ANSI/CAN/UL 583:2025

JOINT CANADA-UNITED STATES
NATIONAL STANDARD

STANDARD FOR SAFETY

Electric-Battery-Powered Industrial Trucks

ANSI/UL 583-2025

SCC FOREWORD

National Standard of Canada

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UL Standard for Safety for Electric-Battery-Powered Industrial Trucks, ANSI/CAN/UL 583

Eleventh Edition, Dated December 15, 2022

Summary of Topics

This revision of ANSI/CAN/UL 583 dated May 1, 2025 includes the following changes in requirements:

– Revision to Update Paragraph Reference in 19.1(c);

– Addition of Requirements for Safety Markings; Markings and Advisory Notes for Sections 28, 38, 50, 56, 60, 62, 67, Annex A5, and Annex B

Text that has been changed in any manner or impacted by ULSE's electronic publishing system is marked with a vertical line in the margin.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated July 26, 2024 and February 7, 2025.

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ANSI/CAN/UL 583:2025

Standard for Electric-Battery-Powered Industrial Trucks

The first edition was titled Industrial Gasoline-Tractors. The second and third editions were titled Power-Operated Industrial Trucks (Electric Battery-Powered & Gasoline-Powered). The fourth edition was titled Power-Operated Industrial Trucks.

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Eleventh Edition

December 15, 2022

This ANSI/CAN/UL Safety Standard consists of the Eleventh Edition including revisions through May 1, 2025.

The most recent designation of ANSI/UL 583 as an American National Standard (ANSI) occurred on May 1, 2025. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on May 1, 2025.

No Text on This Page

CONTENTS

Preface

This is the Eleventh Edition of ANSI/CAN/UL 583, Standard for Electric-Battery-Powered Industrial Trucks.

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

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

Annex A is identified as Normative, as such, form mandatory parts of this Standard.

Annex B, identified as Informative, is for information purposes only.

This ANSI/CAN/UL 583 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

In Canada, there are two official languages, English and French. For this reason, where this Standard requires safety markings, it must provide a French translation of such markings. Annex B provides translations in French of the English safety markings specified in this Standard, for use wherever required in Canada.

This Eleventh Edition joint American National Standard and National Standard of Canada is based on, and now supersedes, the Tenth Edition of UL 583.

Comments or proposals for revisions on any part of the Standard may be submitted at any time. Proposals should be submitted via a Proposal Request in the Collaborative Standards Development System (CSDS) at https://csds.ul.com.

This Edition of the Standard has been formally approved by the Technical Committee (TC) on Industrial Trucks, TC 583.

This list represents the TC 583 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

TC 583 Membership

Name	Representing	Interest Category	Region
Bablo, Joseph	UL Solutions	Testing & Standards Org.	USA
Bender, Curtis	Tennant CO	Producer	USA
Bhattacharya, Rana	Electrovaya	Supply Chain	Canada
Burch, Christopher	FM Approvals LLC	Testing & Standards Org.	USA

TC 583 Membership Continued on Next Page

TC 583 Membership Continued

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Riley, Rolland	U S Army Ccdc Ground Vehicle Systems Center	Government	USA
Rupp, Mark	American Association Of Cleaning Equipment Manufacturers	General Interest	USA
Sanders, K	East Penn MFG CO INC	Producer	USA
Smith, R.	R K Smith Engineering INC	General Interest	USA
Spencer, Richard	Crown Equipment Corporation	Producer	USA
Sudler III, Samuel	SEA LTD	General Interest	USA
Tao, Luke	Hua Zhen(Guang Zhou) Standards Technical Services Co., Ltd	Testing & Standards Org.	China
Tepen, M.	Ford Motor CO	Commercial / Industrial User	USA
Wechsler, David	American Chemistry Council	General Interest	USA
Weidner, Gary	GW Technical Services	General Interest	USA
Xu, Michael	Cummins Inc	Supply Chain	Canada

International Classification for Standards (ICS): 53.060

This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

CETTE NORME NATIONALE DU CANADA EST DISPONIBLE EN VERSIONS FRANÇAISE ET ANGLAISE

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INTRODUCTION

1 Scope

1.1 These requirements cover electric battery-powered industrial trucks, such as tractors, platform-lift trucks, fork-lift trucks, and other vehicles designed for specific industrial uses, with respect to a risk of fire, electric shock, and explosion. These requirements do not cover such electric powered industrial trucks with respect to other possible risks that may be associated with the use of such trucks.

1.2 These requirements cover power sources intended for use in the electric powered industrial trucks specified in 1.1, with respect to the risk of fire, electric shock, and explosion.

1.3 These requirements cover Types E, CGH, E or CGH, EE, ES, and EX electric powered industrial trucks.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the requirements for that component.

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

a) Involves a feature or characteristic not needed in the application of the component in the product covered by this standard;

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

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

2.3 Specific components are recognized as being 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 for which they have been recognized.

2.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable standard(s) that cover devices that provide those functions.

3 Units of Measurement

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

4 Referenced Publications

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

4.2 The following publications are referenced in this standard:

CSA C22.1, *Canadian Electrical Code, Part I*

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

CSA C22.2 No. 0.2, *Insulation Coordination*

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

CSA C22.2 No. 25, *Enclosures for Use in Class II, Division 1, Groups E, F, and G Hazardous Locations*

CSA C22.2 No. 30, *Explosion-Proof Equipment*

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

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

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

CSA C22.2 No. 145, *Electric Motors and Generators for Use in Hazardous (Classified) Locations*

CAN/CSA-C22.2 No. 157, *Intrinsically Safe and Non-incendive Equipment for Use in Hazardous Locations*

CSA C22.2 No. 243, *Vacuum Cleaners, Blower Cleaners, and Household Floor Finishing Machines*

CSA C22.2 No. 269.1, *Surge Protective Devices – Type 1 – Permanently Connected*

CSA C22.2 No. 269.2, *Surge Protective Devices – Type 2 – Permanently Connected*

CSA C22.2 No. 269.3, *Surge Protective Devices – Type 3 – Cord Connected, Direct Plug-in and Receptacle Type*

CSA C22.2 No. 269.4, *Surge Protective Devices – Type 4 – Component Assemblies*

CSA C22.2 No. 269.5, *Surge Protective Devices – Type 5 – Components*

CAN/CSA-C22.2 No. 60079-11, *Explosive Atmospheres – Part 11: Equipment Protection by Intrinsic Safety "I"*

CAN/CSA-C22.2 No. 61058-1, *Switches for Appliances – Part 1: General Requirements*

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

NFPA 70, *National Electrical Code*

SAE J1128, *Low Voltage Primary Cable*

UL 62, *Flexible Cords and Cables*

UL 66, *Fixture Wire*

UL 83, *Thermoplastic-Insulated Wires and Cables*

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

UL 508, *Industrial Control Equipment*

UL 558, *Industrial Trucks, Internal Combustion Engine-Powered*

UL 674, *Electric Motors and Generators for Use in Hazardous (Classified) Locations*

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

UL 758, *Appliance Wiring Material*

UL 810A, *Electrochemical Capacitors*

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

UL 913, *Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II and III, Division 1, Hazardous (Classified) Locations*

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

UL 1017, *Vacuum Cleaners, Blower Cleaners, and Household Floor Finishing Machines*

UL 1063, *Machine-Tool Wires and Cables*

UL 1203, *Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations*

UL 1276, *Outline of Investigation for Welding Cable*

UL 1426, *Electrical Cables for Boats*

UL 1449, *Surge Protective Devices*

UL 1564, *Industrial Battery Chargers*

UL 2267, *Fuel Cell Power Systems for Installation in Industrial Electric Trucks*

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

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

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

UL 61058-1, *Switches for Appliances – Part 1: General Requirements*

5 Glossary

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

5.2 In the text of this Standard, the term truck is used to mean an electric powered industrial truck. The type or types of truck to which a specific requirement applies is identified by the heading under which the requirement is located and by specific references in the text to the applicable requirements.

5.3 ARCING OR SPARKING PART – A component that emits arcs or sparks under normal operating conditions (e.g. motor brushes or contactor).

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

5.5 BATTERY ASSEMBLY/MONOBLOC – A multi-cell battery design that is ready for use, contains a common pressure vessel construction, a single vent line assembly, shared hardware and is furnished with a single connection cable that has electrical connector at the end. The connector shall prevent accidental matings of mismatched voltages and polarities.

5.6 LOW-VOLTAGE, LIMITED-ENERGY (LVLE) CIRCUIT – A circuit considered to result in a reduced risk of fire and electric shock, characterized by the circuit limitations defined in Table 18.1.

5.7 TYPE CGH – A compressed hydrogen powered unit utilizing a fuel cell that has minimum acceptable safeguards against inherent fire and electric shock hazards.

5.8 TYPE E – An electrically powered unit that has minimum acceptable safeguards against inherent fire and electric shock hazards.

5.9 TYPE EE – An electrically powered unit that, in addition to meeting all requirements for Type E and ES units, has its electric motors and all other electric equipment completely enclosed.

5.10 TYPE E or CGH – A unit that has met all requirements for both a Type E and CGH.

5.11 TYPE ES – An electrically powered unit that, in addition to meeting all requirements for Type E units, is provided with additional safeguards to the electric system to prevent the emission of hazardous sparks and to limit surface temperatures.

