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Commenting on ARISO products

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Format of Comments

Comments should provide:

- clear indication of what part of the text the comment applies to;
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For example, a useful comment would read:

This requirement is difficult to apply in some circumstances, such as in remote locations where phone reception is poor. Suggest changing this requirement to a should (recommendation) and provide guidance on how to achieve this recommendation when in remote locations.

Examples of comments that do not provide any valuable information for consideration include:

I disagree.

This section is wrong.

We don't do it this way.

If you have any questions, please contact the Standards Development Manager listed on the next page.

The ARISO Products Development Team

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Data entry – draft starts next page

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Preface

This Standard was prepared by the Electrical Systems Passenger Rolling Stock Development Group, overseen by the ARISO Rolling Stock Standing Committee.

The major changes in this revision are as follows:

Objective

This Standard represents a common national approach, defining the minimum performance requirements for passenger rolling stock electrical systems.

This Standard provides known good practice for design, construction and maintenance requirements for onboard electrical systems, wiring, separation of wiring, conduits, earthing requirements

Compliance

There are four types of provisions contained within Australian Standards developed by ARISO:

- (a) Requirements.
- (b) Recommendations.
- (c) Permissions.
- (d) Constraints.

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 recognize that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied, or other controls are more appropriate or better.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term ‘may’.

Constraints – provided by an external source such as legislation. Constraints are identified within the text by the term ‘must’.

Using this Standard

Appendices in ARISO Standards may be designated either “normative” or “informative”. A “normative” appendix is an integral part of a Standard and compliance with it is a requirement, whereas an “informative” appendix is only for information and guidance.

ARISO Standards identify known hazards relevant to the railway industry. Appendix A provides a non exhaustive list of hazards relevant to the scope of this Standard.

Commentary

Commentary C Preface

This Standard includes a commentary on some of the clauses. The commentary directly follows the relevant clause, is designated by ‘C’ preceding the clause number and is printed in italics in a box. The commentary is for information and guidance and does not form part of the Standard.

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Section 1 Scope and general

1.1 Scope

This document provides known good and safe practice for design, construction, installation and maintenance requirements for onboard electrical systems, wiring, separation of wiring, conduits, bonding and earthing requirements.

The requirements of this document apply to electrical systems and associated equipment installed onboard the passenger vehicle and the interfaces between those systems. Infrastructure electrical systems external to the vehicle are excluded unless specifically referenced elsewhere in this document.

While light rail is not specifically included in the scope of this document, it can be applied by light rail RSOs.

It is acknowledged that each state and territory has local health and safety regulations that need to be adhered to.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- AS 1319:2018, *Safety signs for the occupational environment*
- AS 1397:2021, *Continuous hot-dip metallic coated steel sheet and strip, Coatings of zinc and zinc alloyed with aluminium and magnesium*
- AS 60529:2025, *Degrees of protection provided by enclosures*
- AS 61386.1:2015, *Conduit systems for cable management — Part 1: General requirements*
- AS 7486:2026, *Rolling Stock Onboard Electrical Energy Storage*
- AS 7505:2024, *Signal Detection Management*
- AS 7529.3:2026, *Australian Railway Rolling Stock, Fire Safety, Passenger*
- AS 7722:2026, *EMC Management*
- AS/NZS 3000:2018, *Electrical installations (known as the Australian/New Zealand Wiring Rules)*
- AS/NZS 3121:2002 (R2020), *Approval and test specification – Insulating mouldings*
- AS/NZS 60947.1:2021, *Low-voltage switchgear and control gear, Part 1: General rules*
- AS/NZS 61439.1:2026, *Low-voltage switchgear and control gear assemblies — Part 1: General rules*
- AS/NZS 62271.200:2026, *High-voltage switchgear and control gear, Part 200: AC metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV*
- IEC 60077-1:2017, *Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules*
- IEC 60077-2:2017, *Railway applications – Electric equipment for rolling stock – Part 2: Electrotechnical components – General rules*
- IEC 60077-3:2019, *Railway applications – Electric equipment for rolling stock – Part 3: Electrotechnical components – Rules for DC circuit-breakers*

