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1	01/12/2025	First Draft incorporating ZE Technology elements from AS7529.1
2	10/03/2026	Update following DG Meeting on 27/02/2026
3	04/05/2026	Update following DG Meeting on 14/04/2026
4	13/05/2026	Update following peer review to be used for PC

Preface

This standard was prepared by the Rolling Stock Fire Safety – Part 4: Track Machines Development Group, overseen by the ARISO Rolling Stock Standing Committee.

The major changes in this revision are as follows:

(a) Inclusion of zero emission technologies such as lithium-ion batteries, electric double-layer capacitors and hydrogen fuel cells.

(b) Structural alignment with the other AS7529 fire safety Standards

(c) A comprehensive update of all sections.

Objective

The object of this document is to provide requirements, recommendations, and guidance for fire safety for track machine rolling stock operating in Australia.

The requirements aim to ensure rolling stock is designed and maintained to reduce fire ignition risk, control fire growth, minimize fire impacts on people and operations, and support safe occupant egress and emergency intervention.

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.

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.

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’.

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.

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.

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 outlines fire safety requirements for track machines. These requirements are intended to form part of a broader rolling stock fire safety strategy aimed at minimizing the risk of harm to staff. This document also aims to reduce the risks that a fire on such rolling stock can pose to the safety of other persons who might be affected. This includes emergency responders, infrastructure workers and nearby passengers.

Fire safety is achieved through design, construction and maintenance measures, including compartmentation, fire-resistant materials, fire suppression systems and features that support evacuation.

This document includes fire safety requirements for track machines configured with zero emission technology used for propulsion or auxiliary supply. This includes battery-electric, electric double-layer capacitors and hydrogen fuel cell technologies. These systems introduce distinct fire safety hazards compared to conventional diesel and electric traction

This document applies to the design, construction, modification and maintenance of track machines, including track machines fitted with zero emission (ZE) energy propulsion systems such as energy storage systems (ESS), electric double-layer capacitors (EDLC) and hydrogen fuel systems (HFS). The document covers requirements for fire prevention, fire detection, fire suppression systems, material flammability and evacuation.

This document does not cover:

(a) operational procedures for rolling stock, including activities such as refuelling, hydrogen recharging, battery charging, and handling flammable liquids or gases during those processes;

(b) track machines with liquified petroleum gas (LPG), liquified natural gas (LNG) or compressed natural gas (CNG) as propulsion fuel;

(c) heritage, light rail and cane rolling stock, but items from this document can be applied to such systems as deemed appropriate by the relevant RIM and/or RSO;

(d) light duty track machines;

(e) road-rail vehicles.

The requirements of this document are aimed at minimising fire risk to life of rolling stock occupants as well as the risks that a fire on such rolling stock can pose to the life and safety of other users of the infrastructure.

The requirements of this document do not address asset protection of either the infrastructure maintenance rolling stock or the infrastructure. The requirements of this document do not contain any specific mitigations for fire safety risks associated with terrorism, or with fires following train-to-train collision and ignition.

This document deals with explosion risks in the context of reducing the risk of a build-up of flammable gases that could result in an explosion. However, mitigating the consequence of a blast from an explosion is not part of the scope of this document.

Compliance with this standard represents the minimum requirement under the designer's duties under Rail Safety National Law.

1.2 General Information

1.2.1 Application by rolling stock type

Fire safety requirements for passenger-carrying rolling stock are specified in AS 7529.3:2014

Fire safety requirements for locomotive and freight rolling stock are specified in AS 7529.1:2026

Section 2 to Section 10 (inclusive) of this document apply to the design and construction of new medium-duty and heavy-duty track machines.

Section 11 of this document applies to the maintenance, modification and refurbishment of existing medium-duty and heavy-duty track machines.

1.2.2 Zero emission track machines

Energy storage system (ESS) and hydrogen fuel system (HFS) present specific fire and explosion risks that are directly influenced by system size, configuration and chemical properties.

Key hazards for ESS include, but are not limited to:

(a) thermal runaway initiation within cells or modules and propagation between adjacent cells, modules or packs;

(b) release of flammable and toxic gases (including pre-ignition off-gas emissions), and the potential for re-ignition after initial suppression;

(c) enclosure over-pressure leading to uncontrolled venting or rupture;

(d) high-velocity venting that can produce jet flames or flame fronts, and the ejection of cell/module components or high-temperature debris due to rapid gas expansion; and

(e) electrical hazards during and after failure events (e.g., arcing/short-circuiting and persistent voltage hazards).