5.12 TYPE EX – An electrically powered unit in which the electric fittings and equipment are so designed, constructed, and assembled that the unit can be used in atmospheres containing specifically named flammable vapors, dusts, and, under certain conditions, fibers.

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

6 Samples

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

TYPE E TRUCKS

CONSTRUCTION

7 General

7.1 All electrical parts shall be mounted within the body of the truck.

7.2 All current-carrying parts of a truck shall be constructed and enclosed so as to reduce the likelihood of mechanical damage and to resist the abuses to which they may be subjected.

Exception: Current carrying parts in an LVLE circuit are not required to comply with 7.2.

7.3 No uninsulated current-carrying part shall be exposed on the outer surface of a truck. This requirement does not apply to battery charger connections on the outer surface of the truck.

7.4 No part of the frame or enclosure of a truck shall be in electrical contact with current-carrying parts or be used as a part of the electrical circuit.

Exception: For a truck having a nominal 24-volt or lower rating, the frame of the truck may be used as a part of the electrical circuit when the circuit is protected by:

a) An overcurrent device (see Section 12, Overcurrent Protection); or

b) A disconnect switch or connector that is positive in action and readily and quickly operable by the driver from the normal driving position.

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

Exception No. 1: Ferrous metal as part of the truck frame may be used for a current-carrying part if it complies with the Exception to 7.4.

Exception No. 2: Ferrous metal may 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.

7.6 Steel, other than stainless, used in accordance with Exception No. 2 to 7.5 shall be zinc-coated or equivalently protected against corrosion.

7.7 Contactors and fuses 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.

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

7.9 A drip pan shall not permit the collection of oil.

7.10 When charging, it shall not be possible to energize the truck movement circuits. This does not apply to trucks designed for permanent charging during operation.

7.11 UL 94, UL 746C, and CSA C22.2 No. 0.17 do not apply to materials used in small parts such as control knobs, buttons, insulating bushings, resilient mounts, clamps, hydraulic hoses, water hoses, and pulley belts.

8 Motors and Electromechanical Brakes

8.1 Motors shall comply with the spacing requirements in UL 1004-1 and CSA C22.2 No. 100.

Exception: A motor located in an LVLE circuit is not required to comply with this requirement.

8.2 Motors shall comply with the performance requirements in Section 9, Motors.

Exception No. 1: A motor located in an LVLE circuit is not required to comply with this requirement.

Exception No. 2: A motor that complies with the requirements in UL 1004-1 and CSA C22.2 No. 100 is acceptable when used within its acceptable insulation systems ratings.

8.3 When lead wires of a motor do not pass out of the motor directly into an acceptable raceway, or when they are brought out through the motor case, they shall pass through openings as defined in 11.10.

8.4 Electromechanical brakes shall comply with Part XVI, Miscellaneous Devices, of UL 508 and CSA C22.2 No. 14.

Exception: An electromechanical brake located in an LVLE circuit is not required to comply with this requirement.

8.5 A terminal for a motor or an electromechanical brake shall comply with the requirements in 10.3 and 10.4.

9 Motors

9.1 A motor shall comply with the requirements in Section 23, Dielectric Voltage Withstand, immediately after being removed from an air circulating oven for a period of 7 hours and maintained at a temperature of 175 °C (347 °F). The potential shall be applied between the terminals and the motor frame.

9.2 A motor complying with 9.1 is not required to comply with the barrier requirements of 17.2.

10 Electric Controls

10.1 An arcing or sparking part in a power circuit shall be enclosed or installed so as to reduce the possibility of flame or molten metal reaching surrounding combustible material on the truck.

10.2 A reversing controller shall be interlocked, either mechanically, electrically, or both, to prevent reversal of the motor when power is applied to the motor being reversed.

Exception: A controller tested for the reversing arrangement provided is considered to meet the intent of the requirement.

10.3 A terminal shall be of such size and shape as to provide the necessary capacity and mechanical support for the conductors connected to it. A terminal employing a threaded screw or bolt for securing the conducting lug to a terminal plate shall provide a minimum of two full threads in the metal. A terminal nut shall be fastened by a lock washer or equivalent means to prevent loosening of the conductor.

10.4 A base for the support of a live part shall be made of:

a) Treated fiber;

b) Molded-phenolic composition;

c) Sheet-phenolic composition;

d) Silicone-melamine-, or polyester-impregnated glass-fiber laminated sheet;

e) Cold-molded composition; or

f) Other material investigated in accordance with 10.5.

10.5 In determining the acceptability of a material other than one specifically specified in 10.4 for the support of a live part, consideration shall be given to:

a) Its resistance to moisture;

b) Its mechanical strength if it is exposed or otherwise subject to mechanical damage;

c) Its combustibility;

d) The means for securing it in place; and

e) Its location with respect to possible adverse effects from operation of the equipment in service – particularly from arcing. The performance of a material with respect to these properties is to be investigated in comparison to the performance of one of the materials specified in 10.4.

11 Wiring

11.1 The internal wiring of the truck shall comply with one of the following: SAE J1128, UL 62 62 and CAN/CSA-C22.2 No. 49, UL 66, UL 83, UL 758, UL 1063, UL 1276, or UL 1426. The wiring shall be considered with respect to the temperature and conditions of service to which the wiring is to be subjected in the intended use.

Exception: This requirement does not apply to wiring located in a LVLE circuit.

11.2 The wiring of a truck shall be rated for the particular application with respect to the temperature and voltage, exposure to oil or grease, and other conditions of service to which the wiring is subjected.

11.3 A bare conductor is permitted to be insulated with insulating tubing or with non-carbonizable beads.

11.4 A short length of rubber-insulated conductor exposed to temperatures that normally are in excess of the maximum acceptable temperatures for the compound involved – for example, at a resistor terminal – is acceptable if supplementary heat-resistant insulation having the dielectric strength required by 20.1 is employed on the individual conductor to protect against breakdown of the insulation resulting from deterioration of the rubber. An insulating sleeve shall be secured in place.

11.5 Wiring shall be protected against mechanical damage by:

a) Enclosing it in the body of the truck; or when mounted on masts, booms, lifts or similar parts, the wiring shall be installed so as to reduce the likelihood of mechanical damage and kinking;

b) Enclosing it in metal raceway, such as armored cable, rigid metal conduit, or electrical metallic and nonmetallic tubing, flexible nonmetallic conduit or nonmetallic insulated tubing; or

c) Other methods in which the wiring is protected against mechanical damage.

Exception: This requirement does not apply to wiring located in a LVLE circuit.

11.6 Protection for insulated leads located within the operator's compartment is not required if:

a) The walls and floor of this compartment are of metal, phenolic composition, or other thermosetting material having equivalent mechanical strength and resistance to impact; and

b) The leads are not likely to be subjected to mechanical damage by the operator.

11.7 Wiring connections to a continuously moving part, or a part for which the degree of movement is appreciable shall be a Type such as S, SJ, SJE, SJO, SEO, SJT, SJTO, SJEO, SO, ST, SE, or STO flexible cord.

Exception No. 1: Individual conductors having flexible stranding, such as Type FFH-2, TFF, or SFF-2, enclosed in flexible tubing may be used in place of flexible cord. The tubing is not required on exposed moving conductors that are readily visible to the operator and are therefore subject to replacement when damaged.

Exception No. 2: Cords determined to be equivalent to those in UL 62 but with an increased number of conductors, are acceptable.

11.8 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.

11.9 A hole by means of which insulated conductors pass through a sheet-metal wall shall be provided with a smooth, rounded bushing, or shall have smooth, rounded surfaces upon which the insulated conductors may bear.

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

11.11 An internal-wiring connection shall be made with a solder lug or a pressure terminal connector.

Exception: Control wiring and other small conductors which are connected by crimped or soldered special-type lugs or eyelets.

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

12 Overcurrent Protection

12.1 Power, control and auxiliary circuits shall have overcurrent protection that is sized to prevent overheating of the smallest size conductor.

12.2 An overcurrent device rated or set for 15 amperes is acceptable for protection of a 18 AWG (1 mm^2) and larger conductors.

12.3 The need for overcurrent protection in the power circuit is to be determined on the basis of the burnout test specified in Section 25, Burnout, and not by the need for protecting the wiring against overloads of short duration. Also, an overcurrent device may be required on the basis of the construction specified in the Exception to 7.4.

12.4 Overcurrent devices in the control and power circuit shall be as close as practicable to the power supply or battery. Non-resettable overcurrent devices shall be identified as to the replacement rating of the device. Required marking shall be provided with the truck separate from the overcurrent device.

12.5 The need for overcurrent protection in the LVLE circuits is to be determined on the basis of the testing specified in Section 18, Low-Voltage Limited Energy Circuit.

12.6 The overcurrent protective device specified in 18.5 shall be either a circuit breaker, fuse or positive temperature coefficient device.

12.7 A fuse or circuit breaker shall be either:

a) Acceptable for branch circuit use; or

b) A supplementary type.

12.8 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 UL 60730-1 and CSA E60730-1.

13 Power Source Compartment or Enclosure

13.1 Support and protection shall be provided for the power source by means of a compartment that is an integral part of the truck or a separate enclosure, such as a tray and cover.

13.2 A metal compartment or separate enclosure that houses a power source shall be at least 1.35 mm (0.053 inch) thick.

Exception: See 13.4.

