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SUBJECT 3456

OUTLINE OF INVESTIGATION

FOR

ELECTRIC-BATTERY-POWERED CARTS FOR COMMERCIAL USE

ISSUE NO: 9

OCTOBER 22, 2010

Summary of Topics

This is the ninth issue of the Outline of Investigation for Electric-Battery-Powered Carts For Commercial Use, Subject 3456, which includes revisions to the definition of a low-voltage circuit and climate conditioning.

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INTRODUCTION

1 Scope

1.1 These requirements cover electric-battery-powered carts designed for a single user for indoor commercial use with respect to a risk of fire, electric shock, and personal injury.

1.2 These requirements cover electric-battery-powered carts powered by batteries supplying 42.2 Vac (peak) or 60 Vdc or less.

1.3 The electric-battery-powered cart shall be equipped with no less than 3 wheels, not including anti-tip devices.

1.4 The maximum speed shall not exceed 3 mph (4.8 kph).

1.5 These requirements do not cover electric-battery-powered carts intended for recreational, residential or industrial use.

1.6 The requirements do not cover electric-battery-powered carts for use in hazardous locations.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this outline shall comply with the requirements for that component. They shall be located and secured so that they are not adversely affected by vibration, temperature, environment and other effects during normal operation. See Appendix A for a list of standards covering components generally used in the products covered by this outline.

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- b) Is superseded by a requirement in this outline.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 ANTI-TIP DEVICE – A component to limit the extent of tipping the cart.

5.3 CART – Electric battery powered cart intended for a single user.

5.4 CIRCUIT CLASSIFICATIONS:

a) High-Voltage Circuit – A circuit of a potential having characteristics in excess of those of a low-voltage circuit.

b) Low-Voltage Circuit – A circuit involving a peak open-circuit potential of not more than 60 Vdc or 30 Vrms (42.4 Vac peak) supplied by a battery, a Class 2 transformer, or by a combination of a transformer and a fixed impedance that as a unit, complies with all performance requirements for a Class 2 transformer. A circuit derived by connecting a resistance in series with a voltage supply circuit as a means of limiting the voltage and current, is not considered to be a low-voltage circuit.

c) Power-Limited Circuit – A circuit wherein the power is limited from a source whose open circuit voltage is less than or equal to 60 Vdc and whose maximum current and power after 60 s of operation comply with the values outlined in Tables 39.1 and 39.2. Limited power control circuits shall comply with the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1.

5.5 CONTROL CIRCUIT – A circuit that is considered neither a Power, Low-Voltage, or Limited Power Circuit. Also, a circuit which supplies a motor that has a locked-rotor current of 15 amperes or less, and is protected by an overcurrent device having a maximum rating or setting of 15 amperes.

5.6 ELECTROSTATIC DISCHARGE (ESD) – Discharge created by static electricity.

5.7 OPERATING CONTROL – Control which starts or regulates the equipment during normal operation.

5.8 POWER CIRCUIT – A circuit that has a source of supply capable of short circuit currents greater than 15 amperes, and that is not protected by an overcurrent device having a maximum rating or setting of 15 amperes. Also, a circuit is considered a power circuit if it supplies a motor except as noted in the control circuit definition.

5.9 PROTECTIVE CONTROL – Automatic controls and interlocks including relays, switches, sensors and other auxiliary equipment used in conjunction therewith to form a safety control system, which is intended to prevent unsafe operation of the controlled equipment.

5.10 RISK OF ELECTRIC SHOCK – A risk of electric shock is determined to exist within a circuit defined in 5.4(a).

5.11 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The risk for damage to property or injury to persons, other than by electric shock, from available electrical energy is determined to exist, 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:

- a) An available continuous power level of 240 volt-amperes or more, or
- b) A reactive energy level of 20 joules or more.

For example, a tool, or other metal short-circuiting a component is capable of causing a burn or a fire when enough energy is available at the component to vaporize, melt, or more than warm the metal.

5.12 RISK OF FIRE – A risk of fire is determined to exist within a circuit unless that circuit meets the requirements defined in 5.4(c).

5.13 SERVICE PERSONNEL – Persons having technical training and experience required to be aware of the risks encountered when performing a task and the measures to be taken to minimize the risks to themselves and other persons.