- IEC 60077-4:2019, *Railway applications – Electric equipment for rolling stock – Part 4: Electrotechnical components – Rules for AC circuit-breakers*
- IEC 60077-5:2019, *Railway applications – Electric equipment for rolling stock – Part 5: Electrotechnical components – Rules for HV fuses*
- IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*
- IEC 60349-1:2010, *Electrical traction – Rotating electrical machines for rail and road vehicles – Part 1: Machines other than electronic converter-fed alternating current motors*
- IEC 60349-2:2010, *Electrical traction – Rotating electrical machines for rail and road vehicles – Part 2: Electronic converter-fed alternating current motors*
- IEC 60571:2012, *Railway applications – Electronic equipment used on rolling stock*
- IEC 60865-1:2011, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*
- IEC 60947-5-1:2024, *Low-voltage switchgear and control gear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*
- IEC 61071:2017, *Capacitors for power electronics*
- IEC 61133:2016, *Railway applications – Rolling stock – Testing of rolling stock on completion of construction and before entry into service*
- IEC 61373:2026, *Railway applications – Rolling stock equipment – Shock and vibration tests*
- EN 45545-2:2020+A1:2023, *Railway applications – Fire protection on railway vehicles – Part 2: Requirements for fire behaviour of materials and components*
- EN 50200:2015, *Method of test for resistance to fire of unprotected small cables for use in emergency circuits*
- EN 50264-1:2008, *Railway applications – Railway rolling stock power and control cables having special fire performance – Part 1: General requirements*
- EN 50306-1:2020, *Railway applications – Railway rolling stock cables having special fire performance – Thin wall – Part 1: General requirements*
- EN 50343:2024, *Railway applications – Rolling Stock – Rules for installation of cabling*
- EN 50382-1:2008+A1:2013, *Railway applications – Railway rolling stock high temperature power cables having special fire performance – Part 1: General requirements*
- UNIFE Railway Industry Substance List (RISL):2025, *A rail-sector guidance document maintained by UNIFE (European Rail Supply Industry Association). It provides a consolidated list of prohibited, restricted, and declarable substances that may be present in railway products, components, materials, and manufacturing processes.*

NOTE:

Documents for informative purposes are listed in a Bibliography at the back of the Standard.

1.3 Defined terms and abbreviations

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

1.3.1 ampere (A)

unit of electric current

1.3.2

alternating current (AC)

electric current that periodically reverses direction

1.3.3

cable

single, two or more core assembly laid up together, with or without fittings, reinforcements or protective covers

1.3.4

circuit breaker (CB)

switch that automatically opens a circuit under predetermined conditions such as overcurrent or undervoltage

1.3.5

conductor

wire or other conducting material suitable for carrying electric current

1.3.6

direct current (DC)

electric current flowing in one direction only

1.3.7

direct current circuit breaker (DCCB)

circuit breaker designed for switching and protection in DC systems

1.3.8

electromagnetic compatibility (EMC)

ability of equipment or systems to operate satisfactorily in their electromagnetic environment without introducing intolerable electromagnetic disturbances

1.3.9

energized

in a state where an electrically operated device is supplied with operating voltage or current

1.3.10

enclosure

part that provides a specified degree of protection to equipment against external influences and against contact with live parts

1.3.11

extra-low voltage (ELV)

voltage not exceeding 50 V AC or 120 V DC

1.3.12

fuse

device that protects a circuit from excessive current by opening the circuit when the fuse element melts

1.3.13

heavy current

an electrical current that is large enough to require special consideration for conductors, equipment, protection, and safety.

1.3.14

high rupture current (HRC) fuse

fuse designed to safely interrupt high prospective fault currents

1.3.15

high speed circuit breaker (HSCB)

circuit breaker designed to interrupt fault currents rapidly to limit damage or equipment stress

1.3.16

high voltage

voltage exceeding the limits of low voltage

1.3.17

IAC

internal arc classification

Note 1 to entry: As defined in AS/NZS 62271.200:2026.

1.3.18

ingress protection (IP) rating

designation indicating the level of protection an enclosure provides against intrusion by solid objects, dust and moisture

1.3.19

light current

electrical current in electrical circuits used for signalling, communication, measurement, monitoring, and control, carrying relatively small amounts of power compared with power distribution circuits.

1.3.20

low voltage (lv)

voltage exceeding 50 V AC or 120 V ripple free DC but not exceeding 1 000 V AC or 1 500 V DC

1.3.21

RSO

rolling stock operator as defined in Rail Safety National Law

1.3.22

SFAIRP

so far as is reasonably practicable as defined in Rail Safety National Law

1.3.23

trunking

electrical wireway, generally rectangular in cross-section, with removable covers

1.3.24

volt (V)

unit of electric potential difference

1.3.25

voltage

potential difference normally existing between conductors or between a conductor and earth

General rail industry terms and definitions are maintained in the ARISO Glossary. Refer to:

<https://www.ariso.org.au/glossary/>

Section 2 Operating conditions

2.1 Environment

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

For the purposes of design calculations and the application of referenced standards, environmental design conditions shall be based on the intended operating location(s) of the rolling stock. Environmental data shall be obtained from recognized sources, such as the Australian Bureau of Meteorology or equivalent nationally recognized datasets.

2.2 Shock and Vibration

All electrical equipment shall comply with the requirements for shock and vibration as provided in IEC 61373:2026.

Section 3 Fire performance

Passenger rolling stock shall comply with the requirements as set out in AS 7529.3:2026.

Section 4 Electromagnetic compatibility

4.1 Design and construction

Electrical system design shall incorporate appropriate measures, including earthing and bonding, cable segregation, shielding and filtering to achieve electromagnetic compatibility (EMC) compliance.

Electrical system design shall minimize unacceptable electromagnetic interference (EMI) to external infrastructure electrical systems, including signalling and communications systems.