13.3 The cover of a compartment or separate enclosure that houses a power source shall remain closed by the force of gravity or shall be provided with a fastener.

13.4 A metal cover for a compartment or separate enclosure that houses a power source shall have:

a) Such strength and rigidity that, in conjunction with an air spacing provided between it and the terminals, the uninsulated terminals are not short-circuited when a 1110-N (250-pound) force is applied to any 930-cm^2 (1-square-foot) area of the cover; or

b) Insulation secured to the inner surface to reduce the likelihood of short-circuiting of the uninsulated terminals.

13.5 The compartment or separate enclosure that houses a battery or fuel cell shall be provided with means for ventilation that reduces the likelihood of accumulation of explosive hydrogen-air mixtures.

13.6 Means shall be provided as a part of the truck to restrain a power source from moving more than a total of 12.7 mm (1/2 inch) in a horizontal direction.

13.7 A nonmetallic cover of a power source enclosure shall comply with the following requirements for Path II in UL 746C and the requirements in CSA C22.2 No. 0.17:

a) 12 mm (1/2 inch) or 20 mm (3/4 inch) flame test;

Exception: This test is not required for material having a minimum flammability rating of V-1 or better.

b) Impact Test consisting of three, 136 J (100 foot-pounds) impacts. The test is to be conducted by dropping a steel sphere 101.6 mm (4 inches) in diameter and weighing 4.5 kg (10 pound) from a height of 3.0 m (10 feet) onto at least 2 corners and onto the center of the enclosure. When the power source is located under an overhead guard, the impact on the power source cover is reduced to 68 J (50 foot-pounds) produced by dropping a steel sphere weighing 4.5 kg (10 pounds) from a height of 1.5 m (5 feet). To reduce the likelihood of unintentional contact that may involve a

risk of electric shock from an uninsulated live part, an opening in an enclosure shall comply with either of the following:

1) For an opening that has a minor dimension less than 25.4 mm (1 inch), such that an uninsulated live part shall not be contacted by the probe illustrated in Figure 13.1; or

2) For an opening that has a minor dimension of 25.4 mm (1 inch) or more, such that an uninsulated live part shall be spaced from the opening as specified in Table 13.1.

Figure 13.1

Articulate Probe with Web Stop

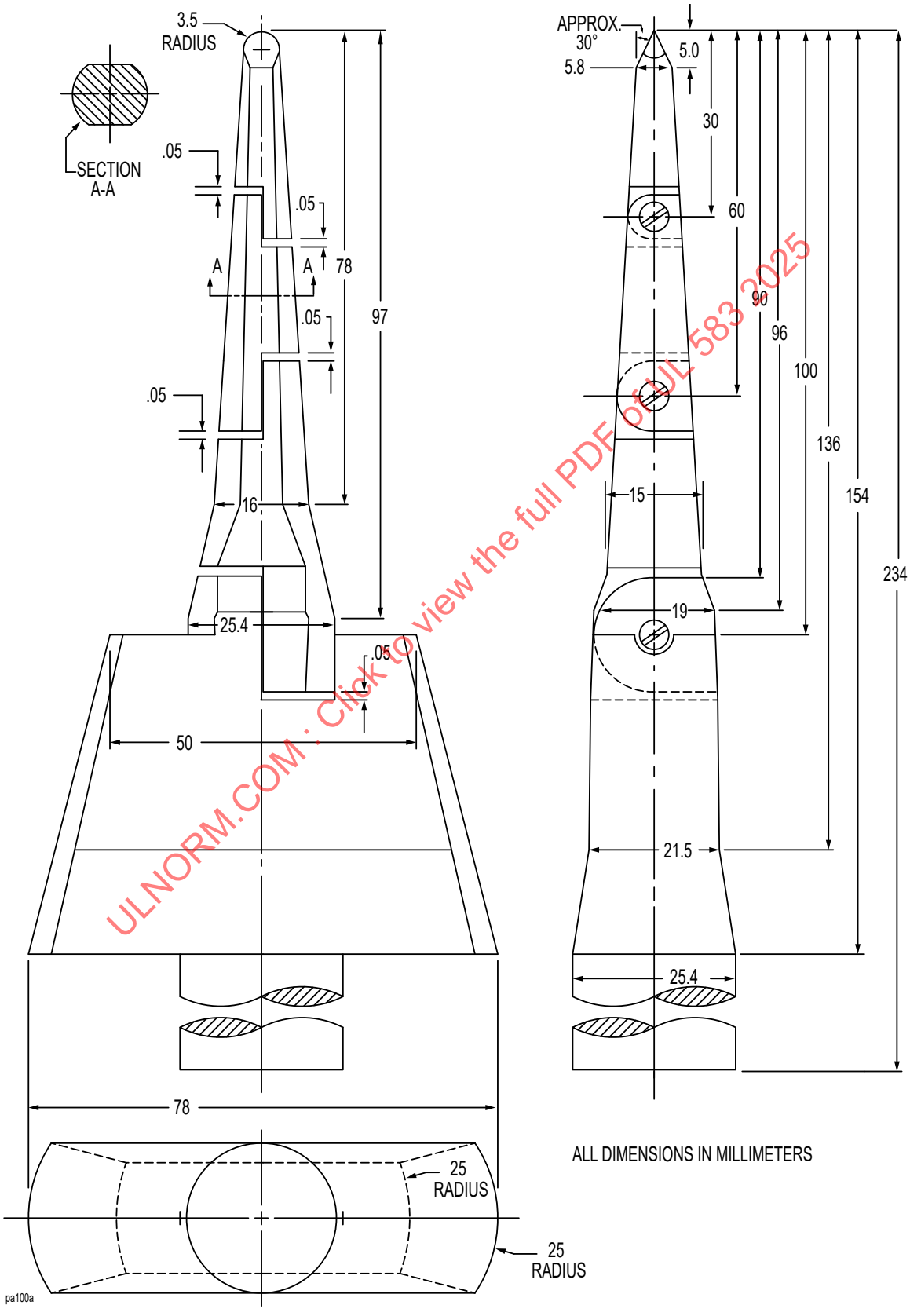

Table 13.1
Minimum Acceptable Distance from an Opening to a Part that may Involve a Risk of Electric Shock

Minor dimension of opening[a]		Minimum distance from opening to part[a]	
mm	(Inches)	mm	(Inches)
19.1	(3/4)	114.0	(4-1/2)
25.4	(1)	165.0	(6-1/2)
31.8	(1-1/4)	190.0	(7-1/2)
38.1	(1-1/2)	318.0	(12-1/2)
47.6	(1-7/8)	394.0	(15-1/2)
54.0	(2-1/2)	444.0	(17-1/2)
	b	762.0	(30)

[a] Between 19.1 mm (3/4 inch) and 53.98 (2-1/8 inches), interpolation is to be used to determine a value between values specified in the table.

[b] More than 53.98 (2-1/8 inches), but not more than 152 mm (6 inches).

13.8 The probe specified in 13.7 and illustrated in Figure 13.1 shall be applied to any depth that the opening will permit; and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure.

13.9 With reference to the requirements in 13.7, the minor dimension of an opening is the diameter of the largest cylindrical probe having a hemispherical tip that can be inserted through the opening.

14 Industrial Truck Power Sources

14.1 Lead acid batteries

14.1.1 Only insulated batteries shall be used.

14.1.2 The connections shall be such that the potential between any two adjacent cells cannot be more than 24 volts nominal.

14.1.3 For battery terminals, measures shall be taken to reduce the risk of a connection coming loose causing arcing or overheating.

14.2 Lithium batteries

14.2.1 Lithium batteries shall comply with the requirements in UL/ULC 2580 or UL/ULC 2271. The battery compartment and enclosure shall comply with the requirements in Section 13, Power Source Compartment or Enclosure.

14.3 Fuel cells

14.3.1 Fuel cells shall comply with the requirements in UL 2267. The fuel cell enclosure or the compartment in which the fuel cell is located within the industrial truck shall comply with the requirements in Section 13, Power Source Compartment or Enclosure.

14.4 Electrochemical capacitors

14.4.1 Electrochemical capacitors shall comply with the requirements in UL 810A.

14.5 Onboard battery chargers

14.5.1 Onboard battery chargers shall comply with the requirements in UL 1564 and CAN/CSA-C22.2 No. 107.2.

14.5.2 On a truck equipped with a built-in battery charger, battery terminals shall be protected by insulating boots or covers.

Exception No. 1: A terminal that is intentionally connected to ground on the truck frame is not required to be provided with a boot or cover.

Exception No. 2: This requirement does not apply to a built-in battery charger equipped with a ground-fault circuit interrupter or an isolated secondary.

15 Power Source Connectors

15.1 A truck shall be equipped with a power source connector located to provide mechanical protection as required for other electrical parts of the truck.

15.2 One part of the connector shall be permanently mounted to either the truck or the power source enclosure. The length of the cable attached to the free part of the connector shall be as short as practical, without interfering with the disconnecting operation and without placing stress on terminals.