ESS capacity in rolling stock typically ranges from 50 kWh to over 15 MWh. The fire risk varies depending on the battery chemistry, housing, energy density, battery management system, state of charge, and charging method. Battery chemistries with higher energy density typically pose greater risks of thermal runaway, fire, and gas release than chemistries designed for enhanced thermal stability and reduced propagation risk.

Electric double-layer capacitors (EDLC) are also used in zero emission rolling stock for regenerative braking, peak load reduction and short-term energy buffering. EDLCs provide high power density and rapid charge–discharge performance but have lower energy density compared to batteries. While their thermal runaway risk is typically lower than high-energy batteries, EDLCs contain electrolytes that can pose fire and gas release hazards under fault conditions.

Key hazards for HFS include, but are not limited to:

(f) leakage and dispersion of hydrogen creating flammable or explosive atmospheres, including accumulation in confined or semi-enclosed spaces;

(g) high-pressure storage failures (including rapid decompression events) and jet fires from uncontrolled releases; and

(h) for cryogenic/liquefied systems, boiling liquid expanding vapour explosion hazards.

Hydrogen combustion can produce flames that are difficult to detect visually, increasing reliance on appropriate fire detection technologies and procedures presenting additional challenges for fire detection systems and emergency response.

HFS stores can range from 100 kg to over 4,000 kg of hydrogen depending on the track machine type, storage method and operational range. Storage can involve compressed gaseous hydrogen at pressures typically between 350 and 700 bar or alternatively, cryogenic or liquefied hydrogen for larger-capacity systems.

1.2.3 Alignment with evolving technologies and industry trends

The provisions in this document are based on current practices. As new battery chemistries, hydrogen fuel systems and alternative fuels like ammonia are developed, additional or updated safety requirements could become necessary.

Currently, this document does not include specific technical requirements or detailed safety provisions for ammonia-fuelled rolling stock; however, the general fire safety principles outlined herein could be applied where relevant, at the discretion of designers and RSOs.

1.2.4 Operational context

While this document defines design requirements to support fire safety, it does not prescribe operational responses to fire events. Decisions related to train stopping, staff evacuation and response coordination are the responsibility of the RSO, in accordance with their safety management system (SMS) and applicable rail safety legislation.

Where performance-based solutions are applied, it is important that fire development timelines and evacuation timings are evaluated as part of demonstrating that the fire safety risk has been reduced so far as is reasonably practicable.

1.2.5 Fire behaviour and infrastructure considerations for enclosed environments

Hydrogen-powered rolling stock in enclosed environments such as tunnels introduce particular fire and explosion risks due to the properties of hydrogen. These risks influence aspects of rolling stock design and can also inform infrastructure planning and operational practices.

In confined spaces, leaked hydrogen can accumulate near tunnel ceilings, especially where ventilation is limited or airflow is disrupted. Effective dispersion and dilution of hydrogen are essential to avoid the formation of flammable concentrations. Tunnel ventilation characteristics, including minimum airflow rates and directional controls, impact both gas movement and the effectiveness of emergency responses.

Hydrogen can burn with a near invisible flame which will require consideration when selecting an appropriate fire detection system. Further details and requirements are contained in Section 9.

Hydrogen power might introduce horizontal jet flame which will need to be considered for vehicle design including aspects such as egress.

Tunnel structural behaviour under exposure to hydrogen jet flames or lithium battery fires could also warrant consideration. High-temperature flames can cause localized degradation of structural reinforcement and protective finishes. Heat-resistant materials or fire-resilient design features can help limit potential damage during prolonged fire exposure.