5.14 TIPPING ANGLE – The angle of the test plane relating to horizontal at which the forces become zero under all uphill wheels.

5.15 TOUCH CURRENT – Electric current through a human body or an animal body when it touches one or more accessible parts.

5.16 ULTIMATE ENCLOSURE – Any exposed surface that could be subjected to impact or damage by external means.

5.17 USER – Any person other than service personnel.

5.18 USER ACCESS AREA – An area to which, under normal operating conditions, one of the following applies:

- a) Access is gained without the use of a tool;
- b) The means of access is deliberately provided to the operator; or
- c) The operator is instructed to enter regardless of whether or not tools are required to gain access.

6 Reference Standards

6.1 Other standards applying to carts are the Standard for Requirements and Test Methods for Wheelchairs (Including Scooters), ANSI/RESNA WC, Vol. 1 and the Standard for Additional Requirements for Wheelchairs (Including Scooters) with Electrical Systems, ANSI/RESNA WC, Vol. 2.

7 Samples

7.1 Unless otherwise stated, compliance with the performance requirements for a cart shall be determined by testing a representative model of a new vehicle.

CONSTRUCTION

8 General

8.1 All electrical parts shall be enclosed within the body of the cart to provide protection of internal components and prevent contact with uninsulated live parts.

Exception: Current carrying parts in a limited power circuit are not required to comply with this requirement.

8.2 A current-carrying part shall be of nonferrous metal.

Exception: Ferrous metal is permitted to be used for a resistor terminal in the power circuit and for all parts of the lighting, warning-signal, and other auxiliary and motor-control circuits.

8.3 Parts formed of iron or steel and functioning as a guard or enclosure for hazardous parts or acting as load supporting components where their failure could create a risk of fire, electric shock, injury to persons, or impact the operation of the product shall be protected against corrosion by painting, galvanizing, plating or by other equivalent means.

8.4 Where breakage or deterioration of a part such as an enclosure, a frame, a guard, or the like can result in a risk of injury to persons, the part shall be constructed to meet the demand or expected loading conditions.

8.5 The requirement in 8.4 also applies to those positions of a part adjacent to a moving part identified to involve a risk of injury to persons.

8.6 Contactors and overcurrent protection devices shall be located so as to be readily accessible for servicing, such as complete replacement or the replacement of contacts and inspection after the removal of a cover or covers. Other arcing and operating parts shall be accessible for servicing and inspection.

8.7 A gasket employed between a cover and a box shall be cemented or otherwise secured to one of the gasketed surfaces.

8.8 A drip pan shall not permit the collection of any fluids.

8.9 When charging, it shall not be possible to energize the cart movement circuits. See Section 22.

9 Internal Wiring

9.1 The internal wiring shall consist of general-use or appliance-wiring. The wiring shall be considered with respect to the temperature, voltage, ampacity and conditions of service to which the wiring shall be subjected in the end cart installation.

Exception: Wiring located in low voltage and limited power circuits are not required to comply with this requirement.

9.2 Wiring shall be protected against mechanical damage by:

- a) Enclosing it in the body of the cart; or
- b) Enclosing it in a metal raceway, armored cable, rigid metal conduit, electrical metallic and nonmetallic tubing, flexible nonmetallic conduit or nonmetallic insulated tubing.

Exception: Wiring located in low voltage and limited power circuits are not required to comply with this requirement.

9.3 Wiring connections to a continuously moving part, or a part for which the degree of movement is appreciable shall be flexible type cord.

9.4 All of the splices and connections shall be mechanically secure and shall provide electrical contact without stress on connections and terminals. A splice shall be provided with insulation equivalent to that on the wires involved.

9.5 A hole in the wall within the overall enclosure of a product which insulated conductors pass, shall be provided with a bushing or shall have smooth, rounded surfaces.

9.6 Wireways shall be smooth and free from sharp edges, burrs, fins, or moving parts that may damage wiring.

9.7 An internal-wiring connection shall be made with a solder lug, pressure terminal connector or crimped lugs.

9.8 A terminal lug shall be arranged so that in any position it cannot contact either the frame of the cart or other electrical circuits, or the shank of the lug shall be provided with insulation equivalent to that on the conductor.