15.3 Live parts shall be recessed from the face of the connector to reduce the possibility of shorting.

15.4 The removable portion of the connector shall be provided with means for being grasped during removal.

15.5 A power source connector shall have the proper rating for use in its application.

16 Lamps, Lampholders, and Horns

16.1 General

16.1.1 Each lamp and lampholder shall be totally enclosed.

16.1.2 A lamp lens shall be protected against mechanical damage by bars, grids, recessing, or equivalent means.

16.1.3 When a bayonet-type lampholder is employed, the spacing within the lampholder between live parts of opposite polarity and between live parts and noncurrent-carrying metal parts other than the enclosure shall not be less than 1.2 mm (3/64 inch) measured through air or over the surface of insulating material.

Exception: If a lamp is in an LVLE circuit, mechanical damage protection is not required.

16.1.4 The requirements in 16.1.1 – 16.1.3 do not apply to lamps in LVLE circuits. See 7.2.

16.2 Horns

16.2.1 The coil and other electrical parts of an electrical horn or warning device shall be enclosed. See 32.2.

17 Spacings

17.1 General

17.1.1 The spacings in a truck shall not be less than the minimum acceptable values specified in Table 17.1.

Exception: Spacings for components as specified in 16.1.3, and spacings based on the guidance in 17.1.2 – 17.1.4, are permitted.

17.1.2 Minimum acceptable spacings are not specified for a rotating part, such as an armature assembly, of a motor rated 24 volts-nominal or less or a motor of the control, blower, or signal-circuit type that is employed in a 50-volt or lower-voltage circuit, that has a locked-rotor current of 15 amperes or less, and that is protected by an overcurrent-protective device having a maximum rating or setting of 15 amperes if:

a) The armature winding is insulated with an alkyd-base, silicone-base, or equivalent insulating varnish that is resistant to moisture, acid, and oil;

b) The end of the commutator segments– where the insulating material is placed between the commutator bars and the retaining V ring – is coated with an alkyd-base, silicone-base, or equivalent insulating compound that is resistant to moisture, acid, and oil; and

c) The device complies with the requirements in 23.1.

17.1.3 Minimum acceptable spacings are not specified in an LVLE circuit, see Section 18, Low-Voltage Limited Energy Circuit.

17.1.4 The minimum acceptable spacings within a component – for example, a switch – supplied as a part of a truck shall not be less than the minimum acceptable spacings for the component or the minimum acceptable spacings specified in Table 17.1, whichever are smaller.

Table 17.1
Minimum Acceptable Spacings

Location	Nominal voltage 24 volts or less				Nominal voltage greater than 24 volts			
	Through air		Over surface		Through air		Over surface	
	mm	Inch	mm	Inch	mm	Inch	mm	Inch
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	1.6[a]	(1/16)	3.2[a]	(1/8)	3.2[b]	(1/8)	6.4[b]	(1/4)
In a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity[c]	0.8	(1/32)	1.6	(1/16)	1.6	(1/16)	3.2	(1/8)
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	1.6	(1/16)	1.6	(1/16)	1.6	(1/16)	1.6	(1/16)
In other than a power circuit at a location where conductive dust cannot accumulate, such as a small totally enclosed cavity[c]	0.8	(1/32)	0.8	(1/32)	0.8	(1/32)	0.8	(1/32)

Table 17.1 Continued on Next Page

Table 17.1 Continued

Location	Nominal voltage 24 volts or less				Nominal voltage greater than 24 volts			
	Through air		Over surface		Through air		Over surface	
	mm	Inch	mm	Inch	mm	Inch	mm	Inch
Between any uninsulated live part and the ultimate enclosure[d]	12.7	(1/2)	12.7	(1/2)	12.7	(1/2)	12.7	(1/2)
Between any uninsulated live part and the ultimate enclosure where the enclosure is formed of 3.2 mm (1/8 inch) thick cast metal or 6.4 mm (1/4 inch) thick steel plate[d]	6.4	(1/4)	6.4	(1/4)	6.4	(1/4)	6.4	(1/4)

[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.

17.1.5 Solid state circuitry (e.g. motor controllers, dc-dc converters, machine controls, etc.) as used in industrial trucks and evaluated by this standard may employ, as an alternative to the spacing requirements of Table 17.1, the spacing requirements in UL 840 and CSA C22.2 No. 0.2. When UL 840 and CSA C22.2 No. 0.2 are used, the following considerations shall apply:

a) The spacing requirements of UL 840 and CSA C22.2 No. 0.2 shall not be used for spacings to an ultimate dead metal enclosure;

b) When a truck component employs a voltage limiting device for application of the requirements in UL 840 and CSA C22.2 No. 0.2, the device shall comply with UL 1449 and CSA C22.2 No. 269 series; and

Exception: This requirement does not apply to circuits supplied only by batteries.

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 and CSA C22.2 No. 0.2.

17.2 Barriers

17.2.1 An insulating barrier or liner used as the sole separation between an uninsulated live part and a dead metal part, including the enclosure, or between uninsulated live parts of opposite polarity shall be of a material as specified in 10.4 and 10.5. The barrier or liner shall not be less than 0.71 mm (0.028 inch) thick.

Exception No. 1: In a truck rated 24 volts or less, the thickness shall not be less than 0.33 mm (0.013 inch).

Exception No. 2: The barrier or liner may have a thickness of less than as specified if the barrier or liner complies with 17.2.4.

Exception No. 3: A barrier or liner having a minimum flammability rating of V-1 or better is not required to comply with 10.5(c).

Exception No. 4: A barrier or liner fully enclosed by metal, or enclosed within material that complies with 32.2, is not required to comply with 10.5(c).

17.2.2 An insulating barrier or liner used in addition to an air space in place of the required spacing through air shall not be less than 0.71 mm (0.028 inch) thick. If the barrier or liner is of a material that does not comply with the requirements in 10.4 and 10.5, the air space shall not be less than 0.8 mm (1/32 inch).

Exception No. 1: In a truck rated 24 volts or less, the thickness shall not be less than 0.33 mm (0.013 inch).

Exception No. 2: The barrier or liner may have spacing less than as specified if the barrier or liner complies with 17.2.3 and 17.2.4.

17.2.3 For a truck rated more than 24 volts, a barrier or liner that is of material as specified in 10.4 and 10.5 and is used in addition to not less than half of the required minimum acceptable spacing through air shall have a minimum thickness of not less than 0.33 mm (0.013 inch). For a truck rated 24 volts or less, the minimum thickness shall be not less than 0.15 mm (0.006 inch).

Exception No. 1: The barrier or liner may spacing less than as specified if the barrier or liner complies with 17.2.4.

Exception No. 2: A barrier or liner having a minimum flammability rating of V-1 or better is not required to comply with 10.5(c).

Exception No. 3: A barrier or liner fully metal enclosed, or enclosed within material that complies with 32.2, is not required comply with 10.5(c).

17.2.4 Insulating material having a thickness less than that specified in 17.2.1 – 17.2.3 is permitted to be used if, upon investigation, the material is found to be equivalent in performance to the materials specified in those paragraphs.

17.2.5 A barrier or liner as specified in 17.2.1 – 17.2.3 shall be secured in place and shall be located so as to minimize the possibility of damage during operation of the equipment.

18 Low-Voltage Limited Energy Circuit

18.1 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:

a) Class 2 transformer or Class 2 Power Unit; or

b) A combination of a battery source or an isolated transformer secondary winding and one or more resistors, or a regulating network complying with 18.3, 18.4, and 18.6; or

c) A battery with output current limited by overcurrent protection complying with 12.6 in accordance with 18.5 and Table 18.1.

Table 18.1
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.	

18.2 A part or device located in or supplied by an LVLE circuit is not required to 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.

18.3 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 18.1.

18.4 With reference to the voltage limit specified in 18.1, measurement is to be made with the unit connected to the intended supply voltage and with all loading circuits disconnected.

18.5 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 18.1.

18.6 If a regulating network is used to limit the output under any conditions, the LVLE current limitation in Table 18.1 shall not be affected by malfunction of a single component, excluding resistors. The network shall comply with the value in Table 18.1.

19 Separation of Circuits

19.1 A LVLE 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 specified in Table 17.1, or 17.1.5; or

c) The use of barriers – see 19.5.

19.2 An insulated conductor of internal wiring of a LVLE circuit shall be either:

a) Separated by barriers or segregated from live parts connected to different circuits; or

b) Provided with insulation acceptable for the highest voltage involved.

19.3 Segregation of insulated conductors is to be accomplished by clamping, routing, or equivalent means that provides permanent separation from live parts of a different circuit.

19.4 A live part in a LVLE circuit shall be constructed so that the possibility of the live part touching dead metal or touching live parts of other circuits is minimized.

19.5 The barriers specified in 19.1 are permitted to be grounded metal not less than 0.51 mm (0.020 inch) thick, or insulating material not less than 0.71 mm (0.028 inch) thick.

PERFORMANCE

20 Abnormal Operation

20.1 As a test of the ability of a truck to withstand abuse, the truck shall be tested as specified in 20.2 and 20.3. There shall be no indication of damage to any parts of the truck that causes a risk of fire, electric shock, or explosion as a result of this test. A thermostat or an overcurrent-protective device that causes interruption of power to the traction or pump motor shall not operate during the first 5 cycles of the test specified in 20.2. If such interruption does occur during the remainder of the test, a thermostat shall be

permitted to reclose and an overcurrent-protective device is to be replaced or reclosed. The test shall then be continued until all of the prescribed operations have been concluded.

