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Industrial trucks — Electrical requirements

Chariots de manutention — Exigences électriques

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 20898 was prepared by Technical Committee ISO/TC 110, *Industrial trucks*, Subcommittee SC 2, *Safety of powered industrial trucks*.

Industrial trucks — Electrical requirements

1 Scope

This International Standard specifies the electrical requirements for the design and manufacture of self-propelled industrial trucks including masted and variable reach rough terrain trucks (see ISO 5053:1987, 3.1.3.1.8), and tow tractors with a rated drawbar pull up to and including 20 000 N. This International Standard applies to trucks with battery voltages in accordance with ISO 1044. For additional requirements of trucks with mains power, see IEC 60204-1.

This International Standard does not apply to

— trucks used in potentially explosive atmospheres, or

— issues related to electromagnetic compatibility.

This International Standard does not repeat all the technical rules which are state of the art and which are applicable to the material used to construct the industrial truck, for which reference can be made to ISO 12100-2.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1044, *Industrial trucks — Lead-acid traction batteries for electric trucks — Preferred voltages*

ISO 12100-2, *Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles*

ISO 14121-1, *Safety of machinery — Risk assessment — Part 1: Principles*

ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

EN 50272-3, *Safety requirements for secondary batteries and battery installations — Part 3: Traction batteries*

IEC 60204-1:2005, *Safety of machinery — Electrical equipment of machines — Part 1: General Requirements*

IEC 60947-5-1, *Low-voltage switchgear and control gear — Part 5-1: Control circuit devices and switching elements — Electromechanical control circuit devices*

IEC 60384-14, *Fixed capacitors for use in electronic equipment — Part 14: Sectional specification: Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
arcing part
mechanical device that interrupts current during operation

3.2
auxiliary circuit
electrical circuit that controls lights, fans and other accessories

3.3
battery compartment
compartment on the truck that houses the battery

3.4
battery enclosure
container or tray that houses the individual cells

3.5
control circuit
electrical circuitry that controls truck movement

3.6
deactivate
make inactive or ineffective.

3.7
direct contact
contact of person with live parts

3.8
electrical enclosure
compartment on a truck that houses uninsulated live electrical components

3.9
electrical or electronic steering
system where input is not mechanically connected to output

3.10
exposed conductive part
conductive part of electrical equipment, which can be touched and which is not normally live, but which may become live under fault condition

3.11
frame fault
accidental connection of a live part to the truck structure

3.12
indirect contact
contact of persons with exposed conductive parts which have become live under fault conditions

3.13
live part
conductor or conductive part intended to be energized in normal use

3.14
nominal current
current in amperes that the electrical system is able to carry continuously without exceeding the allowable temperature indicated

3.15
nominal voltage (of the truck system)
total number of battery cells connected in series in the truck's system multiplied by the nominal cell voltage

3.16
power circuit
electrical circuitry that supplies the motors which cause truck movement, i.e. traction, steering and lifting

3.17
rated operating current
I_e
value of current which is determined by the conditions of use of the contactor

3.18
rated thermal current
I_{th}
value of current which determines the temperature rise conditions of the main circuit in the absence of any closing or opening operation of the contacts

3.19
risk of fire
any device that has a surface temperature greater than 175 °C or that emits sparks outside of its enclosure

3.20
routine test
test required for all production trucks

3.21
type test
test to verify compliance with this International Standard for each truck type

4 List of hazards

Table 1 contains all the significant hazards, hazardous situations and events, as far as they are dealt with in this International Standard, from ISO 14121-1:2007, Annex A and referenced in brackets, and are applicable in the situations described and could involve risks to persons if not addressed. The corresponding requirements offer guidance to limit the risk or reduce the hazard in each situation.