9.9 A charging plug shall be mechanically secured, by positive action, within the profile of the cart so that it is protected from jarring, vibration and impact that would dislodge or damage the plug when it's not in use. The weight of the charging plug or cord shall not be one of the means for securement.

9.10 The charging cord shall not have contact with the ground when the charging plug is mechanically secured as defined in 9.9.

10 Motors and Electromechanical Brakes

10.1 Motor construction shall comply with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1. Motors with integral motor protection shall comply with the Standard for Impedance Protected Motors, UL 1004-2, or the Standard for Thermally Protected Motors, UL 1004-3.

Exception No. 1: When the protection is not integral to the motor, the motor/controller combination shall be evaluated as an electronically protected motor that complies with the Standard for Impedance Protected Motors, UL 1004-2, or the Standard for Thermally Protected Motors, UL 1004-3.

Exception No. 2: Motors located in low voltage and limited power circuits are not required to comply with this requirement.

10.2 Electromechanical brakes shall comply with Part XVI, Miscellaneous Devices, of the Standard for Industrial Control Equipment, UL 508.

Exception: Electromechanical brakes located in low voltage and limited power circuits are not required to comply with this requirement.

11 Switches and Motor Contactors

11.1 A safety switch shall be incorporated to not allow movement of the cart when the cart is energized and the user is not in the intended operating position.

11.2 A safety switch shall comply with the requirements of the relevant component standard and be suitable for 100,000 cycles of operation at the rated load and ambient temperature.

Exception: A safety switch located in a limited power circuit need only comply with the 100,000 cycle endurance test.

11.3 A motor contactor or switch shall be rated for the load that it controls. A motor contactor shall have the current interrupting capacity not less than the locked rotor load of the motor controlled.

Exception: A motor contactor or switch complies with the requirements in Section 36, Arc-Rupture Test.

11.4 A motor contactor or switch intended to provide a safety related function shall comply with the requirements of the relevant component standard and be suitable for 100,000 cycles of operation at the rated load and ambient temperature.

11.5 A switch that controls an inductive load other than a motor, such as a transformer, shall not be less than twice the rated full-load current of the transformer, or similar device, unless the switch has been investigated and found acceptable for the application.

12 Battery Chargers

12.1 Battery chargers shall comply with the Standard for Power Units Other Than Class 2, UL 1012, or the Standard for Class 2 Power Units, UL 1310, as applicable.

12.2 The battery chargers shall be suitable for outdoor use, and shall incorporate back-feed protection.

12.3 The power supply cords used with the battery chargers shall be Type SJTW, SJEW, SJTOW, SJEOW, SJTOOW, SJEOW flexible cord.

13 Inverters and Converters

13.1 Inverters and converters with a nominal output of 24 Vdc or less shall comply with the Standard for Power Converters/Inverters and Power Converter/Inverter Systems for Land Vehicles and Marine Crafts, UL 458.

Exception: Inverters and converters with a nominal output of more than 24 Vdc shall comply with the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741.

14 Lights and Audible Devices

14.1 Lights, including light emitting diodes (LED), vacuum fluorescent display (VFD), backlit liquid crystal display (LCD), and any other displays that may be a source of ignition if mechanically damaged shall be protected against mechanical damage. Refer to nonmetallic Electrical Enclosures, Section 16.

Exception: This requirement does not apply to light located in a low voltage and limited power circuit.

14.2 The coil and other electrical parts of an electrical audible device shall be totally enclosed. Refer to nonmetallic Electrical Enclosures, Section 16.

Exception: This requirement does not apply to audible device located in a low voltage and limited power circuit.

15 Batteries

15.1 Lithium batteries shall comply with the Standard for Lithium Batteries, UL 1642. Lithium cells shall be provided with the appropriate reverse charging protection in the battery circuitry.

15.2 Lead acid type batteries shall comply with the construction requirements of the Standard for Standby Batteries, UL 1989. In addition, lead acid-type batteries shall comply with the Pressure Release Test or the Flame Arrester Vent Cap Tests of UL 1989, whichever applies.