Exception: When the truck has a cut-back function (activated by temperature, current, etc.) which reduces the truck's performance, but allows it to continue operation, and this happens after the first five cycles, the test shall continue at the reduced performance level.

20.2 A load equal to 110 % of the rated capacity is to be placed on the load carrier at the load center distance specified by the manufacturer. A lift height/load combination is to be selected that will yield the most work (actual capacity × lift height). For the purposes of the abnormal test, the 110 % rated load is to be lifted to the lift height that was selected to yield the most work. The truck is to be quickly and rapidly operated through 25 reversals of direction of travel, reversals of lifting, and other operations that are performed by the truck such as flashing of lamps, blowing of horn, and other normal operating sequences.

Exception No. 1: The test may be conducted without reversal of direction.

Exception No. 2: Tow tractors are not covered by this requirement.

20.3 The test course for a fork-lift and a platform-lift truck is to be 12.2 m (40 feet) long. At the end of this course, the load is to be raised to the height designated by 18.2 and lowered to the hauling position. The truck with the load is then to be returned to the starting point by reversing the direction of travel.

Exception: The test may be conducted without reversal of direction.

20.4 If a lift truck has multiple load ratings and corresponding maximum – lift heights, the test specified in 21.2.1 is to be conducted for the rated load condition that will produce maximum work (in lbf).

20.5 A truck that is designed to utilize different types of power sources shall be tested independently.

Exception: When a truck is designed with a battery and electrochemical capacitor combination, the capacitor is not required to be tested independently.

21 Temperature Test

21.1 General

21.1.1 The materials employed in the construction of a truck, when tested as specified for the type of truck, shall not exceed the temperatures in both 21.1.4 and for each component, if specified for that component during operation under conditions of rated load.

21.1.2 For constructions that incorporate current limiting devices, temperature limiting devices, cooling fans, or a combination, the test shall be conducted as follows:

a) Constructions with cooling fans only:

With the cooling fans disconnected, the temperature limits specified in 21.1.4 shall apply.

b) Constructions with cooling fans, and current limiting/and or temperature limiting devices:

With the current and temperature limiting devices disabled or not functional, the temperature limits specified in 21.1.4 shall apply. If a cooling fan operates during the test, the test shall then be repeated with the cooling fan(s) disconnected and with current and temperature limiting devices connected. During the repeated test, a current or temperature limiting device is permitted to terminate the test by interruption of power to the traction or

pump motor. If an interruption only reduces performance, the test shall be continued and the temperature limits specified in 21.1.4 shall apply.

c) Constructions without cooling fans, and with current limiting and/or temperature limiting devices:

If a current and/or temperature limiting device interrupts the power to the traction or pump motor by means of power reduction, the test shall continue and the temperature limits specified in 21.1.4. If the power is terminated, the test shall be repeated 5 times. Between each test, the current and temperature limiting devices shall be allowed to reset. The temperature limits specified in 21.1.4 shall apply.

21.1.3 Prior to the temperature test, a truck is to be equipped with a fully charged storage battery of the maximum voltage and ampere-hour capacity or a fully charged fuel cell of the maximum operating pressure and continuous output power intended to be used with that specific truck. The tests specified in 21.2.1 – 21.4.1 are to be conducted at such a rate of power consumption that the battery is discharged in 8 hours. A greater rate of power consumption to enable normal operation of the truck is to be used when necessary. The rate of power consumption is to be determined by one of the following:

a) Fully charged battery:

$$Battery\ depletion\ time = \left[\frac{(480\min)\,(Amp\ Hours\ Consumed)}{(Amp\ Hour\ Rating)(\#\ of\ Cycles)}\right] - \left[\frac{Cycle\ Time}{\#\ of\ Cycles}\right]$$

Where:

480 min = 8 hours x 60 min/hour

Amp Hours Consumed = The amount of amps consumed during the battery depletion qualification cycles

Amp Hour Rating = Maximum ampere-hour rating for the specific truck

# of Cycles = Number of cycles used during battery depletion qualification (typical number of cycles is 5)

Cycle Time = Time needed to complete the # of cycles during the battery depletion qualification

Exception: If the maximum ampere-hour battery is not available, a smaller ampere-hour capacity battery may be used; however, the difference of battery weight shall be compensated on the truck.

b) Fully charged fuel cell:

1) For truck designs that incorporate interchangeability between a battery and fuel cell, the tests specified in 21.2.1 – 21.4.1 are to be conducted at the same rate of battery discharge as was calculated in 21.1.3(a). If the fuel cell does not have the capacity to run for 8 hours, an allowance of ten minutes is permitted to refuel the fuel cell during the test as required upon low state of fuel / energy notification by the fuel cell; or

2) For truck designs that do not incorporate interchangeability between a battery and fuel cell, the tests specified in 21.2.1 – 21.4.1 are to be conducted. If the fuel cell does not have the capacity to run for 8 hours, an allowance of ten minutes is permitted to refuel the fuel cell during the test as required upon low state of fuel / energy notification by the fuel cell. The truck shall operate with the fuel cell at maximum charge sustain load until temperature stabilization of truck components or 8 hours of run time.

21.1.4 During the test specified in 21.2.1 – 21.4.1, the enclosure surface temperature of a component shall not exceed the maximum temperature rating for the component or a maximum limit of 175 °C (347 °F), whichever is less. The test may be conducted at any ambient temperature with the range of 0 – 40 °C (32 – 104 °F) when it is corrected by addition [if the ambient temperature is lower than 25 °C (77 °F)] or subtraction [if the ambient temperature is higher than 25 °C (77 °F)]. The test is to be continued until constant temperatures have been reached. A temperature is considered to be constant when readings taken during any continuous 1 hour period of the test indicate an increase of no more than 3 °C (5 °F). The maximum duration is eight hours.

21.1.5 The test course is to be smooth. The length of the test course for the test specified in 21.2.1 – 21.4.1 is to be at least 60 m (200 feet). During the tests, the vehicle is not to be operated over any standing water. The test course for a truck other than as specified in 21.1.6 is to include a ramp that has a horizontal projection of 18 m (60 feet). The ramp is to have a 5 % grade or a grade for which the truck is designed to ascend, whichever is less. The grade shall not be less than 1 %.

21.1.6 A truck designed for operation on a level surface and marked in accordance with 28.2 is to be tested on a level test course.

21.2 Fork-lift and platform-lift trucks

21.2.1 A fork-lift truck and a platform-lift truck are to be operated over the course hauling a rated load. At the end of the test course, the truck is to negotiate a right-angle turn after which the load is to be raised to full height and then lowered to the hauling position. The truck with the load is then to be returned to the starting point, where the load is again to be raised and lowered and deposited at right angles to the test course. The truck is then to be operated with no load over the same course and, at the end of the course the forks or platform are to be raised to full height and lowered. The truck is then to be returned to the starting position, the load is to be picked up, and the run is to be repeated with loaded and unloaded trips alternating.

Exception: When the truck employs motor regeneration, plugging or a combination of both for stopping, not including the ramp, the truck shall come to a complete stop every 100 feet (30.4 m).

21.2.2 If a lift truck has multiple load ratings and corresponding maximum-lift heights, the test specified in 21.2.1 is to be conducted for the rated load condition that will produce maximum temperatures.

21.3 Load-carrying, fixed-platform trucks

21.3.1 A load-carrying, fixed-platform truck is to be operated over the test course hauling a rated load. If the length of the test course exceeds 90 m (300 feet), the truck is to be stopped and started at intervals of approximately 60 m (200 feet). The test course is to be negotiated not less than 6 times per hour. The test is to be conducted so that the truck is in motion approximately 80 % of the time.

Exception: When the truck employs motor regeneration, plugging or a combination of both for stopping, not including the ramp, the truck shall come to a complete stop every 30 m (100 feet).

21.4 Tractors

21.4.1 Two load configurations, consisting of trailers are to be provided for a tractor as shown below:

a) Configuration 1 shall be equal to the normal rated draw-bar pull of the tractor on level surface.

b) Configuration 2 shall be equal to the normal rated draw-bar pull of the tractor on the rated grade.

21.4.2 The tractor is to be operated over the test course (see 21.1.6) using the following sequence per cycle:

a) The tractor shall operate over the test course 60 m (200 feet) without grade, using load configuration 1.

b) The tractor shall operate over the test course 60 m (200 feet) including grade, using load configuration 2.

c) The tractor shall operate over the test course 60 m (200 feet) including grade without trailer (no load).

This cycle is to be repeated, allowing time at the starting point for normal coupling and uncoupling operations. If the length of the test course exceeds 90 m (300 feet), the truck is to be stopped and started at intervals of approximately 60 m (200 feet). The cycle shall be completed no less than 6 times per hour. The maximum duration for this test is 8 hours.

Exception: When the truck employs motor regeneration, plugging or a combination of both for stopping, not including the ramp, the truck shall come to a complete stop every 100 feet (30.4 m).

22 Brake Test

22.1 A truck that employs mechanical brakes, as the primary means for stopping, shall be tested as specified in 22.2. During the test, the temperatures on the external surfaces of the brakes shall not be more than 175 °C (347 °F), based on a 25 °C (77 °F) ambient temperature. The brakes shall not ignite or emit flame or hot particles.

