



Electrical Systems



Rolling Stock Standard

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This Australian Standard® AS 7530 Electrical Systems was prepared by a Rail Industry Safety and Standards Board (RISSB) Development Group consisting of representatives from the following organisations:

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DPTI SA

RTBU

Bombardier

TfNSW (ASA)

The Standard was approved by the Development Group and the Rolling Stock Standing Committee in **Select SC approval date**. On **Select Board approval date** the RISSB Board approved the Standard for release.

Choose the type of review

Development of the Standard was undertaken in accordance with RISSB's accredited process. As part of the approval process, the Standing Committee verified that proper process was followed in developing the Standard.

RISSB wishes to acknowledge the positive contribution of subject matter experts in the development of this Standard. Their efforts ranged from membership of the Development Group through to individuals providing comment on a draft of the Standard during the open review.

I commend this Standard to the Australasian rail industry as it represents industry good practice and has been developed through a rigorous process.

Paul Daly

Chief Executive Officer

Rail Industry Safety and Standards Board

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AS 7530:2018

Electrical Systems

Document details

First published as: **Enter first publication identifier (AS XXXX:yyyy)**

ISBN **Enter ISBN.**

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PO Box 518 Spring Hill Qld 4004, Australia

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Document control

Document identification

Designation / Title
AS 7530:2018 Electrical Systems

Document history

Publication Version	Effective Date	Reason for and Extent of Change(s)
2018	Select Board approval date	

Draft history

Version	Date	Change(s)
	30/05/2018	Public consultation draft

Approval

Name	Date
Rail Industry Safety and Standards Board	Select Board approval date

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1 Introduction

1.1 Purpose

A standard which represents a common national approach, defining the minimum performance requirements for rolling stock electrical systems.

1.2 Scope

Provision of known good practice for design, construction and maintenance requirements for on board electrical systems, wiring, separation of wiring, conduits, earthing requirements.

The standard will represent passenger rolling stock requirements and will exclude locomotives, freight vehicles, and infrastructure maintenance vehicles.

1.3 Compliance

There are two types of control contained within Australian Standards developed by RISSB:

- (a) Requirements.
- (b) Recommendations.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard.

Requirements are identified within the text by the term 'shall'.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred.

Recommendations are identified within the text by the term 'should'.

Recommendations recognise that there could be limitations to the universal application of the control, i.e. the identified control cannot be able to be applied or other controls can be appropriate / better.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities, or interfacing organisations where the risk may be shared.

Controls in RISSB standards address known railway hazards as included in an appendix.

1.4 Referenced documents

1.4.1 Normative references

The following referenced documents are indispensable for the application of this Standard:

- (a) AS 1319 Safety signs for the occupational environment
- (b) AS 1359 Rotating electrical machines – General Requirements
- (c) AS 1397 Continuous hot-dip metallic coated steel sheet and strip—Coatings of zinc and zinc alloyed with aluminium and magnesium
- (d) AS/NZS 2053 Conduits and fittings for electrical installations
- (e) AS/NZS 3121 Approval and Test Specification – Insulating Mouldings.

- (f) AS 7505 Signal Detection Management.
- (g) AS 7529.1 Australian Railway Rolling Stock – Fire Safety – Locomotive.
- (h) AS 7529.3 Australian Railway Rolling Stock – Fire Safety – Passenger.
- (i) AS 7732 EMC Management.
- (j) EN 50200 Method of test for resistance to fire of unprotected small cables for use in emergency circuits.
- (k) EN 50264-1 Railway Applications - Railway Rolling Stock Power and Control Cables Having Special Fire Performance - Part 1: General Requirements.
- (l) EN 50306-1 Railway Applications - Railway Rolling Stock Cables Having Special Fire Performance - Thin Wall - Part 1: General Requirements.
- (m) EN 50382-1 Railway Applications - Railway rolling stock high temperature power cables having special fire performance – Part 1 General requirements.
- (n) IEC 60077 Railway applications – Electric equipment for rolling stock.
- (o) IEC 60349-2 Electrical traction – Rotating electrical machines for rail and road vehicles. Electronic converter-fed alternating current motors.
- (p) IEC 60529 Degrees of protection provided by enclosures (IP Code).
- (q) IEC 60571 Railway applications – Electronic equipment used on rolling stock.
- (r) IEC 61133 Railway applications – Rolling stock – Testing of rolling stock on completion of construction and before entry into service.
- (s) IEC 61373 Railway applications – Rolling stock equipment – Shock and vibration tests.
- (t) IEC 61386-1 Conduit systems for cable management – Part 1: General requirements.