Commentary C4.1

IEC TR 61000-5-1:2023 provides useful guidance on achieving EMC in electrical and electronic installations. It focuses on practical methods for reducing EMI and improving the immunity of equipment and systems

IEC TR 61000-5-2:1997 provides practical guidance on the earthing (grounding) and cabling of electrical and electronic systems to achieve EMC. It aims to minimize EMI between equipment and improve the immunity of sensitive systems

4.2 Testing and verification

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

- (a) AS 7722:2026; and
- (b) AS 7505:2024.

Section 5 Material requirements

5.1 General

Materials and substances used at any stage of the rolling stock lifecycle, including design, manufacture, operation, maintenance and disposal:

- (a) must comply with applicable Australian legislation relating to hazardous materials and substances; and
- (b) shall comply with recognized railway industry or international material control frameworks that provide an equivalent or higher level of control of restricted and prohibited substances.

Materials shall be selected such that they do not present unacceptable risks to:

- (c) passengers;
- (d) operational or maintenance personnel;
- (e) the environment; or
- (f) the safe operation of rolling stock.

The selected material control framework shall be documented as part of the rolling stock design and assurance process.

5.2 Compliance with legislation

Materials and substances must comply with:

- (a) applicable Work Health and Safety (WHS) legislation in the jurisdiction of operation;
- (b) applicable environmental protection legislation relating to hazardous substances and waste; and
- (c) applicable chemical control regulations, including restrictions on the use, handling, storage and disposal of hazardous materials.

5.3 Restricted and prohibited substances

Materials shall be assessed against a recognized restricted substances list (RSL).

The following are acceptable restricted substance lists:

- (a) UNIFE Railway Industry Substance List (RISL) (2025); or
- (b) equivalent international frameworks such as:
 - (i) EU REACH Regulation (EC No. 1907/2006);
 - (ii) RoHS Directive (2011/65/EU), where applicable to electrical and electronic equipment; or
 - (iii) an organization-specific restricted substances list demonstrated to provide an equivalent or higher level of control.

Where multiple frameworks are used, the most stringent requirement shall apply.

5.4 Material declaration and supply chain control

Suppliers shall provide sufficient information to demonstrate compliance with Section 5, including:

- (a) material composition declarations for relevant components;
- (b) identification of any restricted or declarable substances; and
- (c) confirmation of compliance with the nominated material control framework.

Material compliance shall be traceable through the supply chain to the extent necessary to demonstrate conformity.

5.5 Integration with other requirements

Material selection shall be consistent with other relevant requirements of this Document, including:

- (a) fire and smoke performance requirements (see Section 3);
- (b) electrical performance and insulation requirements (see Section 4, Section 6 and Section 7); and
- (c) environmental and operating conditions (see Section 2).

NOTE:

Commonly used standards and frameworks supporting compliance with this section include:

- (a) EN 45545-2:2020+A1:2023 (fire performance of materials),
- (b) IEC 62474:2018 (Edition 2.0) (material declaration for electrotechnical products), and
- (c) AS/NZS 3000:2018 (general safety principles for electrical installations).

Section 6 General electrical circuits and equipment requirements

6.1 General

The rolling stock electrical systems, electrical circuits, electrical equipment, earthing and bonding and EMC arrangements shall be designed to ensure safe operation, effective fault protection and compatibility with the overall internal and external interface electrical systems.

All persons shall be protected against electric shock.

The protection system shall comply with AS/NZS 3000:2018, Clause 1.5.5.

An effective earthing system capable of ensuring the reliable passage of the electrical system fault currents shall be designed and implemented for all electrical power sources.

The earthing system shall be capable of ensuring safe step, touch and transfer potentials for all electrical equipment.

All electrical circuits shall be protected by an over current protection device with protection grading to minimize disruption to power supplies and maximize availability of the rolling stock.

Earth fault protection shall be provided for all electrical systems.

Earth leakage protection shall be provided on circuits that expose persons to an increased risk of electric shock.

Isolation points for all final circuits shall be easily identifiable.

All electrical circuits and equipment shall be protected from mechanical damage.

Effective insulation shall be maintained between live electrical equipment, circuits, earth and between different parts, voltages or sources of the rolling stock electrical system.

Where electrical systems incorporate power electronic converters, energy storage systems or electronic control systems not explicitly covered by this document, compliance with the electrical safety principles of Section 6 shall be demonstrated using applicable railway standards such as AS 7486:2026.

6.2 Circuits and earthing

The rolling stock electrical system shall incorporate a documented earthing and bonding scheme appropriate to the intended operating environment and electrical system configuration.

The earthing and bonding design scheme shall provide protective earthing arrangements, bonding requirements and return current strategy essential for the electrical safety, equipment protection, electromagnetic compatibility and reliable system operation.

Electrical circuits and earthing arrangements shall be designed and installed to ensure:

- (a) safe operation under normal conditions;
- (b) effective control of fault currents; and
- (c) protection of persons and equipment.

Train batteries shall be provided with switches installed in the positive and negative rails.

Batteries shall be protected by HRC fuses in both the positive and negative rails unless an alternative arrangement is adopted that provides an equivalent level of protection and safe isolation.

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, unless otherwise justified by the system design.