22.2 The truck, equipped with a fully charged power source (see 21.1.3) and while hauling its rated load at maximum acceleration, is to be operated over a level course. The truck is to be brought to a complete stop every 30 m (100 feet) by application of the brakes. The test is to be conducted for 2 hours or until the power source is discharged, whichever comes first.

22.3 A truck that is designed to utilize different types of power sources shall be tested independently.

Exception: When a truck is designed with a battery and electrochemical capacitor combination, the capacitor is not required to be tested independently.

23 Dielectric Voltage Withstand

23.1 Immediately after the Temperature Test, Section 21, a truck shall withstand for 1 minute, without breakdown the application of a sinusoidal potential of 1000 V plus twice rated voltage if the truck is rated more than 72 V, or 500 V otherwise within a frequency range of 40 – 70 Hz. The test potential is to be applied between the current-carrying parts and the frame, with all power sources disconnected, and with all current-carrying parts normally connected to the frame disconnected.

Exception: For a dc circuit, either an alternating-current or a direct-current potential may be used. When a direct current potential is used, the potential is to be the value indicated, multiplied by 1.414.

23.2 Printed-wiring assemblies and other electronic-circuit components that are damaged by application of the test potential or that short-circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are made. Testing a representative subassembly instead of an entire unit is not prohibited. Individually shunting the semiconductor devices in the unit before the test is made to avoid destroying them in the case of a malfunction elsewhere in the secondary circuits is not prohibited.

24 Arc-Rupturing Test

24.1 Motor controllers and contactors in motor circuits

24.1.1 A switch and a current-rupturing device connected in the motor circuit, such as a contactor and a speed controller, shall show no welding or complete disintegration of the contact material; and the device shall make the load circuit. When subjected to 100 cycles of making and breaking the stalled rotor current of the motor that it controls, there shall be no arcing to the frame or enclosure nor other manifestation of a risk of fire, such as the burning or melting of the lead insulation; and the device shall continue to function both mechanically and electrically. Temperature-limiting devices and current-limiting devices (such as electronic monitoring circuits) of a power controller are to be allowed in the power circuit to limit the current or open the circuit to prevent a risk of fire and electric shock under the test conditions. When one of those devices causes an interruption of the power (i.e. speed reduction), the test shall be continued.

24.1.2 If two or more current-rupturing devices are connected in series and operate in a sequence so that normally one device is intended to make and break the circuit, all but that one are to be shunted out of the circuit in order that, in turn, all switches in that circuit may be tested under stalled-rotor conditions.

24.1.3 In conducting the test specified in 24.1.1, a fully charged power source (see 21.1.3) is to be used as the supply source. A truck that is designed to utilize different types of power sources shall be tested independently.

Exception: When a truck is designed with a battery and electrochemical capacitor combination, the capacitor is not required to be tested independently.

24.1.4 If the frame of the truck is not normally connected to the current-carrying parts, the frame is to be connected through an ordinary – nontime-delay – 30-ampere cartridge fuse to the positive pole of the battery for the first 50 cycles of operation and to the negative pole for the remaining 50 cycles. The rate of operation is to be one complete make-and-break operation every 10 seconds, with the device remaining energized for approximately 1 second per cycle.

24.1.5 If the frame of the truck is normally connected to the current-carrying parts, the following test is to be conducted. The rate of operation and the duration of the on period are to be as specified in 24.1.4. If the battery is protected by a fuse having a current rating not more than 125 % of the current drawn by the motor under locked-rotor conditions, the performance is not acceptable if the fuse opens.

24.1.6 The test is permitted to be interrupted at not less than 25 operations to permit cooling of the motor.

24.1.7 A contactor that is not tested in the truck is to be mounted in a metal enclosure of the minimum size in which it is intended to be used. The limiting impedance for the test may consist of resistors or direct-current motors.

24.1.8 For a speed controller, the test is to be conducted with the speed control handle moved from the off position through all running positions to the full-speed position and then back to the off position. This is to be counted as 1 cycle of operation.

24.2 Switches controlling other than motor circuits

24.2.1 A switch or relay shall comply with UL 508 or UL 61058-1 and with CSA C22.2 No. 14 or CAN/CSA-C22.2 No. 61058-1.

Exception No. 1: A switch or relay located in an LVLE circuit is not required to comply with this requirement.

Exception No. 2: A switch or relay that complies with 24.3, Overload Test, is not required to comply with this requirement.

24.2.2 A nonmetallic enclosure of a switch or relay shall have a minimum flammability rating of V-2.

Exception No. 1: A switch or relay located in an LVLE circuit is not required to comply with this requirement.

Exception No. 2: A switch enclosure tested in accordance with 7.11 is not required to comply with this requirement.

24.2.3 In addition to 24.2.1, a switch or relay that is used outside of the manufacturer's stating ratings, 24.3, Overload Test, shall be conducted.

24.3 Overload test

24.3.1 A switch or relay that is used outside of the manufacturer's stated ratings shall not exhibit an electrical or mechanical malfunction that may result in either an electric shock or fire hazard. The switch or relay shall show no welding or complete disintegration of the contact material at the application voltage when a load is applied that is equal to the load circuit when tested in accordance with 24.3.2.

24.3.2 For the overload test, a switch or relay is to be operated by means of its actuating member for 100 cycles of operation, making and breaking the minimum test current every 10 seconds, with the device remaining energized for approximately 1 second per cycle. During the overload test, a nontime-delay 30A fuse shall be connected between the dead metal parts of the switch and the frame of the truck (or ground).

25 Burnout

25.1 When a stalled truck motor is energized for 5 minutes with its controller in each position, there shall be no emission of flame or molten metal from the truck enclosure, and no ignition of cotton or paper placed in accordance with 25.2; and the enclosure surfaces of each component of the truck, excluding the surface of the resistor elements, shall not exceed 175 °C (347 °F) – based on an ambient temperature of 25 °C (77 °F). Melting of solder employed in electrical components or at electrical connections is acceptable if this performance does not result in a risk of fire, or the dropping of molten solder into the operator's compartment.

25.2 For each portion of this test, a fully charged power source (see 21.1.3) is to be employed. All covers provided are to be in their intended positions. All the necessary control switches and interlocks are to be defeated so that energy can be supplied continuously to the circuit under test. Only one circuit is to be tested at a time. Each control circuit is to be tested individually. Cotton or other material having the same combustibility as cotton is to be loosely packed around all openings. Clean paper is to be placed under the truck, and cotton is to be supported at the bottom and sides of all motors and on any exposed parts in any portion of the truck involving contact with or collection of combustible materials.

Exception: A truck that is designed to accept multiple types of power sources shall be tested independently, however if the truck is designed with a battery and electrochemical capacitor combination, the capacitor is not required to be tested independently.

25.3 Tests are to be conducted first with the control in the positions that cause resistors to be energized, allowing them to cool between tests. The motor alone is then to be tested. If more than one section of a resistor or more than one step in operating speed is provided on the control, the truck is to be tested in each position with control switches blocked so that the circuit under test can be quickly placed across the fully charged power source (see 21.1.3) . A truck employing a solid-state speed control is to be tested at the maximum speed setting with the full speed – shorting – contactor, if provided, disabled and

mechanically held both open and closed. The setting of any current-limiting feature is to be as specified in 58.3. The control is to be advanced to the desired position and maintained in that position for 5 minutes. Between each portion of the test, the truck is to be allowed to cool to room temperature. The test is to be considered acceptably completed at the end of 5 minutes of operation, or when the truck becomes inoperative because of a circuit element malfunction or the opening of any overcurrent, temperature-limiting, or current-sensing device if the results are in accordance with 25.1. If the truck becomes inoperative during the test as a result of a malfunction, for example, opening or short-circuiting of a solid-state component or conductor, the test is to be conducted 5 times. The emission of dense smoke, but not flame, is acceptable.

Exception: The test is not required to be repeated 5 times if the truck becomes inoperative 3 times as a result of the same circuit-element malfunction.

25.4 The test specified in 25.3 is to be repeated at lower speeds on a truck employing a solid-state speed control unless it is determined that the maximum speed setting represents the most severe condition.

25.5 Temperature-limiting devices, current-limiting devices such as electronic monitoring circuits, or overcurrent-protective devices such as fuses or circuit breakers are permitted to be used in the power circuit to limit the current or open the circuit to prevent a risk of fire, electric shock, or explosion under the test conditions specified in 25.1. To determine the reliability of an over-current- or temperature-limiting device, the test specified in 25.1 is to be conducted 3 times, each time allowing temperatures to return to ambient conditions. If the overcurrent- or temperature-limiting device is replaceable it is to be replaced for each test; if it is resettable it is to be reset.

25.6 If an overcurrent-protective device as specified in 25.5 is used, three samples of the overcurrent-protective device are to be connected directly across a fully charged power source (see 21.1.3). Cotton is to be loosely packed around the overcurrent-protective device enclosure. The overcurrent-protective device shall open without igniting the cotton.

Exception: A truck that is designed to accept multiple types of power sources shall be tested independently, however if the truck is designed with a battery and electrochemical capacitor combination, the capacitor is not required to be tested independently.

25.7 For a Type E truck only, the burnout test specified in 25.1 – 25.6 is not required to be conducted if a disconnect switch or power source connector is provided that is mechanical and positive in action and operable by the driver from the normal driving position.

