset deliberately upon clearing of the fault;
- b) Disconnect both poles of the hazardous voltage circuit;
- c) Be capable of handling full load disconnects of the hazardous voltage circuit that it is isolating; and
- d) Not result in a hazardous condition upon automatic actuation.

12 Enclosures

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.

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.

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 $\pm$ 10 percent.

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.

13 Materials

13.1 Nonmetallic materials

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.

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.

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.

- a) Resistance to Impact;
- b) Crush Resistance;
- c) Abnormal Operations;
- d) Severe Conditions; and
- e) Mold Stress Relief Distortion.

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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.

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.

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.

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.

13.2 Metallic materials

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.

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.

13.2.3 Conductive parts in contact at terminals and connections shall not be subject to corrosion due to electrochemical action.