1.4.2 Informative references

The following referenced documents are used by this Standard for information only:

- (a) AS/NZS 3191 Electric flexible cords
- (b) AS/NZS 3788 Pressure equipment - In-service inspection
- (c) EN 50121-3-1 Railway Applications - Electromagnetic Compatibility - Part 3-1: Rolling Stock - Train and Complete Vehicle
- (d) EN 50126 Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)
- (e) EN 50128 Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems
- (f) EN 50153 Railway Applications – Rolling Stock – Protective Provisions Relating to Electrical Hazards
- (g) EN 50155 Railway applications – Electronic equipment used on rolling stock
- (h) EN 50163 Railway applications – Supply voltages of traction systems
- (i) EN 50343 Railway Applications – Rolling Stock –Rules for Installation of Cabling

1.5 Definitions

A: Ampere

AC: Alternating Current

Cable: A single, two or more core cables laid up together, either with or without fittings, reinforcements or protective covers.

CB: Circuit Breaker is a switch suitable for opening a circuit automatically, because of pre-determined conditions such as over current or under voltage.

Conductor: a wire or other form of conducting material suitable for carrying current.

DC: Direct Current

DCCB: Direct Current Circuit Breakers

EMC: Electro Magnetic Capability

Enclosure: a part providing an appropriate degree of protection of equipment against external influences and against contact with live parts.

Energised: To provide an electrically operated device with its operating current or voltage.

Extra low voltage: Not exceeding 50 V AC or 120 V DC.

Fuse: A device for protecting a circuit against damage from excessive current flowing in it by opening the circuit on the melting of the fuse element.

High Voltage: Exceeding Low Voltage limits.

HRC fuses: High Rupture Current fuses

HSCB: High Speed Circuit Breaker

IP rating: Ingress Protection rating are used to define levels of sealing effectiveness of electrical enclosures against intrusion from foreign bodies (tools, dirt etc) and moisture.

Locomotive: Self-propelled, non-passenger-carrying railway vehicles used for hauling or propelling other (typically freight or passenger) rolling stock.

Low voltage: Exceeding extra low voltage, but not exceeding 1000 V AC or 1500 V DC.

Passenger rolling stock: Rolling stock that carries people and facilities for these people. Excludes locomotive and infrastructure maintenance rolling stock

Rolling Stock: Any vehicle that operates on, or intends to operate on, or uses a railway track, including any loading on such a vehicle, but excluding a vehicle designed for both on- and off-track use when not operating on the track. Rolling stock is a collective term for a large range of rail vehicles of various types, including locomotives, freight wagons, passenger cars, track machines and road-rail vehicles

RSO: Rolling Stock Operator

Trucking: a truck or trough for housing and protecting electrical cables and conductors.

V: Volts

Voltage: difference in potential normally existing between conductors and between conductors and earth.

2 Operating environment conditions

The maximum and minimum ambient operating temperature ranges, humidity levels, precipitation levels and other environmental operating conditions in Australia should be considered in the selection and design of vehicle electrical systems and equipment to ensure the specified reliability and life span.

For the purpose of design calculations and applying referenced standards, the operating temperatures and environmental conditions shall be derived using the environmental conditions of the location of operation.