Table 1 — List of significant hazards, hazardous situations and hazardous events

Hazard		Corresponding requirements	
1	**Mechanical hazards**	5.1.11	Slack chains
	Crushing hazard (1.1)	5.1.12	Low voltage
	— between truck components	5.1.14	Controls — General
	— between truck and obstacles	5.1.15	Controls — Travel
	Impact by collision (20)	5.1.16	Controls — Load handling
	— when driven by the operator	5.1.17	Controls — Steering
	Loss of stability (18)	5.1.18	Contactors
	— from excess speed	7.1	Minimum marking electric trucks
	— from faulty battery mass	7.3	Minimum marking IC trucks
2	**Electrical hazards**	5.1.1	Traction batteries
	Electric shock (2.1)	5.1.2	Battery leads
	Overloading	5.1.3	Battery connectors
	— all voltages	5.1.4	Battery charging
		5.1.5	Emergency switching off requirements
		5.1.6	Design construction
		5.1.8	Wiring and wire construction
		5.1.9	Electrical shock protection
		5.1.13	Overcurrent protective devices
		5.2.1	Battery
		5.2.2	Circuit protection
		5.2.3	Control systems
		5.2.4	Wiring and wire construction
		5.2.5	Electrical shock protection
		6.2.1	Abnormal operation
	120 V < voltages ⩽ 240 V	5.1.1	Traction batteries
		5.1.7	Trucks with nominal voltage exceeding 120 V dc
3	**Thermal hazards**	6.2.2	Temperature
7	**Material/substance hazards**	5.1.1	Traction batteries
	Battery electrolyte	5.1.2	Battery leads
	Fire or explosion hazard (all voltages)	5.1.3	Battery connectors
		5.1.4	Battery charging
		5.1.5	Emergency switching off requirements
		5.1.6	Design construction
		6.1	Insulation resistance testing
		6.2.1	Abnormal operation

Table 1 (*continued*)

Hazard		Corresponding requirements	
		6.2.3	Arc rupture
		6.2.5	Connector testing
		6.2.6	Contactor testing
	120 V < voltages ⩽ 240 V	5.2.8	Trucks with nominal voltage exceeding 120 V dc
		7.1	Minimum marking electric trucks
		7.3	Minimum marking IC trucks
4.5	Ergonomic hazards (8)	7.1	Minimum marking electric trucks
4.5.1	Human error (8.6)	7.3	Minimum marking IC trucks
4.6	Hazards due to functional disorders (10)	5.2.13 5.2.15	Low voltage Controls — General
4.6.1	Failure of energy supply	5.2.16	Controls — Travels
4.6.2	Failure of control system	5.2.17	Controls — Load handling
4.6.3	Loss of machine stability	5.2.18	Control — Steering
		5.2.19	Contactors
		5.3.2	Circuit protection
		5.3.3	Control systems

5 Requirements

5.1 Electrical requirements for battery powered trucks

5.1.1 Traction batteries

5.1.1.1 All trucks shall be equipped with an insulated battery.

5.1.1.2 Cells assembled in metal containers shall be insulated from each other.

5.1.1.3 The cell connections shall be such that the potential between any two adjacent cells cannot be more than 24 V dc nominal.

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

5.1.1.5 On trucks equipped with an on-board battery charger, the 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 need not be provided with a boot or cover.

Exception No. 2: This requirement does not apply to on-board battery chargers complying with 5.1.1.6 equipped with a ground-fault circuit interrupter or an isolated output.

5.1.1.6 When trucks are fitted with on-board chargers the requirements in IEC 60204-1:2005, 6.3 up to and including 6.3.2, 7.2.1 and 8 up to and including 8.2 shall apply. The enclosure containing equipment connected to the mains supply shall be IPxxB of IEC 60529. However, for top surfaces the degree of protection shall be at least IPxxD.

5.1.1.7 For batteries with nominal voltages exceeding 120 V dc, the battery enclosure shall be lockable or facilities shall be provided so that the battery compartment can be secured to prevent unauthorized access to the battery if a lockable cover is not present on the battery enclosure.

5.1.1.8 For batteries with nominal voltages exceeding 120 V dc the following protective measures against indirect contact can be selected:

a) protective electrical insulation or;

b) protection by earth - free equipotential bonding or;

c) protection by automatic disconnection or signalling.