25.8 There shall be no emission of flame or molten material when a motor of the control, blower, or signal-circuit type that:

a) Has a locked-rotor current of 15 amperes or less; and

b) Is protected by an overcurrent-protective device having a maximum rating or setting of 15 amperes is tested as specified in 25.9.

25.9 The motor is to be energized continuously under locked-rotor conditions until:

a) Thermal equilibrium is reached; or

b) The circuit is permanently opened by winding burnout or by the protective device. The temperature on any exposed surface of the motor shall not be more than 175 °C (347 °F), based on an ambient temperature of 25 °C (77 °F).

26 Solid-State Circuitry

26.1 All power and control circuits of a truck employing solid-state circuitry shall be subjected to a component malfunction analysis. Any solid-state component of a power or a control circuit the malfunction of which could result in a risk of fire or electric shock is to be tested in the following manner. The opening or short-circuiting of any single solid-state component shall not result in any uncontrolled operation of the truck, a risk of fire, or a risk of electric shock.

27 Marking-Plate-Adhesion Test

27.1 General

27.1.1 To determine if a marking plate secured by adhesion is in accordance with 28.4, representative samples shall be subjected to the tests of 27.2.1 – 27.4.1. In each test, three samples of the marking plates are to be applied to the same test surfaces as employed in the intended application.

27.1.2 The marking plate is considered to be in accordance with the requirements if, immediately following removal from each test medium and after being exposed to room temperature for 24 hours following removal from each test medium:

a) Each sample demonstrates good adhesion and the edges are not curled.

b) The marking plate resists defacement or removal as demonstrated by scraping across the test panel with a flat metal blade 1.6 mm (1/16 inch) thick, held at a right angle to the test panel.

c) The printing is legible and is not defeated by rubbing with thumb or finger pressure.

27.2 Oven aging test

27.2.1 Three samples of the marking plates under test are to be placed in an air oven maintained at a temperature of 60 °C (140 °F) for 240 hours.

27.3 Immersion test

27.3.1 Three samples of the marking plates are to be placed in a controlled atmosphere maintained at 23 ±2 °C (72 ±3.6 °F) with a 50 ±5 % relative humidity for 24 hours. The samples are then to be immersed in water at a temperature of 23 ±2 °C (72 ±3.6 °F) for 48 hours.

27.4 Standard atmosphere test

27.4.1 Three samples of the test samples are to be placed in a controlled atmosphere maintained at 23 ±2 °C (72 ±3.6 °F) with 50 ±5 % relative humidity for 72 hours.

MARKINGS

Advisory Note: In Canada, there are two official languages, English and French. For this reason, where this Standard requires safety markings, it must provide a French translation of such markings. Annex B provides translations in French of the English safety markings specified in this Standard, for use wherever required in Canada.

28 Details

28.1 Each industrial truck shall be marked where it will be visible with the following:

a) Name or trademark of the manufacturer.

b) One of the following Type designations:

1) Type E;

2) Type CGH;

3) Type E or CGH;

4) Type ES; or

5) Type EE;

c) Catalog designation or equivalent identification.

d) Battery nominal voltage, maximum ampere-hour capacity and the hour rating at which this capacity is determined. Fuel cell catalog number or the equivalent, output electrical rating in nominal system volts, maximum continuous amperes, and the maximum VA. The dimensions or dimensional limits of the batteries or fuel cell that may be used.

Exception: An industrial truck that is designed to utilize both a battery and fuel cell shall include both ratings.

e) Maximum rated load in kilograms, pounds, or both, including type and position of loading, as follows:

1) Platform or pallet truck – low-lift and non-elevating: Load rating in kilograms, pounds, or both, with load center near the center of the load engaging means.

2) Platform truck – high-lift: Load rating in kilograms, pounds, or both, at a specified load center that the truck can transport and stack to a height established by the truck manufacturer.

3) Crane truck: Lifting rating in kilograms, pounds, or both, and distance in feet measured in a horizontal plane from the hook to the pivot point of the mast or boom.

4) Fork lift truck: Load hauling rating in kilograms, pounds, or both, lift height, and location of load center in inches from vertical surface of forks when in a vertical plane.

5) Tractor: Draw-bar pull in kilograms, pounds, or both.

6) Combination truck: The appropriate combination of ratings as required for two or more of the foregoing types.

f) Replacement fuse size located on or adjacent to fuseholders.

g) The grade in percentage – 1, 2, 3, or 4 – that the truck is designed to ascend if less than 5 %. See 28.2.

h) For a truck that does not provide the required battery enclosure, the following or the equivalent: "Use a Type – battery," The types of batteries intended for use with the truck shall be inserted in the blank.

28.2 A truck tested in accordance with 21.1.6 shall be marked "Operate On Level Surfaces Only" or with equivalent wording.

28.3 If a manufacturer produces industrial trucks at more than one factory, each truck shall have a distinctive marking to identify it as the product of a particular factory.

28.4 Except as specified, required markings shall be provided on a metal nameplate permanently secured to the vehicle or on a marking plate complying with Section 27, Marking-Plate-Adhesion Test.

SERVICE MANUAL

29 Instructions

29.1 It is recommended that a truck be provided with a service manual detailing the extent and frequency of inspection and servicing recommended by the manufacturer. This recommendation shall cover:

a) Inspection and replacement of contacts of switches;

b) Keeping the truck free from accumulation of grease, dirt, and other possibly combustible materials;

c) Inspection for frayed and deteriorated insulations;

d) Periodic checking of the brakes; and

e) Other factors that through lack of service increase the risk of fire, electric shock or explosion.

TYPE EE TRUCKS

CONSTRUCTION

30 General

30.1 A Type EE truck shall comply with the construction requirements for a Type E truck and, in addition, shall comply with the construction requirements in Sections 31 – 36.

Exception: A Type EE truck shall not be powered by fuel cells.

31 Motors and Electromechanical Brakes

31.1 A motor and an electromechanical brake shall be of the enclosed type.

31.2 Openings in a motor or electromechanical brake enclosure shall be closed by one of the following:

a) Metal bands or covers with a thickness of no less than 0.66 mm (0.026 inch) thick shall be provided with means for retaining the band in a closed position (e.g. thumbscrew, latch, or the equivalent).

b) Nonmetallic bands or covers shall comply with the performance requirements specified in UL 1004-1 and CSA C22.2 No. 100 and shall be retained by the same means specified in (a).

32 Electric Controls

32.1 A switch, a controller, a contactor, or a similar arcing or sparking part shall be housed in a metal enclosure without openings.

Exception: A switch, controller, contactor, or similar arcing or sparking part may be enclosed within a plastic enclosure when it complies with 32.2.

32.2 A nonmetallic material used to provide an enclosure shall be phenolic, an equivalent thermosetting material, or an equivalent thermoplastic material. Such a material shall comply with the following requirements for Path II in UL 746C:

a) 12 mm (1/2 inch) or 20 mm (3/4 inch) flame test;

Exception: This test is not required for material having a minimum flammability rating of V-1 or better.

b) Impact Test;

c) Relative Thermal Index determined during the tests specified in Section 21, Temperature Test; and

d) Mold Stress Relief.

33 Wiring

33.1 Wiring shall be protected against mechanical damage by enclosing it in the body of the truck; enclosing it in metal raceway, such as armored cable, rigid metal conduit, or electrical metallic tubing; or protecting it with metal, phenolic composition, or other thermosetting material having equivalent mechanical strength and resistance to impact and having no greater combustibility than phenolic. This enclosure or protection shall be such that any flame or molten material, which may be caused by an electrical disturbance in the wiring, cannot reach surrounding combustible material.

Exception: Cord or cable that complies with the requirements in 11.7 is considered to comply with this requirement.

34 Overcurrent Devices

34.1 An overcurrent device shall be housed in a metal enclosure without openings.

Exception: An overcurrent device may be enclosed within a plastic enclosure when the enclosure material complies with 32.2.

35 Battery Enclosure

35.1 The battery enclosure shall be provided with a cover with means for locking the cover in the closed position to deter opening by unauthorized persons. Insulation provided to reduce the likelihood of shorting of the battery terminals shall be secured to the inner surface of a metal enclosure, over the terminals.

35.2 All upper openings shall be covered with a heavy-gauge wire mesh, expanded metal, or a perforated cover complying with Table 35.1. If the distance between an uninsulated live part and an opening is 102 mm (4 inches) or less, the size and shape of the opening shall not permit entrance of a rod having a diameter greater than 12.7 mm (1/2 inch). If the distance between an uninsulated live part and the opening is greater than 102 mm (4 inches), the opening shall not permit entrance of a rod having a diameter greater than 19.0 mm (3/4 inch).

Table 35.1
Cover for Upper Openings in Battery Enclosure

Type of covering	Minimum acceptable wire-diameter of screen or thickness of sheet steel, mm (inch)			
	Covering having openings or perforations 3.2 cm^2 (1/2 square inch) or smaller in area		Covering having openings or perforations larger than 3.2 cm^2 (1/2 square inch) in area	
1. Screen	1.30	(0.051)	2.06	(0.081)
2. Perforated sheet steel and sheet steel employed for expanded metal mesh:				
A. Uncoated	1.07	(0.042)	2.03	(0.080)
B. Zinc-coated	1.14	(0.045)	2.13	(0.084)

36 Static-Discharge Devices

36.1 A Type EE truck shall comply with the requirements in 47.1 and 47.2. A conductive ground strap is considered to be an equivalent static discharge device for Type EE trucks.