3 Fire performance

Passenger rolling stock shall comply with the requirements as set out in AS 7529.3 Australian Railway Rolling Stock – Fire Safety – Passenger.

Locomotives shall comply with the requirements as set out in AS 7529.1 Australian Railway Rolling Stock – Fire Safety – Locomotive.

4 EMC

Rolling stock shall be tested in accordance with the requirements of the following standards;

- (a) AS 7722 EMC Management; and
- (b) AS 7505 Signal Detection Interface.

5 Material requirements

Materials and substances used at any stage of the rolling stock life cycle throughout the entire supply chain shall comply with legislation on materials prohibited or restricted in Australia and equivalent accepted international guidelines (UNIFE Railway Industry Substance List).

6 General electrical circuits and equipment requirements

6.1 Circuits and earthing

Train batteries shall have switches installed in positive and negative rails. Batteries shall be protected by high rupture current (HRC) fuses in both the positive and negative rail.

All single-phase circuits shall have one pole of each device connected directly to the negative or neutral line with no switches, fuses or contacts.

DC circuits may have double pole switches connected directly to the negative or neutral line with no switches, fuses or contacts.

The practice of de-energising devices by short-circuiting the operating coil is not permitted.

Use of economy resistors or separate pull-in and holding coils for contactor, solenoids or similar devices is not acceptable.

Where regular switching by hand is anticipated, separate switches shall be provided.

Circuit breakers shall not be used where regular switching by hand is anticipated.

6.2 Auxiliary contacts

An auxiliary contact is a contact in a circuit, up to and including low voltage, which is not fitted with arc suppression devices.

Auxiliary equipment that use contacts such as control voltage contactors, relays, master controllers and manual switches should use gold or silver contacts with a self-cleaning action as a method of prolonging contact life.

Condensation of moisture inside the contact enclosure shall be prevented.

Auxiliary contacts should be positioned to ensure isolation of creepage from high voltage circuits.

6.3 Power contacts

All power contactors shall be fitted with contact tips, securely fixed to their support and arranged for easy removal without further dismantling.

Contact screws of size M8 or larger shall not be provided with screw driver slots.

Current shall be taken from moving contacts by flexible shunts having crimped end connections, with flared ends to avoid abrasion of the shunt.

Shunts shall be supported and restrained to prevent damage due to movement or vibration or both.

Passage of current through springs or bearings shall be prevented.

Contacts shall be protected against corrosion.

Power contacts shall have a wiping action to avoid contact arcing causing deterioration of contact surfaces.

Blow-out coils shall be connected to the positive side of the contacts.

All arc chute components have adequate resistance to erosion and burning from the arcs to which they might be subjected.

6.4 Coil and windings

All coils shall be continuously rated and mechanically suitable for the railway environment.

Encapsulated coils shall be suitable for a temperature in service of up to 150°C. Where the maximum temperature in service will exceed this figure the coil details shall be submitted to the authorised RSO representative for approval.

Insulated coils shall be fully impregnated to prevent the ingress of fluids.

The coil conductor and its insulation system shall have mechanical protection to prevent any chafing or movement damage caused by normal installation, removal or storage conditions.

Connections to coils shall be to terminals securely fixed to the coil body or adjacent to the coil body so that rewiring is unnecessary on coil replacement.

6.5 Cable connectors

All cable connectors and plug-in components including relays, printed circuit boards and electronic cards or racks shall comply with the following;

- (a) The plug or device shall be adequately and positively secured against working loose by means additional to the friction of the electrical contact.
- (b) The plug contacts shall be adequately safeguarded against failure to make good contact.
- (c) Incorrect insertion of the plug or device shall be prevented.
- (d) Where non-interchangeable parts have similar plug in components they shall be provided with a means to prevent them being inserted in the wrong position.

Circular cable connectors, upon connection, shall produce an audible or otherwise mechanical feedback, able to be sensed by the technician, to indicate that the connector has locked into position.