1.3 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 1530.1:1994 + Amd 1 (2005) + Amd 2 (2016), *Methods for fire tests on building materials, components and structures – Part 1: Combustibility test for materials*

- AS 1530.4:2014, *Methods for fire tests on building materials, components and structures – Fire-resistance test of elements of construction*
- AS 2444:2001, *Portable fire extinguishers and fire blankets – Selection and location*
- AS 5062:2022, *Fire protection for mobile and transportable equipment*
- AS 7240 (all parts), *Fire detection and fire alarm systems*
- AS 7486:2022, *Railway energy storage – Rolling Stock onboard electrical energy storage systems*
- AS 7522:2021, *Access and egress*
- AS/NZS 1841:2007, *Portable fire extinguishers General Requirements*
- AS/NZS 3504:2006, *Fire blankets*
- AS ISO 31000:2018, *Risk Management - Guidelines*
- IEC 63341-1:2025, *Railway applications - Hydrogen and fuel cell systems for rolling stock - Part 1: Fuel cell power system*
- IEC 63341-2:2025, *Railway applications - Hydrogen and fuel cell systems for rolling stock - Part 2: Hydrogen fuel system*
- ISO 834-1:2025, *Fire-resistance tests — Elements of building construction — Part 1: General requirements*
- EN 54 (all parts), *The European standard series for fire detection and fire alarm systems*
- EN 403:2004, *Respiratory protective devices — Escape hood for fire — Requirements, testing, marking*
- EN 45545-2:2020+A1:2023, *Fire protection on railway vehicles - Part 2: Requirements for fire behaviour of materials and components*
- EN 45545-3:2024, *Railway applications – Fire protection on railway vehicles – Part 3: Fire resistance requirements for fire barriers*
- EN 45545-4:2024, *Railway applications – Fire protection on railway vehicles – Part 4: Fire safety requirements for railway rolling stock design*
- EN 50553:2012, *Railway applications — Rolling stock — Energy consumption*
- CSA T/S 601:2024, *Hydrogen fuel cell power systems for rolling stock*
- UN ECE R134:2019, *Uniform provisions concerning the approval of vehicles with regard to their hydrogen propulsion system*

NOTE:

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

1.4 Defined terms and abbreviations

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

1.4.1
battery management system (BMS)
system that monitors and controls the battery's performance, ensuring safe operation and optimal efficiency

1.4.2
battery thermal management system (BTMS)
system dedicated to controlling the battery's thermal environment, managing heating and cooling functions to maintain the battery within its optimal operating temperature range

Note 1 to entry: While often integrated or coordinated with the BMS, the BTMS is functionally distinct and focused solely on thermal regulation

Note 2 to entry: A cane railway network typically operates on a 610 mm gauge.

1.4.3
computational fluid dynamics (CFD)
numerical modelling technique used to simulate fluid flow, heat transfer and species dispersion, including smoke, hot gases and flammable or toxic vapours, by solving the governing conservation equations within a defined computational domain

1.4.4
design category
defined in EN 45545-1, which is based on the design and layout characteristics of the railway vehicle.

Note 1 to entry: Track machines are generally classified in the 'N' (standard vehicle) design category.

1.4.5
design fire
representation of a fire that is characterised by the variation of heat output with time and is used as a basis for assessing fire safety systems.

1.4.6
Integrity (E)
ability of an element or component to withstand exposure to fire on one side without the passage of flames or hot gases that could cause ignition of materials on the unexposed side, as defined in EN 45545-3:2024.

Note 1 to entry: Integrity (E) performance is expressed as a time in minutes (e.g., E15, E30, E60) corresponding to the period during which the element maintains its separating function.

1.4.7
electric double-layer capacitor (EDLC)
energy storage device that stores electrical energy through electrostatic charge accumulation at the interface between an electrode and an electrolyte

1.4.8
energy storage system (ESS)
physical systems consisting of one or more battery units and/or electric double-layer capacitors and associated components required to connect to the direct current link

Note 1 to entry: This includes converters, control and monitoring systems, inductors, protection devices, and thermal management equipment. These systems are primarily intended to support traction.

1.4.9
energy storage unit (ESU)
physical equipment which is comprised of energy storage technologies such as batteries or EDLCs

1.4.10
fire engineering brief (FEB)
document presenting the completed fire-engineering analysis, results and justification demonstrating that the design satisfies the relevant fire-safety performance requirements

1.4.11
fire engineering report (FER)
document presenting the completed fire-engineering analysis, results and justification demonstrating that the design satisfies the relevant fire-safety performance requirements.

1.4.12
fuel cell module
assembly incorporating one or more fuel cell stacks and, if applicable, additional components that is intended to be integrated into a power system or a vehicle

1.4.13
fuel cell power system
generator system that uses one or more fuel cell modules to generate electric power and heat

1.4.14
fuel cell stack
assembly of cells, separators, cooling plates, manifolds and a supporting structure that electrochemically converts, typically, hydrogen-rich gas and air reactants to direct current power, heat and other reaction products

1.4.15
hazard level (HL)
classification level used to differentiate material fire-safety requirements derived from the operation and design categories, as defined in EN 45545-1.