5.1.1.9 A battery enclosure where the battery nominal voltage exceeds 120 V dc shall be:

a) metal and lined with a material bonded to the metal that is impervious to the electrolyte or,

b) constructed of an insulating material.

5.1.2 Battery leads

5.1.2.1 A battery lead for battery nominal voltage up to and including 120 V dc shall be:

a) acceptable for application due to cross section of wires and thickness of insulation (see IEC 60227-1 and IEC 60245-1);

b) insulated with a suitable material rated for the temperatures and voltages of the truck;

c) resistant to the electrolyte;

d) able to withstand flexing, handling, and impact at temperatures referenced in 5.1.3.2;

e) average insulation thickness shall not be less than 1,5 mm for a wire less than or equal to 35 mm^2 and shall not be less than 2 mm for a wire greater than 35 mm^2.

5.1.2.2 A battery lead where the battery nominal voltage exceeds 120 V dc shall meet the requirements of IEC 60204-1:2005.

5.1.3 Battery connectors

5.1.3.1 If a battery connector is installed, one part of the connector shall be permanently mounted to either the truck or the battery enclosure. The length of the cable attached to the free part of the connector shall be as short as practicable, without interfering with the connector mating, operational efficiency or disconnecting operations and without placing stress on terminals and leads. (See 5.1.2.)

5.1.3.2 The battery connector shall be rated for the voltage of the battery and be designed for use in the application and shall be resistant to battery electrolyte and battery gases. Connectors shall have a minimum temperature rating of –20 °C to +90 °C and comply with the tests defined in 6.2.5.

5.1.3.3 The connector shall be designed so that opposite polarities can not be coupled together. Different operating voltages shall be indicated either by colour or by a coding device to prevent charger/battery/truck mismatch.

5.1.3.4 The half-connector connected permanently to the battery shall be protected against the accidental contact of persons with energized parts. Live parts shall be recessed from the face of the connectors. For battery voltage greater than 60 V dc, protection shall be IP2X or higher, in accordance with IEC 60529.

5.1.3.5 When the two half-connectors are coupled their enclosure shall provide a degree of protection IP23, in accordance with IEC 60529.

5.1.3.6 Any two half-connectors which may be separated by a force less than 15 N shall be equipped with a device to ensure the connection remain secure. A handle may be devised to facilitate connection or disconnection.

5.1.3.7 The connector shall meet the type test described in 6.2.5.

5.1.4 Battery charging

5.1.4.1 When external-charging supply cables are connected to the truck or to the truck battery it shall not be possible to energize the truck movement circuits. This does not apply to trucks designed for permanent charging during operation.

5.1.4.2 For nominal battery voltages exceeding 120 V dc, the charger shall be controlled via the connector auxiliary contacts or other device to prevent arcing at the connector and to ensure the charger is not energized until it is connected to the battery.

5.1.5 Emergency switching off requirements (disconnection) connections for batteries

5.1.5.1 An emergency switching off control or battery connector when used as an emergency switching off device shall be accessible to the operator in the normal operating position at all times.

5.1.5.2 The emergency switching off device shall be capable of interrupting without danger the power supplies to all moving elements. It shall be capable of interrupting the normal maximum current (including motor starting current) by one of the following methods:

a) battery connector for nominal battery voltage up to and including 120 V dc. Above 120 V dc, provision shall be made to prevent the use of the battery connector for emergency switching off purposes;

b) manually actuated power switch directly disconnecting one line of power supply;

c) manually actuated control switch disconnecting the power supply to the coil of one contactor in one line of the power supply. Simultaneously the power controller (e.g. inverter or controller for separate excited motors) shall be deactivated. In trucks driven by series-wound dc motor(s) with mechanical commutator without power controller, two independent contactors are necessary to switch off battery supply.

In the case of b) or c) they shall be a positive action type in accordance with IEC 60947-5-1 and the actuator coloured red. See also IEC 60947-3. A contrasting colour shall be used if the background is red.

It shall be possible to re-establish the power supply to the moving elements only by manual resetting of the switching off device followed by the normal operation of the controls.