6.6 Low voltage switches

Low-tension tumbler or rotary switches shall have a quick action mechanism. Switch contacts shall be of the wiper or wiping butt type.

Rotary switches which have more than 2 positions shall be capable of continuous rotation in either direction.

Rotary switches of all types shall have a shaft suitable for the application required to prevent failure between maintenance cycles.

Rotary switches shall have all positions clearly marked.

Push buttons, except where otherwise specified, shall be shrouded and secured from behind. After installation, the design shall prevent dismantling from the front by unauthorised persons.

6.7 Hi voltage switch gear

HSCBs and line-switches type testing shall comply with IEC 60077-3 and IEC 61373.

HSCBs and line-switches operational frequency rating, as per IEC 60077-3, shall be 'C3'.

HSCBs shall primarily use natural cooling with any other type of cooling to be supplemental.

The unprotected cable connection between HSCBs and the electrical supply should be as short and as direct as possible.

HSCBs shall primarily use direct over-current release.

Parallel connection with HSCBs and line-switches shall be limited to detection and control equipment.

HSCBs and line-switches shall have the provision to be monitored remotely through the train operating system or equivalent.

The main power supply HSCB's performance characteristic and configuration shall ensure discrimination with respect to the overhead power supply dc circuit breakers (DCCBs) to ensure the HSCB can quickly detect, break and limit onboard electrical fault currents before the fault can trip the overhead power supply DCCBs.

The main power supply HSCB system shall provision for protection against excessive automatic and manual HSCB reset.

6.8 Circuit protection

6.8.1 Circuit breakers

Miniature circuit breakers shall be back connected except where otherwise approved by RSO in writing.

In ac circuits above 100 A and up to 400 A, circuit breakers shall be the magnetically tripped type.

The operating lever shall be down in the 'off' or 'tripped' position, and the 'off' position shall be clearly marked.

Each circuit breaker shall be labelled with the circuit it protects.

Circuit breakers shall comply with the following standards:

- (a) IEC 60077-3 Railway applications – Electric equipment for rolling stock – Part 3: Electrotechnical components – Rules for DC circuit-breakers.
- (b) IEC 60077-4 Railway applications – Electric equipment for rolling stock – Part 4: Electrotechnical components – Rules for AC circuit-breakers.

6.8.2 Fuses

Separate requirements exist in this section for the following classes of fuses:

- (a) Low voltage and extra low voltage fuses.
- (b) High voltage fuses.

6.8.2.1 Low voltage and extra low voltage fuses

Low voltage and extra low voltage fuses shall be back connected.

Spare fuses of each type shall be mounted in unconnected fuse holders adjacent to each fuse panel, or group of panels in one location. The number of spare fuses of each type at a location shall be equal to the number of fuses of each type divided by three and rounded up.

6.8.2.2 High voltage fuses

High voltage fuses shall comply with IEC 60077-5 Railway applications – Electric equipment for rolling stock – Part 5: Electrotechnical components – Rules for HV fuses.

Spare fuses of each type shall be mounted in unconnected fuse holders adjacent to each fuse panel, or group of panels in one location.

6.9 Capacitors

Electrolytic capacitors shall not be used with single-phase capacitor start motors.

Where capacitors are used as part of a surge suppression circuit, the required capacity shall be available at the surge frequency.

Discharge resistors shall not be integral with the capacitors.

7 Mounting and installation of electrical equipment

7.1 General construction

All electrical equipment, circuits and systems shall be robustly constructed and arranged so as not to suffer deterioration, wear or damage due to vibration or shock loads found in the rolling stock environment seen throughout its expected life and shall be in compliance with IEC 61373 Railway applications – Rolling stock equipment – Shock and vibration tests.

The degree of protection in accordance with IEC 60529 Degrees of protection provided by enclosures (IP Code) shall be given for each group and the rationale for the group to have that IP rating.

7.2 Safety requirements

The design of all components and systems shall be in accordance with legislative requirements. Information on the latest laws can be checked by visiting the relevant state legislation website.