DC circuits may have double-pole switches, or may be connected directly to the negative or neutral line with no switches, fuses or contacts, provided that:

- (d) safe isolation is achieved; and
- (e) the arrangement is consistent with the defined earthing system.

The practice of de-energizing devices by short-circuiting the operating coil shall not be permitted.

The use of economy resistors or separate pull-in and holding coils for contactors, solenoids or similar devices shall not be permitted unless the design of the equipment incorporates these functions internally and demonstrates equivalent reliability and safety performance.

Circuit breakers shall not be used where regular switching by hand is anticipated unless specifically designed and rated for such duty.

Earthing and bonding arrangements shall be designed to:

- (f) provide a reliable fault current return path;
- (g) minimize touch and step potentials; and
- (h) maintain integrity under vibration, environmental conditions and service life.

Where alternative circuit configurations or earthing arrangements are used, compliance with the electrical safety principles defined in Section 6 shall be demonstrated.

6.3 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 uses 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 shall be positioned to ensure adequate clearance and creepage from other circuits with different operating voltages.

Commentary C6.3

Additional insulation materials can be used to increase the creepage distance where other alternatives are not feasible.

Auxiliary contacts shall comply with IEC 60947-5-1:2024.

6.4 Power contacts

Power contacts shall comply with IEC 60077-2:2017.

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 screwdriver slots.

Flexible shunts with crimped end connections and flared ends to prevent shunt abrasion shall be used to transfer current from moving contacts.

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.

Power contact devices, including arc control arrangements such as blow-out coils, shall be designed and applied in accordance with IEC 60077-2:2017 and IEC 60077-1:2017 to ensure effective arc control and interruption under the operating conditions of the equipment.

6.5 Coil and windings

All coils shall comply with IEC 60085:2007.

All coils shall be continuously rated for a 100% duty cycle unless otherwise specified 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 authorized 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.

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

Cable connectors shall provide a positive means of confirming correct engagement. This means of confirming correct engagement may include audible, tactile or visual indication to the technician.

6.7 Low-voltage switchgear

Low-voltage switchgear shall comply with AS/NZS 61439.1:2026 and AS/NZS 60947.1:2021.

Low-voltage 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 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 unauthorized persons.

Where electronic, touch-panel or software-based control interfaces are used in place of or in conjunction with mechanical switches, they shall:

- (a) provide equivalent functionality, reliability and safety; and
- (b) include clear indication of operating status and measures to prevent unintended operation.

6.8 High-voltage switchgear and circuit protection

6.8.1 General

High-voltage switchgear and circuit protection equipment shall comply with the applicable requirements of:

- (c) IEC 60077-1:2017;
- (d) IEC 60077-2:2017; and
- (e) IEC 61373:2026.

High-voltage switchgear and circuit protection equipment shall be suitable for the operating voltage, current and fault levels of the rolling stock electrical system.

High-voltage switchgear shall be selected and installed to provide safe switching, isolation and protection of high-voltage electrical systems.

Where incorrect switching sequences could create a hazardous condition, suitable mechanical, electrical or software interlocking shall be provided.

High-voltage switchgear shall be arranged to permit safe inspection, maintenance and replacement.

6.8.2 Circuit breakers

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

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

The operating lever shall be down in the off or tripped position.

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:

- (f) IEC 60077-3:2019; and

(g) IEC 60077-4:2019.

6.8.3 High speed circuit breakers

The type testing of high-speed circuit breakers (HSCBs) and line switches shall comply with IEC 60077-3:2019 and IEC 61373:2026.

HSCBs and line switches shall have an operational frequency rating of C3 in accordance with IEC 60077-3:2019.

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 shall be as short and as direct as possible.

HSCBs should 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 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.

Commentary C6.8.3

Discrimination in this context refers to coordination between onboard protection devices and upstream infrastructure protection systems such that electrical faults are isolated by the nearest practicable device, minimizing unnecessary interruption to the external power supply

6.8.4 Line switches and isolators

Line switches and isolators shall be suitable for the operating voltage, current and switching duty of the application.

Line switches and isolators shall:

- (a) provide clear indication of their operating position;
- (b) prevent inadvertent operation;
- (c) maintain adequate creepage and clearance distances in all operating positions;
and
- (d) be accessible for inspection and maintenance.

Devices intended solely for isolation shall not be used to interrupt load current unless specifically designed and rated for that purpose.

Where line switches or isolators are used for maintenance isolation, provision shall be made for securing the device in the isolated position.

6.8.5 High-voltage contactors

High-voltage contactors shall be suitable for the operating voltage, current and switching duty of the circuit.

High-voltage contactors shall:

- (a) safely make and break the intended circuit current;
- (b) incorporate suitable arc control or arc suppression measures;
- (c) maintain electrical and mechanical performance under vibration and shock conditions; and
- (d) be suitable for the operating duty of the application.

Power contact devices, including arc control arrangements such as blow-out coils, shall be designed and applied in accordance with IEC 60077-1:2017 and IEC 60077-2:2017 to ensure effective arc control and interruption under the operating conditions of the equipment.

Monitoring or protective measures shall be provided where failure of a contactor to open could create a hazardous condition.