5.1.5.3 If the battery connector is used as an emergency switching off system, the removable part of the connector shall have a means for disconnecting without damage to the battery connectors or cables.

When the connector is used for emergency switching off, the device shall be capable of being disconnected quickly in case of emergency and the two half-connectors shall be able to be separated easily. The maximum force to separate the two half connectors shall not exceed 150 N.

5.1.6 Design construction

5.1.6.1 Any arcing part in a power circuit shall be enclosed or installed so as to avoid the possibility of flame or molten metal causing a risk of fire.

5.1.6.2 Sparking components or components which can reach a temperature of 300 °C or more shall not be located where explosive gas/air mixtures may be present, e.g. above or close to a battery where the hydrogen concentration exceeds 4 % hydrogen by volume [lower explosion limit (LEL)] either during charging or discharging. Battery connectors shall be accepted as non-sparking components provided they are not used as an emergency switching-off device.

5.1.6.3 Contactors and fuses shall be located so as to be 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.

5.1.6.4 There shall be no electrical connection to the truck frame, with the exception of:

a) frame fault detection system;

b) lighting and ancillary equipment, provided that its input voltage does not exceed 60 V dc (nominal) and it is galvanically separated from the main power source;

c) earthing during charging when using on-board chargers;

d) suppression capacitors, minimum standard Class Y in IEC 60384-14, if input voltage exceeds 60 V dc;

e) the screen of screened (shielded) cables and components. This condition shall meet the requirements of the insulation resistance testing in 6.1.

5.1.6.5 After switching off the power supply the voltage of charged capacitors with a capacity greater than 60 µF shall be discharged below 60 V within 5 s, see IEC 60204-1:2005, 6.2.4. Alternatively, provide a warning label instructing to discharge the capacitor.

5.1.7 Trucks with nominal battery voltage exceeding 120 V dc

5.1.7.1 Control and auxiliary circuits shall have a voltage not exceeding 120 V dc and shall be galvanically separated from the main power source. Circuits for heating purposes and battery state of charge instrumentation are excepted.

5.1.7.2 Equipotential bonding shall be provided between the frame of the vehicle and metallic electrical enclosures (e.g. motor frames).

5.1.7.3 An automatic device for frame fault detection for circuits directly connected to the main power source shall give an audible and/or visual signal, or alternatively bring the truck to a controlled stop and de-energise the truck in the event of a fault.

5.1.8 Wiring and wire construction

5.1.8.1 Multi-core cables shall have insulation for the circuit of the highest voltage.

5.1.8.2 Cross-sectional area of a conductor shall be sized so conductor temperature does not exceed the temperature rating of insulation used.

5.1.8.3 Copper conductors external to enclosures (excluding short connections between electric or electronic components and wires that are an integral part of proprietary components) shall be flexible enough for application and be of suitable mechanical strength for application.

5.1.8.4 All conductors shall be either effectively insulated and where necessary protected against mechanical damage or shall be so placed and safeguarded as to avoid damage when the truck is in its normal operating condition. Wiring that flexes during normal operation of the truck functions shall be relieved of mechanical strain at their electrical termination. Protection for insulated leads inside the operator's compartment is not required if leads are not subject to damage by the operator.

5.1.8.5 Power terminals shall be of such a size and shape as to provide the necessary capacity and mechanical support for the conductors connected to it. For power terminals, measures shall be taken to reduce risk of a loose connection causing overheating or arcing.

5.1.8.6 Installation of truck manufacturer's approved electrical accessories for field installation by qualified personnel should be capable of installation without major disturbances of factory installed wiring or require cutting, splicing or soldering of terminals. Electrical accessories shall meet the requirements of this International Standard.

5.1.8.7 Wiring and cables shall not be exposed to contamination by lubricants and shall not be supported on surfaces that are unsuitable for their insulation class, or retain lubricants.

5.1.9 Electrical Shock Protection [direct contact and indirect contact (spacing)]

5.1.9.1 Uninsulated live parts of trucks in operating condition shall be protected to a degree of IPxxB preventing direct contact. For top surfaces, the minimum degree shall be IPxxD in accordance with IEC 60529.