Note 1 to entry: Three hazard levels (HL 1, HL 2 and HL 3) are defined, with HL 3 representing the most stringent fire.

1.4.16
heating, ventilation, and air conditioning (HVAC)
system or assembly of systems installed on rolling stock to provide heating, ventilation, air circulation, filtration and air-conditioning functions that maintain suitable environmental conditions for staff and equipment.

Note 1 to entry: HVAC system may include air-intake and exhaust components, filters, fans, ducting, control devices, and associated.

1.4.17
heavy duty track machine
track machine able to travel at speeds greater than 60 km/h or weighing in excess of 20 tonnes gross/maximum service mass

1.4.18
hydrogen fuel system (HFS)
system designed to store hydrogen and to process it to supply the fuel cell power system

Note 1 to entry: It includes the refuelling on-board devices, fuel lines and the associated monitoring, control & safety devices.

1.4.19
high power equipment
equipment with circuits operating with a rated power greater than 20 kW

Note 1 to entry: high power equipment is typically used in urban areas and often having a shared right-of-way with road traffic.

1.4.20
high voltage
nominal voltage exceeding 1000 volts ac or exceeding 1500 volts dc

1.4.21
Insulation (I)
criterion of fire-resistance performance describing the ability of an element to reduce heat transfer and limit the temperature rise on the unexposed face when exposed to fire, as defined in EN 45545-3.

Note 1 to entry: Insulation (I) performance is expressed as a time in minutes (e.g., I15, I30, I60) corresponding to the period during which the average and maximum temperature rises on the unexposed.

1.4.22
international laboratory accreditation cooperation (ILAC)
organization for the accreditation of laboratories and inspection bodies that develops mutual recognition arrangements and promotes international acceptance of accredited test, calibration and inspection results.

1.4.23
infrastructure maintenance rolling stock
on track vehicles, track machines and road-rail vehicles

1.4.24
international fire engineering guidelines (IFEG)
guideline jointly developed by Australian, New Zealand, Canadian and United States authorities providing an internationally consistent framework for the application of fire-safety engineering principles to building and infrastructure design.

1.4.25
lower flammability limit (LFL)
minimum concentration of a combustible gas or vapor in air that can ignite and propagate a flame.

1.4.26
lithium iron phosphate (LFP)
battery chemistry that uses a lithium iron phosphate ($LiFePO_4$) cathode, a carbon-based anode and a lithium salt electrolyte.

1.4.27
light duty track machine
track machine unable to travel at speeds greater than 15 km/h and weighing no more than 5 tonnes gross/maximum service mass

1.4.28
medium duty track machine
track machine that is not a heavy duty or light duty track machine

1.4.29
National Association of Testing Authorities in Australia (NATA)
national accreditation body responsible for the assessment and recognition of laboratories, inspection bodies, calibration facilities and other conformity-assessment organisations in Australia.

1.4.30
nickel-cobalt-aluminium (NCA)
battery chemistry that uses a lithium nickel cobalt aluminium oxide ($LiNi_xCo_yAlzO_2$) cathode, a carbon-based anode and a lithium salt electrolyte in a lithium-ion cell

1.4.31
National Engineers Register (NER)
list maintained by the Institution of Engineers Australia that includes individuals who have been assessed as meeting professional and ethical standards in a recognized area of practice, including fire safety engineering

1.4.32
occupied staff compartment
designated space on a track machine that is intended to be occupied by staff for extended periods during travel or work modes, where they can drive, operate or supervise the machine or its equipment

1.4.33
operation category
defined in EN 45545-1, category that characterises the operating environment of the railway vehicles with regard to the fire safety requirements

1.4.34
rail infrastructure manager (RIM)
As defined in Rail Safety National Law.

1.4.35
rolling stock operator (RSO)
As defined in Rail Safety National Law.

1.4.36
running capability
ability of the train to reach a 'place of safety' with a fire onboard

1.4.37
self-rescue device
personal protective device that provides short-duration respiratory protection to staff during evacuation through smoke-filled or toxic environments

1.4.38
so far as is reasonably practicable (SFAIRP)
As defined in Rail Safety National Law.