6.8.6 High-voltage earthing devices

Where high-voltage earthing devices are provided, they shall provide for the discharge and earthing of isolated high-voltage circuits.

Earthing devices shall:

- (a) provide a reliable connection between the isolated circuit and earth;
- (b) be capable of carrying the prospective fault current for the required duration;
- (c) be protected against inadvertent operation; and
- (d) be clearly identified.

Provision shall be made to safely discharge stored electrical energy before, or as part of, the earthing process.

Where necessary, mechanical or electrical interlocking shall be provided to prevent simultaneous connection of the traction supply and earth.

The operating position of earthing devices shall be clearly indicated.

6.8.7 High-voltage connectors

High-voltage connectors shall be suitable for the electrical, environmental and mechanical conditions of railway service.

High-voltage connectors shall:

- (a) prevent incorrect mating or connection;
- (b) prevent access to live parts during connection and disconnection;
- (c) maintain electrical continuity and insulation integrity throughout their service life;
- (d) remain secure under vibration and shock conditions; and
- (e) be clearly identifiable where multiple connector types are provided.

Connectors serving different functions shall be designed to prevent incorrect mating.

Connectors shall provide a positive means of confirming correct engagement. Such confirmation may include audible, tactile or visual indication.

Where connection status is not readily visible, the design shall provide a means of confirming full engagement.

6.8.8 Fuses

6.8.8.1 Low-voltage and extra-low-voltage fuses

Low-voltage and extra-low-voltage fuses should be back connected.

Spare fuses of each type should 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 should be equal to the number of fuses of each type divided by 3 and rounded up.

6.8.8.2 High-voltage fuses

High-voltage fuses shall comply with IEC 60077-5:2019.

High-voltage fuses shall:

- (a) be rated for the maximum operating voltage, load current and prospective fault current of the protected circuit;
- (b) be installed such that replacement can be carried out safely;
- (c) be protected against vibration-induced loosening or damage;
- (d) be clearly identified with their rating and application; and
- (e) provide protection coordination with associated switching and protection devices.

Fuse mounting arrangements shall prevent the installation of an incorrect fuse type or rating where this could adversely affect safety or performance.

Where access to high-voltage fuse assemblies is required, provision shall be made to safely isolate the associated circuit before inspection or replacement.

Spare high-voltage fuses should be stored in a protected location and clearly identified.

Spare fuses of each type should 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 should be equal to the number of fuses of each type divided by 3 and rounded up.

6.9 Capacitors

Capacitors and associated suppression functions may be integrated within equipment or assemblies provided that the required electrical performance and safety including insulation, integrity and control of stored energy are maintained.

Where integrated arrangements are used, they shall not present a risk of residual voltage or unintended energization following isolation.

All capacitors shall comply with IEC 61071:2017.

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.

Capacitors shall be provided with a means of safely discharging stored energy following isolation.

Section 7 Mounting and installation of electrical equipment

7.1 General construction

Documentation shall be maintained to demonstrate compliance with the requirements of this section, including relevant design and installation records.

All electrical equipment, circuits and systems shall be 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.

All electrical equipment, circuits and systems shall comply with IEC 61373:2026.

The degree of protection in accordance with AS 60529:2025 shall be specified for each group, and the rationale for the assigned IP rating shall be documented in the supporting design records.

7.2 Safety requirements

The design of all components and systems must be in accordance with legislative requirements.

Electrical components and systems must comply with applicable legislative requirements.

Live parts capable of causing an electric shock shall be protected against accidental or direct contact by the crew, maintenance staff, cleaning staff or passengers.

Any equipment that can be accessed by the crew, maintenance staff or passengers shall be free of sharp edges and burrs.

7.3 Mounting of electrical equipment

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 a single 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 a single 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 60077-1:2017, with the following provisions:

- (a) Creepage distance is to be determined by the vulnerability of equipment to increased risk of electrical tracking caused by environmental contaminants.
- (b) In the case of roof-mounted equipment or equipment mounted in areas where its position and orientation are likely to promote the accumulation of contaminants

(e.g. dust, dirt or water), the creepage distance calculation is to include distances over surfaces that are liable to retain such contaminants.

- (c) Where an insulating tube or equivalent is used to carry compressed air to an item energized at a high voltage, the creepage distance is to be at least 300% of that specified in IEC 60077-1:2017.
- (d) Such an insulating tube is to be located so that condensate cannot collect on the high voltage item or insulating tube.

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.

7.5 Insulators

All insulators shall comply with AS/NZS 3121:2002 (R2020).

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

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

- (e) Above 650 V, 10 000 V test.
- (f) Below 650 V, 3 500 V test.

Insulators shall be resistant to arc tracking and be of a high quality and high-strength moulded or cast insulating material.

Moulded 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 Cables

Cables shall comply with the following standards, as applicable:

- (g) EN 50200:2015
- (h) EN 50264-1:2008
- (i) EN 50306-1:2020
- (j) EN 50382-1: 2008+A1:2013
- (k) EN 50343:2024

Cable systems or insulation and jacket thicknesses that are not certified to the aforementioned standards but demonstrate technical conformance to the aforementioned standards may be proposed.