5.1.9.2 Protection against indirect contact shall be achieved by electric separation in accordance with 6.3.2.3 of IEC 60204-1:2005.

5.1.9.3 The cover of an electrical enclosure other than the battery, containing live parts in excess of battery voltage 60 V dc shall be secured by use of a tool.

5.1.10 Lamps and lampholders

Each lamp and lampholder shall be enclosed by a material rated for the maximum temperature at which it operates.

5.1.11 Slack/broken chains

Electric or electronic devices, used for detecting slack/broken chains and terminating movement on trucks designed to travel with an elevated operator position, shall be so designed and fitted that in the event of a failure, the terminating movement function is preserved.

If the detection means is by mechanically operated switches that directly disconnect the raising and lowering function, the switches shall be of positive opening type according to IEC 60947-5-1.

If the detection is by means of other type switches or sensors used with an electronic circuit, the safety related parts shall be in accordance with category 3 of ISO 13849-1.

5.1.12 Low voltage

Electrical systems shall be so designed that safety is not jeopardized under every condition of battery voltage. Upon reaching the operational state of the truck all functions shall operate until the voltage falls to 70 % of the nominal voltage. If there is a risk due to voltages lower than this level, then the control system shall prevent operation of the relevant function of the truck.

5.1.13 Overcurrent protective devices

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

5.1.13.2 An overcurrent protective device shall be capable of interrupting the maximum fault current without creating a fire hazard.

5.1.13.3 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 according to the replacement rating of the device. Required marking shall be provided with the truck separate from the overcurrent device.

5.1.14 Controls — General

5.1.14.1 The electric circuits shall be so designed or protected that frame faults shall not cause inadvertent movements that cannot be controlled by the operator.

5.1.14.2 All power and control circuits (e.g. drive line, pump drive unit and steering) of a truck employing solid-state circuitry are to be subjected to a system malfunction analysis. Any component malfunction shall not result in the risk of fire, uncontrolled motion or electric shock. The safety related parts shall be in accordance with ISO 13849-1. If not otherwise specified, power and control circuits shall meet the appropriate category of ISO 13849-1 to fulfill malfunction analysis. The lowest level category is 1.

5.1.15 Controls — Travel

5.1.15.1 The travel control system shall be so arranged that on level ground the truck will start from rest only when the control (s) for speed and direction are activated. In addition, means shall be provided so that the travel circuit can be activated only by resetting the speed and/or directional control(s) when the operator assumes an operating position.

5.1.15.2 Any uncontrolled full power travel conditions due to a fault in the electronic power switching circuit shall be terminated within 0,2 s.

5.1.15.3 A separate device independent of the speed control device (accelerator) shall automatically prevent operation of the travel control circuit when the operator leaves the truck, e.g. seat switch, pedestrian tiller switch. Where separate travel controls remote from the driving position are provided, the device can be overridden when this system is selected.

5.1.15.4 The tiller of self-propelled pedestrian-controlled trucks shall incorporate a device to energize the direction of travel away from the operator until pressure on the device is relieved or stop the truck by applying the brakes, if the head of the tiller in its operating position comes into contact with a solid body (e.g. the operator's body).

NOTE The functioning of this device shall minimize misuse in normal operation (e.g. This device shall only be active when the truck actually moves in the direction towards the operator in the normal operating position and the head of the tiller is in the normal operating position.) When the tiller is used to operate the truck from a platform located at the centre of the truck, the device shall be deactivated.

5.1.16 Controls — Load handling

Control circuits shall comply so that in case of a fault, the electrical control to the load handling system shall be disabled, either automatically or manually.

5.1.17 Control — Steering

Electrical and electronic steering control systems shall be arranged so as to avoid operation of the steering system unrelated to the manual input during travel. Any single electrical or electronic fault capable of producing the above condition shall be detected and the steering assistance de-energized within 0,2 s. Where the power steering system is fully dependent on the electrical power source, the truck shall also be brought to a controlled stop automatically. The safety related parts shall be in accordance with category 3 in ISO 13849-1.