Any equipment that can be accessed by the crew or passengers shall be shielded completely from accidental contact with live terminals.

7.3 Mounting of electrical equipment

All electrical equipment, circuits and systems shall be robustly constructed and arranged so as not to suffer deterioration, wear or damage due to vibration or shock loads found in the rolling stock environment seen throughout its expected life and shall be in general compliance with IEC 61373 Railway applications – Rolling stock equipment – Shock and vibration tests.

The degree of protection in accordance with IEC 60529 Degrees of protection provided by enclosures (IP Code) shall be given for each group and the rationale for the group to have that IP rating.

Equipment parts shall be so arranged that they are readily accessible for inspection, adjustment or removal without disturbance or removal of adjacent equipment.

Modules and equipment that perform the same function on one vehicle or a common function on a train are to have mounting points to an accuracy that allows interchangeability from position to position on the vehicle or position to position on the train so that the module or equipment can be installed without any adaptation.

Modules and equipment that do not perform the same function on one vehicle or on a train and have the same mounting point dimensions shall be marked with warnings and fitted with devices to prevent incorrect installation.

Where an item can be reversed on its mounting, mounting point dimensions shall be marked with warnings and fitted with devices to prevent incorrect installation.

Electrical and electronic parts, which are connected to circuits by plugs and which are not interchangeable in terms of their circuit functions, shall be provided with a suitable means to prevent them being inserted incorrectly or in the wrong position. The equipment shall also be clearly labelled.

7.4 Electrical creepage and clearances

Electrical creepage and clearance shall be as specified in IEC 60077-1 section 8.2.6 Dielectric properties; Table 4, Table 5, Table 6a and Table 6b and Annexes A and C, with the following provisions:

Creepage distance shall be determined by the vulnerability of equipment to increased risk of electrical tracking caused by environmental contaminants. In the case of roof mounted equipment, or equipment mounted in areas where the position and orientation are such that accumulation of contamination (dust, dirt, water and so on) is likely to occur, the creepage distance calculation shall not include distances over such surfaces which are liable to retain environmental contaminants.

Where an insulating tube or equivalent is used to carry compressed air to an item energised at a high voltage, the creepage distance shall be at least 300% of that specified in IEC 60077-1, section 8.2.6.3.

Such a tube shall be located so that condensate cannot collect on the high voltage item or insulating tube.

Creepage or clearance where arcs are present, or creepage along the outside of a cable sheath shall be two times the length specified in IEC 60077-1, section 8.2.6.3.

Creepage or clearances in the case of double insulated equipment shall be submitted for approval.

When it is possible for conductive gases to accumulate in enclosures such as camshaft and switch groups, insulating barriers shall be provided between uninsulated metal parts in the high voltage circuit and the low voltage circuits.

Larger clearances or creepage distances are permitted.

7.5 Insulators

All insulators shall comply with AS/NZS 3121 Approval and Test Specification – Insulating Moldings.

All surfaces of insulators or insulating panels shall be smooth, hard, and free from air bubbles, cracks, scratches, inclusions or similar surface imperfections.

The insulator material shall have a minimum dielectric strength of 12 kV/mm.

Insulator materials shall be certified as capable of withstanding the following test voltages:

- (a) Above 650 V, 10,000 V test.
- (b) Below 650 V, 3,500 V test.

Ceramic insulators shall only be used where approved.

Molded mica tubes or components of similar nature, used as part of insulator assemblies shall be mounted such that they do not fail by crushing.

7.6 Cable

Cable systems or insulation and jacket thicknesses that demonstrate technical conformance to the following documents should be recommended by suppliers:

- (a) EN 50200 Method of test for resistance to fire of unprotected small cables for use in emergency circuits.
- (b) EN 50264-1 Railway Applications - Railway Rolling Stock Power and Control Cables Having Special Fire Performance - Part 1: General Requirements.
- (c) EN 50306-1 Railway Applications - Railway Rolling Stock Cables Having Special Fire Performance - Thin Wall - Part 1: General Requirements.