7.7 Terminals and cable terminations

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

Soldered connections in electronic equipment shall comply with IEC 60571:2012.

Low-voltage cables with conductor cross-sectional areas up to and including 6 mm² shall be fitted with approved copper-sleeved, colour-insulated double-crimp lugs, with the insulation sleeve and the lug crimped together.

Heat-shrinkable sleeves used for electrical or mechanical protection shall be in accordance with the requirements of EN 50343:2024.

All terminals shall be capable of retaining at least 2 wires to facilitate cable looping. No more than 4 cables shall be terminated at any single terminal.

Where a design review determines that the use of post terminals is impracticable, push-on quick-connect terminations may be used as an alternative in low-vibration situations.

Spring-type cage-clamp terminals with bootlace ferrules type lugs may be used as a third option.

Piggyback terminals shall not be used.

7.8 Conduit materials and fittings

All conduits shall comply with AS 61386.1:2015.

Conduits shall be supported and fastened securely in position with conduit clips, cleats and/or brackets to prevent movement.

All supports shall be independently applied to conduits, that prevent the conduit being supported by another conduit or by any pneumatic or hydraulic pipes.

All underframe-mounted conduits shall be capable of withstanding impacts from 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 a minimum degree of protection of IP65 in accordance with AS 60529:2025.

Conduits shall not be welded.

7.9 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 rated for the maximum expected operating temperature of the installation.

Cables and looms shall be clear of 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.

7.10 Cable runs

Cable runs shall be installed in accordance with EN 50343:2024.

7.11 Trunking

Steel trunking shall be formed from zinc-coated steel in accordance with AS 1397:2021.

Where aluminium trunking is used, it shall have a wall thickness of not less than 3 mm.

All trunking shall:

- (l) be electrically bonded to earth with a resistance not exceeding 0.1 Ω ;
- (m) be designed to maintain the enclosure ingress protection rating;

- (n) be designed to prevent the ingress of dust and moisture and provide a minimum degree of protection of IP54 in accordance with AS 60529:2025, unless otherwise specified; and
- (o) have earthed access covers:
 - (i) positioned to allow safe installation and removal of cables without damage; and
 - (ii) designed to exclude dust and moisture.

Electrical cables within trunking shall be securely restrained to prevent movement, chafing or damage under vibration conditions in accordance with IEC 61373:2026.

Access covers shall be secured by mechanical fasteners (e.g. screws, clamps or brackets) independent of any friction fit, ribbing or flange.

Where high-voltage cables are installed in trunking adjacent to passenger-accessible areas:

- (p) trunking wall thickness shall be not less than 3 mm;
- (q) electrical clearances shall comply with IEC 60077-1:2017; and
- (r) an air gap or insulating barrier shall be provided between the trunking and interior surfaces.

Additionally, electrical and thermal insulation shall be provided where between the trunking and the passenger wall where necessary to ensure passenger safety and comfort.

7.12 Heavy-current cables

Heavy-current cables shall be installed in accordance with EN 50343:2024.

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

Cable support clamps shall not pinch or crush cable insulation.

Cable support clamps shall adequately support cables under all operating conditions of shock and vibration.

Runs of smaller cable size up to 25 mm² may be run bundled together to give additional support.

Runs of smaller cable shall be secured with cleats, spaced at centres 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 minimize EMI.

EMI reduction strategies for heavy-current cables shall comply with AS 7722:2026.

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

- (s) Twisting three-phase cables at least once per meter for larger cables (e.g. 70 mm²) and at least twice per metre for smaller cables (e.g. 30 mm²).
- (t) Running cables in metal trunking or conduits.
- (u) 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.

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.

7.13 Busbars

Where busbars are used, the following provisions apply:

- (a) The busbars shall comply with:
 - (i) AS/NZS 61439.1:2026;
 - (ii) AS/NZS 62271.200:2026; and
 - (iii) IEC 61373:2026.
- (b) The busbars shall be of adequate stiffness, supported and clamped against movement, resonance, vibrations and magnetic forces under short circuit fault conditions in accordance with IEC 60865-1:2011.
- (c) The busbars shall be of adequate size and stiffness to ensure thermal and electrodynamic stresses are within acceptable limits.
- (d) In locations where access is not restricted, the busbar shall be insulated or shrouded to prevent inadvertent contact using insulation systems appropriate to the operating voltage to minimize inadvertent contact.
- (e) Each busbar terminal and termination shall have the ability to be removed and replaced without disturbing adjacent items.
- (f) Each busbar shall be properly labelled and provided with warning signs where it is applicable.

7.14 Light-current cables

Light-current cables shall be installed in accordance with EN 50343:2024.