NOTE It shall be possible to check the operation of the safety circuit of this system at service intervals in accordance with the manufacturer's instruction.

5.1.18 Contactors

The contactor shall meet the requirements of the type test described in 6.2.6.

5.1.19 Truck testing

5.1.19.1 The truck shall meet the requirements of routine test 6.1.

5.1.19.2 The truck shall meet the requirements of type tests in 6.2.1 to 6.2.4.

5.2 Electrical requirements for internal combustion trucks

5.2.1 Battery

5.2.1.1 Energized battery parts not connected to the truck frame shall be insulated.

5.2.1.2 Starter batteries shall be restrained from movement.

5.2.2 Circuit protection

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

5.2.2.2 An overcurrent protective device shall be capable of interrupting the maximum fault current without creating a fire hazard.

5.2.2.3 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.

5.2.3 Control systems

5.2.3.1 The electrical system shall be designed so that safety is not jeopardized under every condition of starter battery voltage. All functions shall operate until the voltage falls to 85 % of the nominal voltage. If there is a risk due to voltages lower than this level, then the control system shall prevent operation of the relevant function of the truck. Special precautions may be required if systems need to function during engine starting.

5.2.3.2 The electric circuits shall be so designed or protected that frame faults shall not cause inadvertent movements that cannot be controlled by the operator.

5.2.3.3 Control circuits shall comply so that in case of a fault, the electrical control to the load handling system shall be disabled, either automatically or manually.

This requirement is not necessary where the movements are controlled by other means, e.g. direct manually operated hydraulic valves.

5.2.3.4 Electrical and electronic steering control systems shall be arranged so as to avoid operation of the steering system unrelated to the manual input during travel. Any single electrical or electronic faults capable of producing the above condition shall be detected and the steering assistance de-energized within 0,2 s. Where the power steering system is fully dependent on the electrical power source, the truck shall also be brought to a controlled stop automatically. It shall be possible to check the operation of the safety circuit of this system at service intervals in accordance with the manufacturer's instruction. The safety related parts shall be in accordance with category 3 in ISO 13849-1.

5.2.4 Wiring and wire construction

5.2.4.1 Wiring and cables shall not be exposed to contamination by lubrication and fuel, and shall not be supported on surfaces that are unsuitable for their insulation class, or retain lubricants.

5.2.4.2 All conductors shall be either effectively insulated and where necessary protected against mechanical damage or shall be so placed and safeguarded as to avoid damage when the truck is in its normal operating condition. Wiring that flexes during normal operation of the truck functions shall be relieved of mechanical strain at their electrical termination. Protection for insulated leads inside the operator's compartment is not required if leads are not subject to damage by the operator.

5.2.4.3 The installation of truck manufacturer's approved electrical accessories for field installation by qualified personnel shall be capable of installation without major disturbances of factory installed wiring or require cutting, splicing or soldering of terminals. Electrical accessories shall meet the requirements of this International Standard.

5.2.4.4 Copper conductors external to enclosures (excluding short connections between electric or electronic components and wires that are an integral part of proprietary components) shall be flexible enough for the application and be of suitable mechanical strength for the application.

5.2.4.5 Multi-core cables shall have insulation for the circuit of the highest voltage.

5.2.4.6 The cross-sectional area of a conductor shall be sized so the conductor temperature does not exceed the temperature rating of insulation used.

5.2.4.7 Power terminals shall be of such a size and shape as to provide the necessary capacity and mechanical support for the conductors connected to it. For power terminals, measures shall be taken to reduce risk of a loose connection causing overheating or arcing.

5.2.4.8 Any arcing part of the electrical system shall be enclosed or installed so as to avoid the possibility of flame or molten metal causing a risk of fire.

5.2.5 Electrical shock protection [direct contact and indirect contact (spacing)]

5.2.5.1 Uninsulated live parts of trucks in operating condition shall be protected to a degree of IPxxB preventing direct contact. For top surfaces, the minimum degree shall be IPxxD in accordance with IEC 60529.