1.4.39
thermally activated pressure relief devices (TPRD)
safety device fitted to a pressurised vessel that activates in response to elevated temperature to release gas and prevent rupture or explosion

Note 1 to entry: A TPRD is commonly used in hydrogen storage and other high-pressure gas systems to vent the contents of a cylinder or tank in a controlled manner when excessive heat increases internal pressure.

General rail industry terms and definitions are maintained in the ARISO Glossary. Refer to: https://www.ariso.org.au/glossary/

Section 2 Conditions on use of performance and deemed to satisfy provisions

2.1 General approach

This document permits compliance through either deemed-to-satisfy provisions or performance-based solutions, provided that mandatory fire safety outcomes are achieved.

Where verification of compliance with this document is not solely achieved by application of deemed-to-satisfy provisions, the following conditions apply:

(a) Verification shall be completed by or independently assessed and agreed as compliant by, a registered fire engineer experienced in rolling stock fire safety. This includes practitioners registered on the National Engineering Register (NER) in the category of fire safety engineering or equivalent; and

(b) A holistic fire safety assessment shall be undertaken to confirm that the overall level of fire safety achieved by the rolling stock design is SFAIRP for track machines.

2.2 Holistic fire safety assessment

The holistic fire safety assessment required according to Clause 2.1(b) shall:

(a) apply the process and principles of fire engineering design, evaluation and analysis as outlined in the International Fire Engineering Guidelines (IFEG); and

(b) incorporate fire hazard and risk analysis in accordance with the *RISSB Guideline – Rolling Stock Safety Assessment* and AS ISO 31000:2009. The analysis shall document the evaluated risk levels and the reasoning used to demonstrate that fire risks have been reduced so far as is reasonably practicable.

2.3 Fire safety documentation process

A structured fire safety documentation process shall be implemented for all new rolling stock projects and for modifications that impact fire safety. This process shall be undertaken in accordance with the methodology outlined in IFEG.

The process shall include but not be limited to:

(a) preparation of a fire engineering brief (FEB) to establish fire safety objectives, key assumptions and the compliance strategy at the early design phase;

(b) progressive fire engineering risk analysis throughout the project lifecycle, irrespective of whether a deemed-to-satisfy or performance-based approach is used; and

(c) preparation of a fire engineering report (FER) to document the final fire safety design, verify that risks have been addressed and demonstrate compliance prior to commissioning and operation.

For modifications to existing rolling stock, a risk assessment/analysis shall be conducted to evaluate the impact on fire safety. The level of detail shall be proportionate to the scale and safety impact of the change and can require reviewing the original fire safety design basis to confirm that the modification does not compromise previous fire safety verifications or critical safety design elements.

2.4 Competency for fire safety documentation

All fire safety documentation and modification risk assessments should be prepared, reviewed and approved by individuals with demonstrable competency in rolling stock fire safety engineering.

This should include:

(a) registration on the NER in the category of fire safety engineering or equivalent qualifications; and

(b) experience in rolling stock fire risk assessment, system integration and compliance with rail fire safety standards.

2.5 Evacuation and access requirements

Evacuation features shall comply with AS 7522:2025.

Deemed-to-satisfy solutions under this document shall only be applied where these features, such as emergency exits, ladders, escape paths, signage and lighting, meet or exceed the minimum requirements specified in AS 7522:2025.

Where alternative evacuation arrangements are proposed, their effectiveness under fire conditions shall be demonstrated through a performance assessment.

This assessment shall show that evacuation performance is equivalent to or better than, the standard defined in AS 7522:2025 and EN 45545-4:2024.

2.6 Novel design features

Where a proposed vehicle design incorporates novel features or technologies that depart significantly from established practice, an assessment shall be undertaken to address potential fire safety risks.

This shall include but not be limited to, designs involving reinforced plastic primary structures, novel battery chemistries or novel hydrogen storage configurations.

The assessment shall include, where applicable, representative full-scale fire testing, pyrolysis modelling or computational fluid dynamics (CFD) analysis of the novel feature.

Commentary *C2.6*

The purpose of this assessment is to ensure that the proposed design does not introduce unacceptable fire safety risks beyond the scope of the existing provisions of this document.

2.7 Functional integration of HFS & ESS track machines

Freight rolling stock configured to carry a HFS or ESS to supply traction power to a track machine and forming part of a tethered consist, is considered functionally integrated with the track machine. Such rolling stock shall comply with fire safety requirements applicable to track machines, including ignition risk mitigation, fire development mitigation, material performance and fixed fire protection provisions.