PERFORMANCE

37 General

37.1 A Type EE truck shall comply with the performance requirements for a Type E truck, except that the use of a switching device to disconnect the battery circuit shall not be cause for waiving the burnout test.

MARKINGS

Advisory Note: In Canada, there are two official languages, English and French. For this reason, where this Standard requires safety markings, it must provide a French translation of such markings. Annex B provides translations in French of the English safety markings specified in this Standard, for use wherever required in Canada.

38 Details

38.1 A Type EE truck shall be marked in accordance with the requirements in Section 28, Details.

38.2 A Type EE industrial truck shall be marked with the type designation, applied to each side of the vehicle in a prominent location. The marker shall be as illustrated in Figure 38.1. The marker width shall be 127 mm (5 inch). The outline and letters shall be black and the background shall be yellow.

Figure 38.1

Marker for Type EE Truck

TYPE EX TRUCKS FOR USE IN HAZARDOUS LOCATIONS, CLASS I, DIVISION 1

CONSTRUCTION

39 General

39.1 Sections 39 – 49 of this standard cover trucks intended for use in Class I Hazardous (classified) Locations as defined in Article 500 of the National Electrical Code, NFPA 70 and Section 18 and J18 of the Canadian Electrical Code, CSA C22.1.

39.2 A Type EX truck for use in Class I hazardous locations shall comply with the construction requirements in 7.6, 7.7, 7.9, 8.5, 10.2 – 10.5, 11.9 – 11.12, 12.1 – 12.4, 13.5, 13.6, 14.1 – 15.1, 15.3 – 15.5, 16.2, 17.1, 28.2, 35.1, 35.2, and 41 – 47.2.

39.3 Electrical components and wiring shall comply with UL 1203 or UL 913 and with CSA C22.2 No. 25, CAN/CSA-C22.2 No. 157, or CAN/CSA-C22.2 No. 60079-11.

39.4 A current-carrying part shall be of non-ferrous metal.

Exception: Ferrous metal may be used for a current-carrying part if it complies with Exception No. 2 to 7.5.

39.5 No part of the frame or enclosure of the truck shall be in electrical contact with a current-carrying part or be used as a part of the electrical circuit.

39.6 A Type EX truck shall not be powered by fuel cells.

40 Wiring

40.1 The wiring method employed shall be type MI cable with termination fittings, rigid metal conduit, threaded steel intermediate metal conduit, or flexible-connection fittings. All threaded joints shall engage at least five full threads. Boxes and fittings shall comply with the requirements in UL 1203 and CSA C22.2 No. 30.

40.2 Seals shall be provided at the entry to all electrical enclosures. The seals shall comply with UL 1203 and CSA C22.2 No. 30. The properties of the compound shall not be affected by the surrounding atmosphere or liquids, nor by operation of the truck.

41 Protection Against Mechanical Sparks

41.1 The exposed portion of metal parts specified in Table 41.1 shall be made of or covered with medium brass, bronze, copper, or aluminum, with a hardness not more than Rockwell B66, or shall be of other material acceptable for the purpose; or a bumper or band made of wood or equivalent material shall be provided.

Table 41.1
Exposed Portions of Metal Parts

Part	Exposed portion
Truck body	Sides, rear
Tractor body	Sides, rear, front
Wheel hub [a]	Sides
Wheel rim [a]	Sides
Fork – Vertical member	Front
– Horizontal member	Front, sides, top, bottom
– Rack	Front, sides
Fork carriage	Ends
Barrel clamp or barrel handling attachment	Inner and outer surfaces of clamping arms, clamp support, center spacer, and outer surfaces of clamping assembly support
Boom and hook attachment	
– Vertical member	Front
– Horizontal member	Front, sides, top, bottom

[a] Wheel hubs and wheel rims require protection only if they project beyond the body of the truck or tractor while the truck or tractor is moving in a straight line.

42 Motors

42.1 A motor shall comply with the requirements in UL 674 and CSA C22.2 No. 145. No belt drive shall be provided with the motor unless the belts are of electrically conductive material or are enclosed in accordance with 39.3. There shall be no slippage of the belt that may cause temperature rises that could ignite a flammable gas or vapor Class I atmosphere.

43 Electric Controls

43.1 A controller, a circuit breaker, or a resistor shall comply with the applicable requirements in UL 1203 and CSA C22.2 No. 30.

44 Battery Enclosure

44.1 The battery enclosure shall be equivalent in strength to sheet steel having a minimum thickness of not less than 4.24 mm (0.167 inch).

44.2 Ventilating openings in the battery enclosure shall be designed so that there is no access to the cell terminals from the outside.

45 Battery

45.1 A battery complying with the requirements for a Type EX battery shall be provided for a Type EX truck.

45.2 The risk of ignition of the ambient gases or vapors shall be reduced by either inert gas under pressure in the battery case or by having the current-carrying parts of the battery insulated or protected against possible contact with foreign objects when the cover is closed.

46 Battery Plugs and Receptacles

46.1 The running plug for a Type EX truck shall be interlocked with a switch so that the plug can neither be inserted nor withdrawn while the receptacle contacts are live, or the plug shall be locked in the receptacle to deter removal by unauthorized persons.

46.2 A receptacle intended to be used for charging purposes only shall be provided with a cover or dummy plug that is to be locked in place when the battery is not being charged so that there is no access to live terminals while the truck is in operation.

46.3 A plug shall have a holding device or clamp to reduce any stresses on the plug while it is in its receptacle.

47 Wheels and Tires

47.1 All wheels shall be rubber-tired or made of nonsparking material. At least two tires and wheels shall be made of electrically conductive material, or some other equivalent static discharge device shall be provided. The resistance of a nonmetallic conductive tire or wheel, measured between the wheel hub and a metal plate on which the wheel rests, shall not exceed 250,000 ohms.

47.2 With regard to the requirements in 47.1, electrically conductive straps or chains are not considered to be equivalent static discharge devices.

PERFORMANCE

48 General

48.1 A Type EX truck for use in Class I hazardous locations, shall comply with the performance requirements specified for Type EE trucks – see 37.1. In addition, the tests specified in 48.2 – 48.4 shall be conducted.

48.2 Explosion-proof electrical components shall comply with the test requirements in UL 1203 and CSA C22.2 No. 30.

48.3 Intrinsically safe electrical components shall comply with the test requirements in UL 913 and either CAN/CSA-C22.2 No. 157 or CAN/CSA-C22.2 No. 60079-11.

48.4 Maximum operating temperatures on all electrical components shall be determined in accordance with 48.2 and 48.3 as appropriate. Maximum operating temperature on other parts, such as brakes shall be determined under both normal and abnormal operating conditions. The temperature shall be marked as required by 50.1(i).

49 Nonmetallic Conductive Tires

49.1 Wheels

49.1.1 General

49.1.1.1 The resistance of a nonmetallic conductive solid tire or wheel when measured under the conditions specified in 49.1.1.2 – 49.1.3.1, shall not exceed 250,000 ohms.

49.1.1.2 An ohmmeter is to be used to measure the electrical resistance of a wheel. The ohmmeter is to operate on a nominal open-circuit output voltage of 500 volts direct current and a short-circuit current of 5.0 milliamperes, and have an effective internal resistance of 100,000 ohms ±10 %. The measurement of each wheel is to be made between the wheel hub and a metal plate on which the wheel rests. The resistance is to be measured at four locations equally spaced around the circumference of each wheel.

49.1.2 Static load

49.1.2.1 The resistance of three samples of the wheel is to be measured with a load of 45.4 kg (100 pounds) on the wheel. See 49.1.1.1.

49.1.3 Rolling under load

49.1.3.1 A wheel is to be rolled alternately in opposite directions at an average speed of 1.0 kilometers per hour (0.6 miles per hour). The distance of travel in each direction is to be at least equal to the circumference of the wheel. The wheel is to carry a load of 45.4 kg (100 pounds) during the test. The resistance is to be measured at the completion of 50,000 cycles of operation. See 49.1.1.1.

49.2 Tire specimens

49.2.1 General

49.2.1.1 After conditioning as specified in either 49.2.3.1 or 49.2.4.1, as appropriate, and 49.2.5.1, the resistance of aged and unaged specimens of a tire shall be such that:

$$\frac{R_a}{R_u} \leq \frac{250{,}000\ ohms}{R_W}$$

in which:

R_a is the resistance of the aged specimens in ohms;

R_u is the resistance of the unaged specimens in ohms; and

R_w is the resistance of the wheel in ohms as measured in accordance with 49.1.2.1.

49.2.2 Specimens for resistance measurements

49.2.2.1 Specimens for resistance tests after artificial aging – 25.4 mm (1 inch) wide and 152 mm (6 inch) long– are to be cut from a tire. For the measurement of resistance, two stainless steel clamps are to be used – one for each end of a specimen. Each clamp is to consist of two stainless steel plates 63.5 by 38.1 by 1.6 mm (2-1/2 by 1-1/2 by 1/16 inch) thick clamped by two 1/4 inch-20 bolts and wing nuts. The bolt center distance is to be 44.5 mm (1-3/4 inch). Each jaw of the clamps is to cover an area of 25.4 by