5.2.5.2 Protection against indirect contact shall be achieved by electric separation in accordance with 6.3.3 of IEC 60204-1:2005.

5.2.5.3 Exposed high-tension ignition terminals shall be protected against direct contact by barriers or insulated caps suitable for the operating voltage.

6 Verification of battery powered trucks

6.1 Insulation resistance testing (routine test)

6.1.1 The insulation resistance of the truck and traction battery shall be checked separately. The test voltage shall be a minimum of three times the nominal voltage but not more than 100 V (500 V dc maximum for trucks in excess of 120 V dc).

6.1.2 The insulation resistance between energized parts of all electric components and the frame of the industrial truck with the exception of the battery shall be at least 1 000 Ω multiplied by the nominal voltage of the truck system.

6.1.3 The insulation resistance of the disconnected, filled and charged traction battery mounted on the truck shall be at least 50 Ω (500 Ω for trucks in excess of 120 V dc) multiplied by the nominal voltage of the truck system between the energized parts and the frame of the truck. Where the battery is fitted into more than one container this test shall be carried out with the sections (including metal battery containers) electrically connected.

6.2 Type testing

6.2.1 Abnormal operation

6.2.1.1 As a test of the ability of a truck to withstand abuse, the truck is to be tested as described in 6.2.1.2. 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 described in 6.2.1.2. If such operation does occur during the remainder of the test, a thermostat is to be permitted to reclose and an overcurrent protective device is to be replaced or closed. The test is then to be continued until all of the prescribed operations have been concluded.

6.2.1.2 The truck is to be loaded to 110 % of its actual capacity. The truck is to be operated through 25 maximum acceleration and braking cycles of 25 m total travel distance (return trip). When the truck is stopped at the end of each 25 m travel distance, the load is lifted to maximum height for the load, lowered to the hauling position, and other load operating sequences such as tilt, reach, sideshift, etc. are performed.

6.2.2 Temperature

The materials employed in the construction of a truck, when tested as specified for the type of truck, shall not produce any breakdown of electrical components or insulation resulting in a risk of fire when the components are subjected to the temperatures reached during operation under conditions of rated load at an 8 h discharge rate of the maximum amp hour rated battery. The external surface temperature of any component shall not exceed the maximum temperature rating of the component with a maximum limit of 175 °C. If this test is conducted at an ambient temperature less than 25 °C, the maximum temperature is adjusted accordingly.

6.2.3 Arc rupture

6.2.3.1 A switch and a current-rupturing device connected in the power circuit, such as a contactor and a speed controller, shall show no welding or complete disintegration of the contact material. The device shall make the load circuit when subjected to 100 cycles of making and breaking the stalled current of the drive that it controls and 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.

6.2.3.2 A switch connected elsewhere than in a power circuit shall show no welding or complete disintegration of the contact material. The device shall make the load circuit when subjected to 100 cycles of making and breaking of the switch in this circuit in which it is connected and 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 lead insulation, and the switch shall continue to function both mechanically and electrically.

6.2.4 Dielectric test

6.2.4.1 Trucks shall be designed to be capable of complying with a type-test immediately after temperature and arc rupture tests carried out on a new, dry vehicle. The test shall be conducted with the battery disconnected and using an alternating test voltage of approximately sinusoidal wave form with a nominal frequency of 50 Hz to 60 Hz. Residual conductive dust, e.g. motor brush dust, may be removed after temperature test if required.

6.2.4.2 The test shall be the application of the alternating voltage between energized parts and the truck frame. It shall be supplied from a transformer with a minimum rating of 500 VA (volt-ampere).

6.2.4.3 The equipment shall be capable of withstanding an alternating test voltage for 1 min as shown in Table 2.

Table 2 — Test Voltage

Nominal voltage	Alternating test voltage	Max current leakage flow
$U \leqslant 60$ V dc	500 V rms	150 mA
60V dc $< U \leqslant$ 120 V dc	1 000 V rms	150 mA
$U >$ 120 V dc	1 500 V rms	50 mA

If a second test is needed, the alternating test voltage shall be reduced to 80 % of the test voltage specified in Table 2.