Section 3 Ignition risk mitigation measures

3.1 General

Ignition risk mitigation is a key component of fire prevention in track machines.

Potential ignition hazards shall be systematically identified and effectively managed through the implementation of appropriate design, protection and monitoring controls.

Ignition hazards could include, but not limited to:

(a) electrical systems;

(b) ESS;

(c) EDLC;

(d) HFS;

(e) fuel storage;

(f) arson; and

(g) mechanical components and trackside sources.

Fire prevention measures should align with current best practices and follow system-specific requirements outlined in relevant standards.

Commentary *C3.1*

AS 7486 provides informative guidance on onboard electrical energy storage in rolling stock and IEC 63341 to address hydrogen fuel systems on rolling stock.

3.2 Performance requirements

The design of track machines shall, if reasonably practicable to do so, include measures in the vehicle design to mitigate:

(a) reasonably foreseeable vehicle ignition events; and

(b) reasonably foreseeable vehicle borne, track side ignition events caused by vehicles.

3.3 Deemed to satisfy provisions

3.3.1 Track Machines

The performance requirement of Clause 3.2(a) shall be deemed to be satisfied by the demonstration of compliance with the following:

(a) Resistors, exhaust from combustion engines, heating elements, catering or cooking equipment and other radiant heat sources are adequately separated or protected from nearby combustible materials to ensure that these heat sources do not pose an ignition risk.

(b) Equipment that has the potential to operate at a surface or internal temperature that exceeds a threshold that can result in ignition, damage to adjacent materials or thermal degradation of components is fitted with thermal management systems to prevent fire-generating conditions from occurring. Effective methods for controlling equipment temperatures include passive air cooling, active liquid cooling, active air cooling and the use of fire-resistant enclosures.

(c) Heat-generating onboard equipment, such as catering appliances (e.g., ovens, microwave ovens, refrigerators), battery chargers and inverters, are installed with OEM-specified ventilation clearances.

(d) Where such equipment is installed inside or outside the vehicle, the layout design incorporates the differing ventilation requirements specific to each environment.

(e) Electrical circuits are designed and installed to minimize the risk of overheating, arcing and electrical fires by applying appropriate wire size, short-circuit and overload protection, thermal insulation and protective circuit design in accordance with recognized railway standards, including IEC 62995:2018, IEC 61991:2019 and IEC 62497-1:2010.

(f) Circuit components, including resistors, contactors, switches and relays, are designed and installed to minimize the risk of ignition under normal operation and reasonably foreseeable fault conditions.

Commentary *C3.3.1-1*

This includes appropriate selection, protection and coordination of components in accordance with recognized railway standards, including IEC 62497-1:2010, IEC 60571:2012 and IEC 60077:2017.

(g) High-voltage equipment is designed and installed to minimize the risk of ignition from arcing or dielectric failure.

Commentary *C3.3.1-2*

This includes appropriate insulation coordination, clearance, creepage and protective design in accordance with IEC 62497-1:2010.

(h) Vents on tanks or systems containing flammable liquids or gases are fitted with flame arresters or equivalent devices to prevent ignition of the vapour space through flashback.

(i) Compartments containing equipment, such as batteries, that could release flammable gases under normal or fault conditions are vented to prevent these compartments from presenting an ignition or explosion hazard, in compliance with Section 11.

Commentary *C3.3.1-3*

Relevant standards for battery compartments to mitigate explosion risks include AS 7486, AS 2676.2 (guidance on battery ventilation of traditional lead acid or nickel cadmium batteries), IEC 62928 and IEC 62619. These standards require that compartments housing batteries—particularly those capable of releasing flammable gases under normal or fault conditions—be vented to the exterior of the rolling stock to prevent gas accumulation and associated explosion risks.

IEC 62619 specifies safety test requirements for secondary lithium cells and batteries for use in industrial applications, including fault tolerance and thermal runaway containment.

IEC 61881-3 is also relevant, particularly for rolling stock energy storage systems that use electric double-layer capacitors (EDLCs), providing design and performance guidelines specific to capacitor-based ESS technologies.