15.3 Other chemistries, such as nickel-cadmium or nickel-metal-hydride cells shall comply with the Standard for Household and Commercial Batteries, UL 2054.

15.4 A battery shall be protected by means of an ultimate enclosure. Refer to nonmetallic Electrical Enclosures, Section 16, and Battery Compartment or Enclosure, Section 25.

16 Electrical Enclosures

16.1 General

16.1.1 A cart 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.

Exception: Live parts, including terminals, which do not present a risk of electric shock or a risk of electrical energy – high current levels, are not required to be enclosed.

16.2 Nonmetallic enclosures

16.2.1 Materials employed as a nonmetallic electrical enclosure shall comply with Material Property Considerations of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, Path II.

16.3 Metallic enclosures

16.3.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 16.1.

Exception: When the thickness of the sheet metal enclosure is less than that specified in Table 16.1, the electrical enclosure shall comply with the Impact Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, Path II.

Table 16.1
Thickness of sheet metal for enclosures

Sheet metal	Thickness	
	inch	(mm)
Carbon Steel or Stainless Steel (uncoated)	0.020	(0.51)
Carbon Steel or Stainless Steel (zinc coated)	0.023	(0.58)
Aluminum, Copper, or Brass	0.023	(0.58)

17 Nonmetallic Electrical Insulation

17.1 A material that is used for the direct support of an uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 17.1. A material is in direct support of an uninsulated live part when:

- a) It is in direct physical contact with the uninsulated live part, and;
- b) It serves to physically support or maintain the relative position of the uninsulated live part.

Exception No. 1: The generic materials complying with Table 17.2 are not prohibited for the direct support of uninsulated live parts without additional evaluation.

Exception No. 2: Those materials without HWI Performance Level Category (PLC) values or with HWI PLC values higher (worse) than those required by Table 17.1 shall alternatively be subjected to the end-product Abnormal Overload Test in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 3: Those materials without HAI Performance Level Category (PLC) values or with HAI PLC values higher (worse) than those required by Table 17.1 shall alternatively be subjected to the end-product Special Arcing Test in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 4: Those materials that are used in devices that do not incorporate contacts are not required to comply with the HAI Performance Level Category (PLC) requirements.

Exception No. 5: Those materials that are used in devices that incorporate contacts and are not used within 1/2 inch (12.7 mm) of the contacts are not required to comply with the HAI Performance Level Category (PLC) requirements.

Exception No. 6: Those materials without CTI Performance Level Category (PLC) values or with CTI PLC values higher (worse) than the CTI required by Table 17.1 shall alternatively be subjected to the end-product Special Arcing Test in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 7: Those materials without CTI Performance Level Category (PLC) values or with CTI PLC values higher (worse) than the CTI required by Table 17.1 shall be in compliance with the CTI PLC requirement when:

- a) They have a High-Voltage-Arc Tracking (HVTR) PLC value of 1 or lower (better), or
- b) The over surface spacings between the uninsulated live parts are at least 1/2 inch (12.7 mm).

Table 17.1
Minimum material characteristics required for the direct support of uninsulated live parts

UL 94 ^a Flame class	Elec RTI	HWI ^c	HAI ^c	CTI ^d
HB	b	2	1	4
V-2	b	2	2	4
V-1	b	3	2	4
V-0	b	4	3	4

^a Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

^b The electrical RTI value of a material shall be determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used and shall not be exceeded during the Temperature Test, Section 34.

^c The HAI and HWI Performance Level Category (PLC) value of a material shall be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used.

^d The CTI PLC value of a material shall be determined by test in accordance with UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used.

Table 17.2
Generic materials used for the direct support of uninsulated live parts

Generic material	Thickness	RTI, °C
Any cold-molded composition (i.e. concrete)	No limit	No limit
Ceramic, Porcelain, and Slate	No limit	No limit
Diallyl Phthalate	0.028 inch (0.71 mm)	105
Epoxy	0.028 inch (0.71 mm)	105
Melamine	0.028 inch (0.71 mm)	130
Melamine-Phenolic	0.028 inch (0.71 mm)	130
Phenolic	0.028 inch (0.71 mm)	150
Unfilled Nylon	0.028 inch (0.71 mm)	105
Unfilled Polycarbonate	0.028 inch (0.71 mm)	105
Urea Formaldehyde	0.028 inch (0.71 mm)	100

NOTE – Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Test, Section 34.