- (d) EN 50382-1 Railway Applications - Railway rolling stock high temperature power cables having special fire performance – Part 1 General requirements.

7.7 Terminals and cable terminations

Soldered connections will not be accepted for cables above 6 mm² conductor area.

For soldered connections in electronic equipment refer to standard IEC 60571 Railway applications – Electronic equipment used on rolling stock

For voltages up to and including low voltage cables with conductor sizes up to 6 mm² cross-section, shall be fitted with approved copper sleeved, coloured insulated double crimp lugs where the insulation sleeve and the lug are crimped together.

High voltage cables, of conductor size up to 6 mm² shall have the insulation supported by thick wall zero halogen flame retardant heat shrink tubing applied after crimping.

All terminals shall be capable of retaining at least two wires to provide for cable looping. Termination of more than four cables at any single terminal is not allowed.

The 'push-on' quick connect type of termination may also be used as an alternative in low vibration situations, as determined by the design review whenever usage of post terminals is impracticable.

Also, spring type cage clamp terminals in combination with boot lace ferrules type lugs may be used as a third option.

Piggy back terminals shall not be used.

7.8 Conduit and fittings

All conduits shall comply with either of the following standards:

- (a) AS/NZS 2053 Conduits and fittings for electrical installations.
- (b) IEC 61386-1 Conduit systems for cable management - Part 1: General requirements.

Conduits shall be supported and fastened securely in position with conduit clips, cleats and/or brackets to prevent movement. All support shall be independently applied to conduits, that is, under no circumstances shall any conduit be supported by another conduit or by any pneumatic or hydraulic pipes.

A cable-to-space ratio of 40:60 for conduit cable fill-factor shall be used for any new cable installations.

All conduits that are to be underframe mounted shall be capable of withstanding impact by wildlife and other foreign objects, as well as repeated impacts from ballast up to 75 mm diameter at speeds of up to the maximum operating speed of the train.

All underframe conduits shall have at least an IP65 rating in accordance with IEC 60529.

The welding of conduits is not acceptable under any circumstances.

7.9 Trunking

Steel trunking shall be formed from zinc coated steel in accordance with AS 1397 Continuous hot-dip metallic coated steel sheet and strip coatings of zinc and zinc alloyed with aluminum and magnesium.

If aluminum trunking is used, the trunking shall have at least 3 mm wall thickness.

All trunking shall have earthed access covers designed to exclude dust and moisture.

There shall be access covers, positioned to allow the cables to be introduced and removed easily.

Electrical cables shall be secured within the trunking to prevent movement.

The access covers shall be securely attached by screws, clamps or brackets in addition to any ribbing or flange.

Where high voltage cables are run in trunking adjacent to passenger areas, the duct wall thickness shall be at least 3 mm, with an air gap between the duct and the interior car lining.

In addition, electrical and heat insulation could be required between the trunking and the passenger wall to ensure passenger comfort and safety.

7.10 Conduit runs

Conductor runs, and cable runs shall include the following:

- (a) Heavy current connections.
- (b) Light current connections.
- (c) Location of cables and looms.
- (d) Jointing of cable.
- (e) Spare cables.
- (f) Break of cable gauge.

7.11 Heavy current connectors

Heavy current cables of size 35 mm² or more shall be adequately supported by appropriate means such as cable cleats, clamps, and so on. These shall be spaced at not more than 400 mm centers and secured against chafing and movement.

Cable support clamps shall not pinch or crush cable insulation and shall adequately support cables under all operating conditions of shock and vibration.

Runs of smaller cable size up to 25 mm² can be 'run bundled' together to give additional support and should be secured with cleats, spaced at centers of 400 mm or less.

Individual cables or cable bundles shall not be used to support or be supported by another individual cable or cable bundle.