Semiconductors or similar electronics subject to become damaged by application of the test voltage may be bypassed or disconnected. Items a) and b) of 5.1.5.2 shall be disconnected during the test.

6.2.5 Battery connector testing

6.2.5.1 Test of disconnection under overload conditions when the connector is used for emergency switching off

Each assembly of two coupled half-connectors shall be connected to a source of 120 V dc through a circuit having an inductance of $(0{,}5 \pm {}^{0{,}05}_{0})$ mH.

The connector shall carry 1,5 times the nominal current.

After the current is established, it shall be broken by separating the two half-connectors at a velocity of between 0,8 m/s and 1,0 m/s at point of contact break. This test shall be carried out 5 times consecutively.

After these tests, the connector shall be inspected for damage, then coupled again and submitted to the temperature test as in 6.2.5.4.

Failing to be able to couple or to pass the temperature test shall result in rejection.

6.2.5.2 Test of disconnection under emergency conditions when the connector is used for emergency switching off

Each assembly of two coupled half-connectors shall be connected to a source of direct current through an inductive circuit having an impedance such that the time constant of the circuit is 15 ms and the current to be broken shall be 4 times the nominal current, when connected to a supply voltage of 120 V dc. The connector shall be capable of clearing any arcs which are drawn as a result of this emergency disconnection. It is not imperative that the two halves of the connector should remain serviceable after this test.

6.2.5.3 Dielectric test

Each connector without cables shall be able to withstand, for 1 min, a sine-wave alternating current (ac), with a frequency of 25 Hz to 100 Hz, and an effective voltage of 2 000 V applied:

— between the main contacts;

— between the auxiliary contacts, if any, and the main contacts;

— between all the contacts and the metallic parts of the connectors (and the metallic parts fitted on the casing if this is made of insulating material).

6.2.5.4 To test temperature rise for the connector, it shall be connected by a cable of 2 m length of either,

— #6 American wire gauge (AWG) for 50 A,

— 16 mm^2 for 80 A,

— #4 AWG for 120 A,

— 35 mm^2 for 160A,

— 1/0 AWG for 175 A,

— 95 mm^2 for 320 A,

— 300 MCM for 350 A,

— 120 mm^2 for 640 A,

— 500 MCM for 700 A rating, or

— the maximum cable size for the rated current recommended by the connector manufacturer.

Cables shall be connected as recommended by the connector manufacturer. The test shall be conducted at nominal current at an ambient temperature of (20 ± 5) °C. The test shall continue until the temperature is stable. The rise in temperature of the main contacts as measured with thermocouples, or by other methods of equivalent precision, shall not exceed 65 °C.

6.2.6 Contactor testing

6.2.6.1 Verification of making and breaking capacities in proving operation

In verification of making and breaking capacities in demonstrating operation, the power supply shall have sufficient power to permit the verification of the characteristics given in Table 3. It shall consist of a battery source having capacity sufficient to maintain the test current with a voltage not less than 85 % of the rated operating voltage. The making and breaking capacities to be obtained during the test are specified in Table 3 (column marked “proving operation”). The operating coil shall be energized with its rated supply voltage and the time interval between consecutive operations shall be 10 s with a minimum “ON” time of 0,3 s.

Table 3 — Conditions for making and breaking

Equation	Normal operation		Proving operation	
	I [a] [A]	L/R [b] [ms]	I [A]	L/R [ms]
Category 1 pulse control where contactor is only required to make or break under fault conditions			$6{,}0 \times I_{th}$ [d]	15, with a relative tolerance of ± 15 %
Category 2 direct switching	I_e [c]	7,5 with a relative tolerance of ± 15 %	$4{,}5 \times I_e$	15, with a relative tolerance of ± 15 %

[a] I current made or broken – amperes (A).

[b] L/R time constant of circuit – milliseconds (relative tolerance for L/R ± 15 %).

[c] I_e rated operating current – amperes (A).

[d] I_{th} thermal current – amperes (A).