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

The following requirements apply to light-current cables inside enclosures:

- (g) Light-current cables may be run without conduit or trunking.
- (h) Light-current cable looms shall be formed by fastening cables together with fire-retardant ties that comply with EN 45545-2:2020+A1:2023, Hazard Level 2 (HL2), to create neat bundles that prevent rubbing or chafing.
- (i) All looms shall be fastened at not more than 150 mm intervals.
- (j) All individual cables within the loom shall be laid parallel, pulled straight, and shall have a neat appearance.
- (k) All looms shall be parallel and remain parallel when passing around corners.
- (l) Fire-retardant fastenings that comply with EN 45545-2:2020+A1:2023 HL2 shall be applied at the beginning and end of each bend, and where one or more a cable or cables leave the loom, to secure the leaving cable.
- (m) Self-adhesive tape and self-adhesive fasteners shall not be used.
- (n) As far as practicable, cables shall leave looms at right angles to give a neat appearance.
- (o) Sufficient slack shall be provided to prevent a strain being placed on cable terminals and allow for 2 more recrimpings.

The term fastening includes the application of commercial cable ties, which shall be halogen-free and used to secure the cable bundle.

Extra-low-voltage cables shall 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 installed in a manner that results in eddy-current heating within conduits.

Light-current cables and looms shall be adequately secured 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.

7.15 Joining of cables

Cables shall be joined at terminals.

Cables shall not be joined within a cable run unless an approved inline joint repair is used and accepted by the RSO.

Cables shall comply with IEC 60077-1:2017.

Cables shall comply with AS/NZS 61439.1:2026.

7.16 Spare cables

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

Screened 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.

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:

- (p) Serial number.
- (q) Manufacturer's type number.

- (r) Current, voltage and power ratings and whether continuous or otherwise.
- (s) Speed at rated current.
- (t) Maximum speed.
- (u) Field connection (series, separately excited, and so on).

All machine terminals shall be labelled in accordance with IEC 60349-1:2010 and IEC 60349-2:2010 as applicable.

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 on visible areas.

7.19 Enclosure designs

7.19.1 General

Low-voltage (LV) and extra-low-voltage (ELV) enclosures containing circuits rated for >800 A shall be designed as per the guidelines of AS/NZS 61439.1:2026, Appendix ZC.

Enclosures designed to provide increased security against the occurrence or the effects of internal arc faults shall be type tested as per the requirements of AS/NZS 61439.1:2026, Appendix ZD.

All electrical enclosures shall be assessed to determine the arc flash risk.

HV electrical enclosures shall be designed and assessed as per Section 8.104 of AS/NZS 62271.200:2026.

The design process shall determine if there is a need for IAC-classified enclosures or other protective measures to meet the SFAIRP requirements.

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

Enclosure design shall ensure that live parts capable of causing an electric shock are protected against accidental or direct contact by the crew, maintenance staff, cleaning staff or passengers.

The design of enclosures shall assess the risks associated with explosion due to the build-up of flammable gases and or flammable materials.

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

Enclosures containing electrical equipment shall have safety signs in accordance with AS 1319:2018.

Each enclosure shall have an IP rating in accordance with AS 60529:2025. 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 cover attachments 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 shall 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.

Commentary C7.19.1

Examples of enclosures presenting higher electrical or fire risk include those containing high-voltage equipment, energy storage devices, power conversion equipment, or equipment capable of producing arcs under normal or fault conditions.

Earthing connections shall maintain continuity and integrity throughout the service life of the equipment, including under vibration, environmental exposure and maintenance activities.

7.19.2 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.

7.19.3 Terminal boxes mounted within a vehicle

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

Terminal boxes with metallic lids shall be earthed.

Section 8 Testing

8.1 General

Electrical equipment, assemblies and electrical systems shall be inspected and tested to demonstrate compliance with the requirements of this document prior to entry into service.

Testing shall verify that the electrical equipment performs safely and correctly under design/normal operating conditions and does not present unacceptable risks under abnormal or fault conditions.

Testing shall be undertaken using calibrated equipment and documented procedures appropriate to the electrical equipment and sub-assemblies being tested.

8.2 Sub-assembly testing

Each electrical sub assembly shall be inspected and tested before installation into the vehicle.

This shall be completed in accordance with relevant international standards, design directions, and to the OEM guidelines.

The testing shall include:

- (a) insulation resistance;
- (b) dielectric capability;
- (c) continuity of protective earthing;
- (d) individual equipment functional operation; and

- (e) mechanical integrity of electrical connections/

Testing of equipment shall be conducted in accordance with relevant international Standards and equipment part supplier and manufacturer's guidelines.

Electrical testing shall include, as a minimum:

- (f) insulation resistance testing to verify electrical insulation integrity;
- (g) functional testing to confirm the correct operation of electrical circuits and equipment; and
- (h) verification testing following modification, repair or replacement of electrical equipment.

8.3 Static testing

Following installation, completion of equipment and subassemblies, and inspection of individual items of equipment, the completed vehicle shall undergo static testing to verify correct installation, operation and safety of the onboard electrical systems.

The static testing shall include:

- (a) system-wide completion of insulation resistance and dielectric withstand tests;
- (b) completion of earthing and bonding;
- (c) operation of control circuits and auxiliary electrical systems;
- (d) operation of battery systems and associated auxiliary equipment power supplies;
- (e) correct operation of emergency systems; and
- (f) satisfactory operation of electrical systems under normal stationary operating conditions.