Heavy current cable installations shall be designed to minimise electromagnetic interference (EMI).

EMI reduction strategies for heavy current cables shall include the following as a minimum:

- (a) Twisting three-phase cables at least once every meter for larger cables (70 mm²) and at least two or three times per meter for smaller (30 mm²) cables.
- (b) Running cables in metal trunking or conduits.
- (c) Separating such cables from noise-susceptible cables or systems by at least 0.5 m.

Cable runs shall not cross a horizontal floor or surface except where unavoidable, and then a clearance of at least 25 mm shall be established beneath the cables. Where the possibility of cable damage exists, the cables shall be protected by the use of a removable tread plate.

7.12 Busbars

Busbars should be used, with the following provisions:

- (a) The busbar shall be of adequate stiffness, supported and clamped against movement, resonance, vibrations and magnetic forces.
- (b) In locations where access is not restricted, the busbar shall be heat shrink covered to minimise inadvertent contact.
- (c) Each busbar terminal and termination shall have the ability to be removed and replaced without disturbing adjacent items.

7.13 Light current connections

Light current cables outside enclosures shall always be run in conduits or trunking.

The following requirements apply to light current cables inside enclosures:

- (a) Light current cables may be run without conduit or trunking.
- (b) Light current cable looms shall be made up by fastening cables together with fire retardant ties to form neat bundles that prevent rubbing or chafing.
- (c) All looms shall be fastened at not more than 150 mm intervals.
- (d) All individual cables within the loom shall be laid parallel and pulled straight and shall have a neat appearance.
- (e) All lays shall be parallel and remain parallel when passing around corners.
- (f) Fire-retardant fastenings shall be applied at the start and finish of any bend, and at the point at which a cable or cables leave the loom so as to secure the leaving cable.
- (g) Self-adhesive tape and self-adhesive fasteners shall not be used.
- (h) As far as practicable, cables shall leave looms at right angles, to give a neat appearance.
- (i) Sufficient slack shall be provided to prevent a strain being placed on cable terminals and allow for two more re-crimping's.

The term 'fastening' includes the application of commercial cable ties to secure the bundle.

Extra low voltage cables should be kept separate from low voltage cables.

Extra low voltage cables and low voltage cables shall be kept separate from high voltage cables without exception.

Where low voltage cables are carried in the same jumper as extra low voltage cables they shall be separated at the jumper junction box.

AC cables shall not be run in installations that results in the creation of eddy current heating within conduits.

Light current cables or looms shall be secured adequately to prevent movement, chafing or vibration while in service.

Individual cables or cable bundles shall not be used to support or be supported by another individual cable or cable bundle.

7.14 Location of cables and looms

Cables and cable looms shall be run clear of apparatus in order to not impede access for maintenance.

Cables and looms shall be clear of high temperature and electrical arcing areas. Heat or arc barriers shall be provided where it is not possible to avoid such areas.

Cables and cable looms shall not run over or be located near sharp edges. Allowance for the possibility of displacement in service shall be accommodated.

Cable trays, cable trunking, conduits or any surfaces that can contact cables shall be cleared of any metallic swarf to prevent possible damage to cables.

Where cables pass through partitions, suitable bushes or other suitable protection shall be provided to assure the protection of the cables.

7.15 Joining of cables

Cables shall be joined at terminals.

Cables shall not be joined within a cable run.

7.16 Spare cables

Control cables in runs and jumpers shall have at least 10% of the total number as spares in discrete systems.

Shielded cables shall have at least one spare cable.

Multiplexed systems shall have at least one spare per multiplexed cable.

Optical cables shall have at least one spare per system.

Spare optical cables shall be properly secured and terminated.

Spare wires shall be terminated in the same way as other wires.

The spare cables shall be shown in the wiring diagram and labelled with cable markers in the same way as all other cables.

7.17 Break of cable gauge

All cables shall have the capacity to perform their function without deterioration of their insulation in normal operation and under fault conditions. This requires the associated protection device for a given circuit to protect the smallest size, lowest capacity cable.