17.2 Insulating material – such as a relay dust cover, transformer bobbin, inductor bobbin, insulating sheet, encapsulation, or similar material that is used as a barrier in lieu of the required over surface, or through air spacings, or both, shall comply with the requirements in 17.5 – 17.10.

17.3 Vulcanized fiber is not prohibited from being used for insulating bushings, washers, separators, and barriers, and shall not be used as sole support for uninsulated live parts.

17.4 A sensor such as a current transformer, transducer, or similar device shall be provided with insulation that has been evaluated for the maximum voltage and temperature involved in its application, while taking into consideration the presence of other circuits.

17.5 Insulating material is not prohibited from being used as a barrier in lieu of the required spacings per Section 20, Electrical Spacings.

17.6 The insulating material specified in 17.5 shall comply with the requirements in 17.7 when:

- a) The material is in direct physical contact with an uninsulated live part;
- b) The material serves to physically support, or maintain the relative position of the uninsulated live part; and
- c) The material is used as a barrier in lieu of the required over surface or through air spacings.

17.7 An insulating material used as noted in 17.5 shall:

- a) Comply with 17.1; and
- b) Be at least 0.028 inch (0.71 mm) thick.

Exception No. 1: A material that complies with 17.1 and does not comply with the thickness limit in (b) shall alternatively be subjected to a 5000 V ac Dielectric Voltage Withstand Test in accordance with the Internal Barrier requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 2: A material that complies with 18.3 and is used in addition to not less than one-half the required through air spacings is not prohibited from being less than 0.028 inch (0.71 mm) thick, and shall be at least 0.013 inch (0.33 mm) thick. This material shall:

- a) Have the required mechanical strength when exposed or otherwise subjected to mechanical damage;*
- b) Be held in place; and*
- c) Be located so that it is not adversely affected by operation of the equipment in service.*

17.8 The two requirements noted in 17.7 are independent of each other.

17.9 An insulating material shall also comply with the requirements in 17.7 when:

- a) The material is in direct physical contact with an uninsulated live part;
- b) The material does not serve to physically support or maintain the relative position of that uninsulated live part; and
- c) The material is used in lieu of the required over surface, or through air spacings.

Exception: The generic insulating materials in Table 17.3 comply for this application without additional evaluation.

17.10 An insulating material shall also comply with the requirements of 17.7 when:

- a) The material is not in direct physical contact with an uninsulated live part;
- b) The material does not serve to physically support, or maintain the relative position of that uninsulated live part; and
- c) The material is used in lieu of the required through air spacings.

Exception No. 1: The generic insulating materials in Table 17.3 comply for this application without additional evaluation.

Exception No. 2: The Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI) and Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements do not apply for materials that are located at least 1/32 inch (0.8 mm) from uninsulated live parts.

Exception No. 3: The Hot Wire Ignition (HWI), High-Current Arc Resistance to Ignition (HAI) and Comparative Tracking Index (CTI) Performance Level Category (PLC) requirements and RTI requirements do not apply for materials that are located at least 1/2 inch (12.7 mm) from uninsulated live parts.

Table 17.3
Generic materials used as a barrier per 17.8 and 17.9

Generic material ^a	Minimum thickness		RTI, °C
	inch	(mm)	
Aramid Paper	0.010	(0.25)	105
Cambric	0.028	(0.71)	105
Electric Grade Paper	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Mica	0.006	(0.15)	105
Mylar (PETP)	0.007	(0.18)	105
RTV	0.028	(0.71)	105
Silicone	0.028	(0.71)	105
Treated Cloth	0.028	(0.71)	105
Vulcanized Fiber	0.028	(0.71)	105
^a Each material shall be used within its minimum thickness and its RTI value shall not be exceeded during the Temperature Test, Section 34.			