The static testing shall include routine testing, type testing, factory acceptance testing results and vehicle acceptance testing results.

Static testing shall be completed satisfactorily before commencement of dynamic testing.

8.4 Dynamic testing

Following satisfactory completion of static testing, the vehicle shall undergo dynamic testing to verify the performance and integration of onboard electrical systems under operating conditions.

The dynamic testing shall include:

- (a) operation of traction and auxiliary electrical systems throughout the operating speed range;
- (b) electrical systems' performance during acceleration, coasting and braking;
- (c) operation of battery charging and energy management systems;
- (d) correct operation of protective devices, electrical controls, monitoring systems, power interruptions, recovery systems and communication systems; and
- (e) performance of electromagnetic interference between onboard electrical systems.

8.5 Vehicle testing

The vehicle testing shall be completed as static testing and dynamic testing before commissioning.

Static, dynamic and commissioning testing shall be undertaken in accordance with IEC 61133:2016, IEC 61373:2026, IEC 60571:2012, and any additional RSO or RIM testing requirements.

Vehicle-level electrical testing shall include, as a minimum:

- (f) functional verification of integrated electrical systems under representative operating conditions;
- (g) verification of protection systems, including correct operation and coordination of circuit protection devices; and
- (h) verification of electrical system performance following integration, modification or repair.

8.6 Final commissioning testing

Following satisfactory completion of static and dynamic testing, the completed vehicle shall undergo final commissioning testing to confirm that all onboard electrical systems are fully integrated, function as design intended, and are suitable for safe entry into service.

Final commissioning testing shall verify:

- (a) correct integration and operation of all electrical systems;
- (b) satisfactory operation of traction, auxiliary, battery, control, monitoring and communication systems;
- (c) correct sequential and integrated operation of all electrical protection systems;
- (d) correct operation of interfaces between electrical systems and other vehicle systems;
- (e) confirmation that all defects identified during previous stages of testing have been rectified; and
- (f) confirmation that the rolling stock is suitable for entry into operational service.

8.7 In-service verification

Electrical systems shall be subject to verification during service to ensure continued safe operation.

In-service testing and inspection shall include, as a minimum:

- (a) verification of insulation integrity where electrical equipment has been disturbed or exposed to adverse conditions;
- (b) functional checks of electrical systems following maintenance, modification or repair; and
- (c) verification that protective and safety systems remain operational.

Appendix A Hazard Register (Informative)

Hazard number	Hazard
5.2	Harm to Infrastructure Rolling Stock
5.2.1.5	Fire
5.2.1.12 5.2.1.13	Rolling stock electrical systems generating the same frequency as an infrastructure system frequency
5.2.1.19	Harmonics affecting overhead wires causing rolling stock electrical systems to generate the same frequency as an infrastructure system frequency, affecting communication systems and thereby causing EMI
5.2.1.22	Electric train power consumption being excessive causing trains to draw too much current resulting in harm to overhead power systems
5.2.1.30	Trains failing to open MCB before neutral sections causing dewirement (harm to overhead power systems)
5.3	Harm to persons
5.3.1.23	Fire causing burns by thermal radiation
5.3.1.30	Radiation heaters causing burns by conduction
5.3.1.31	Hot equipment causing burns by conduction
5.3.1.41	Repetitive strain injury when manual handling
5.4	Harm to Rolling Stock
5.4.1.3	Inadequate rolling stock maintenance or overhaul
5.4.1.4	Inadequate rolling stock maintenance or overhaul causing excessive wear and tear
5.4.1.18	Explosion
5.4.1.20	Fire
5.4.1.38	EMI
5.4.1.61	Inadequate rolling stock in-service testing
5.4.1.62	Inadequate rolling stock modification
5.5	Harm to Rolling Stock Related Processes
5.5.1.10	Non-compliance with Transport / Rail Safety legislation
5.5.1.11	Non-compliance with Communications legislation
5.5.1.15 5.5.1.21	Non-compliance with Electricity legislation
5.5.1.17	Tag being in the wrong position leading to wayside equipment being unable to (correctly) identify rolling stock
5.5.1.25	Harm to rolling stock - Unable to maintain timetable

Hazard number	Hazard
5.5.1.27	Out of control trains leading to the inability to maintain timetables
5.5.1.30	Traction or braking failure leading to the inability to maintain timetables
5.5.1.34	Non-compliance with OHS/WHS legislation causing harm to persons
5.5.1.45	Design deficiency causing the inability to operate trains
5.5.1.46	Manufacturing deficiency causing the inability to operate trains
5.5.1.47	Maintenance deficiencies causing the inability to operate trains
5.5.1.54	Uncommanded brake applications causing the inability to maintain timetables
5.5.1.56	Incompatible inter-vehicle electrical or air connections creating operational inflexibility

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- EN 50128, *Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems*
- EN 50153, *Railway applications – Rolling stock – Protective provisions relating to electrical hazards*
- EN 50155, *Railway applications – Electronic equipment used on rolling stock*
- EN 50163, *Railway applications – Supply voltages of traction systems*