7.18 Labels and rating plates

7.18.1 Identification labelling

Machines, equipment and devices shall be labelled for identification.

Installation and mounting positions for all machines and equipment shall be labelled.

7.18.2 Equipment labelling

All machines shall carry a rating plate with the following information, as is appropriate to the equipment type:

- (a) Serial number.
- (b) Manufacturer's type number.

- (c) Current, voltage and power ratings and whether continuous or otherwise.
- (d) Speed at rated current.
- (e) Maximum speed.
- (f) Field connection (series, separately excited, and so on).

All machine terminals shall be labelled in accordance with IEC 60349-2 or AS 1359.

Uni-directional rotating machines shall carry an arrow showing the correct direction of rotation, and, in the case of axial fans, of the direction of air flow.

All labels, rating plates, and the arrows required for fans shall be mounted in such a position that they can be seen from the usual point of access.

The labels shall be clearly stamped or engraved and securely attached to the machine.

7.19 Enclosure designs

All enclosures shall be designed to prevent the spread of fire or smoke to other enclosures.

Any equipment that may be accessed by the crew or passengers shall be shielded completely from accidental contact with live terminals.

Enclosures containing electrical equipment shall have safety signs in accordance with AS 1319.

Each enclosure shall have an IP rating in accordance with AS 60529. The rationale for developing that rating shall also be provided.

Enclosure covers shall be strong enough to prevent distortion or damage due to rough handling.

The system of covers' attachment shall preserve the enclosure IP rating between train overhauls.

Easy access covers shall be installed wherever access for maintenance or inspection is required between overhaul periods.

All covers, including those located within passenger compartments, shall be bolted or secured by locks, unless secondary protection is fitted within the enclosure.

Fixed covers that are hinged horizontally or rotated vertically shall be provided with handles for lifting and a means of retaining in the open position by latching.

All covers that infringe the maximum rolling stock outline when open are to have a visual means of determining that they are fixed closed.

Enclosures in which heat or arcs can be generated shall be lined with heat or arc barriers or insulating material.

Enclosures where equipment arcing can be produced shall be vented.

All conductive metallic enclosures including the frames of electrical machines shall be positively earthed by using an earth cable connection to the vehicle's metal frame.

All enclosures and their covers shall be appropriately earthed.

7.19.1 Ventilation of enclosures

Air inlets, outlets and vents shall be designed to prevent the ingress of materials detrimental to the operation of equipment or the health and welfare of any person.

7.19.2 Terminal boxes mounted within a vehicle

Terminal boxes shall be so arranged that water collecting in ducts or conduits cannot reach live parts.

Terminal boxes with metallic lids shall be earthed.

8 Testing

8.1 Sub-assembly testing

Testing of equipment shall be conducted in accordance with relevant international standards and manufactures guidelines.

8.2 Vehicle testing

Refer to IEC 61133 Railway applications – Rolling stock – Testing of rolling stock on completion of construction and before entry into service.

Refer to IEC 61373 Railway applications – Rolling stock equipment – Shock and vibration tests.

Appendix A Hazard Register

Hazard number	Hazard	Section addressing
5.3	Harm to persons	4, 5, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.16, 7.17, 7.18, 7.19, 8.1, 8.2.
5.2	Harm to Infrastructure Rolling Stock	4, 6.1 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.16, 7.17, 7.18, 7.19, 8.1, 8.2.
5.4	Harm to Rolling Stock	4, 5, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.16, 7.17, 7.18, 7.19, 8.1, 8.2.
5.5	Harm to Rolling Stock Related Processes	4, 5, 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, 7.8, 7.9, 7.10, 7.11, 7.12, 7.13, 7.14, 7.16, 7.17, 7.18, 7.19, 8.1, 8.2.

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ISBN: Enter ISBN.

Draft for Public Comment
AS 75330:2018