18 Printed-Wiring Boards

18.1 A printed-wiring board, including the coatings, shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796.

Exception: A printed-wiring board in a low voltage and limited power circuit is not required to comply with the bonding requirements of UL 796 if the board is separated from parts of other circuits such that loosening of the bond between the foil conductor and the base material will not result in the foil conductors or components coming in contact with parts of other circuits of the control or parts of the equipment.

18.2 The printed-wiring board shall be used within its parameters in accordance with Standard for Printed-Wiring Boards, UL 796. The operating temperature shall remain below the printed wiring boards maximum operating temperature (MOT) rating. The temperature used to determine the maximum operating temperature is the ambient surrounding temperature and the highest temperature on the board.

18.3 A printed-wiring board, including the coating, shall have a minimum flammability classification of V-2.

Exception: This requirement does not apply to printed-wiring board in a low voltage and limited power circuit.

19 Limited Power Circuit

19.1 A limited power circuit shall comply with the Limited Power Circuits Test, Section 39. See also 5.4(c).

20 Electrical Spacings

20.1 The spacings in a cart shall not be less than as specified in Table 20.1.

Exception No. 1: Minimum acceptable spacings are not specified in a low voltage and limited power circuit as defined in 5.4.

Exception No. 2: Minimum acceptable spacings within a component shall be determined by the component standard.

Exception No. 3: Solid state circuitry used within carts and evaluated by this outline may employ, as an alternative to the spacing requirements of Table 20.1, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840. When UL 840 is used, the following considerations shall apply:

- a) The spacing requirements of UL 840 shall not be used for spacings to an ultimate enclosure;*
- b) When a cart component employs a voltage limiting device for application of the requirements in UL 840, the device shall comply with the Standard for Surge Protective Devices, UL 1449 (this does not apply to circuits supplied only by batteries); and*
- c) Components supplied by battery circuits shall be considered over-voltage category II. An over-voltage category is the grouping of products based on a typical installed location with respect to over-voltage protection and available energy as defined in UL 840.*

Table 20.1
Minimum acceptable spacings

Location	Nominal voltage 24 volts or less				Nominal voltage greater than 24 volts			
	Through air		Over surface		Through air		Over surface	
	Inch	(mm)	Inch	(mm)	Inch	(mm)	Inch	(mm)
In a power circuit – between a bare live part and (1) a bare live part of opposite polarity, or (2) a bare grounded part other than the enclosure	1/16	(1.6) ^a	1/8	(3.2) ^a	1/8	(3.2) ^b	1/4	(6.4) ^b
In a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity ^c	1/32	(0.8)	1/16	(1.6)	1/16	(1.6)	1/8	(3.2)
In other than a power circuit – between a bare live part and (1) a bare live part of opposite polarity, or (2) a bare grounded part other than the enclosure	1/16	(1.6)	1/16	(1.6)	1/16	(1.6)	1/16	(1.6)
In other than a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity ^c	1/32	(0.8)	1/32	(0.8)	1/32	(0.8)	1/32	(0.8)
Between any uninsulated live part and the ultimate enclosure ^d	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)	1/2	(12.7)
Between any uninsulated live part and the ultimate enclosure where the enclosure is formed of 1/8 inch (3.2 mm) thick cast metal or 1/4 inch (6.4 mm) thick steel plate ^d	1/4	(6.4)	1/4	(6.4)	1/4	(6.4)	1/4	(6.4)
^a These spacings apply to a system not electrically connected to the frame. ^b These spacings also apply to a nominal 24-volt or lower-voltage system electrically connected to the frame. ^c Such as a point where a motor terminal passes through the motor frame. ^d If deformation of the enclosure at the point of measurement of spacings is likely, the spacings after deformation shall be as specified.								

21 Separation of Circuits

21.1 A limited power circuit shall be separated from all other circuits either by:

- a) Locating the circuit in a separate enclosure;
- b) Providing through-air and over-surface spacings as noted in Table 20.1; or
- c) The use of barriers.

21.2 An internal wiring insulated conductor of a limited power circuit shall be either separated by barriers or segregated from live parts connected to different circuits or provided with insulation acceptable for the highest voltage involved.

21.3 The barriers noted in 21.1(c) are permitted to be bonded metal not less than 0.020 in (0.51 mm) thick or insulating material not less than 0.028 in (0.71 mm) thick.