Battery compartment design and fire mitigation measures are driven by the specific battery chemistry used (e.g., NMC, LFP, NCA), as different chemistries exhibit varying flammability, gas emission and thermal stability characteristic

The performance requirement of Clause 3.2(b) shall be deemed to be satisfied by the demonstration of compliance with the following:

(j) Engine and exhaust systems are designed to eliminate spark emissions SFAIRP, which could cause ignition of trackside materials.

Commentary *C3.3.1-4*

Mitigation measures include the use of spark arrestors, particulate filters or flame traps, heat shielding, careful positioning of exhaust outlets away from combustible materials and regular maintenance to prevent carbon build-up or leaks.

(k) Brake systems, forced ventilation systems and current collectors are designed to eliminate spark emissions SFAIRP, which could cause ignition of trackside materials.

(l) Suitable shielding is provided to ensure that sparks from cast iron brake blocks, if fitted, do not pose an ignition risk to underframe-mounted combustible component materials or locations on the underframe where litter, leaf matter or other inflammable debris can accumulate.

3.3.2 HFS and ESS track machines

In addition to the requirements outlined in 3.3.1, the following clauses specify provisions for mitigating ignition risk applicable to HFS and ESS.

For ESS:

(a) ESS systems and circuits shall comply with AS 7486:2022;

(b) track machines with ESS shall include a BMS and BTMS capable of continuous monitoring at the cell, module and string levels;

(c) BMS and BTMS shall be able to detect indicators of battery degradation or abnormal conditions and initiate automatic mitigation actions, such as isolation of affected cells or modules, prior to the onset of a thermal runaway;

Commentary *C3.3.2-1*

Relevant standards for battery management systems' thermal management to prevent thermal runaway include AS 7486, IEC 62928 and IEC 62619.

(d) faults, warnings and alarms from the BMS and BTMS shall be clearly perceptible to the staff under all operating conditions and comply with AS 7533:2021;

(e) batteries that have the potential to release flammable or toxic gases shall be provided with ventilation and/or venting arrangements designed to prevent accumulation of hazardous gas concentrations and to ensure safe discharge to the exterior of the rolling stock, in accordance with the requirements specified in Section 11;

(f) the fire prevention and suppression system design shall address coolant system leaks where flammable liquids such as ethylene glycol are used in ESS cooling systems.

For HFS:

(g) hydrogen fuel cell enclosures and hydrogen storage compartments — including high-pressure storage tanks, underfloor housings, roof-mounted modules, pipe runs and associated enclosures — shall be designed and managed to prevent the accumulation of hydrogen gas;

Commentary *C3.3.2-2*

Potential accumulation points include confined spaces around enclosures, where gas leakage could create a flammable or explosive atmosphere if not properly ventilated, controlled and maintained.

(h) explosive atmosphere management shall include hazardous area classification, ventilation assessment and integration of control measures to limit flammable gas accumulation as defined in IEC 60079-10-1:2020;

(i) electrical circuits and systems in compartments or enclosures where explosive atmospheres can occur shall be designed and installed in accordance with IEC 60079;

(j) hydrogen detection systems shall be installed and configured to automatically isolate or shut down the hydrogen supply in the event of a leak;

(k) external ventilation and gas management under various operational modes, including standstill, motion and confined spaces, as well as limits in open and semi-closed environments (e.g., tunnel conditions), shall be defined and agreed upon by both the manufacturer and RSO.

(l) where venting cannot be eliminated, emission limits and management strategies shall be implemented to ensure hydrogen concentrations remain below an agreed lower flammability limit (LFL) or lower explosive limit (LEL).

Commentary *C3.3.2-3*

NFPA 130, Section 7 outlines ventilation management methods such as airflow rates and smoke control strategies that may be relevant for managing hydrogen dispersion and preventing hazardous gas accumulation in tunnels.

IEC 60079-10-1 provides guidance on explosive atmosphere management, requiring the use of leak detection systems that trigger automatic shutdowns in the event of a hydrogen leak. These standards also establish safety protocols for hydrogen exhaust to prevent exposure to potential ignition sources, ensuring that hydrogen is released in a controlled manner to mitigate fire and explosion risks.

Other relevant standards include CSA TS 601, where mechanical ventilation with air dilution should maintain hydrogen concentrations below the LEL or LFL, with real-time flow monitoring to verify ventilation effectiveness. Dilution boundaries are found using IEC 60079-10-1; NFPA 497 or IEC 63341/UNR134.

IEC 63341 categorizes hydrogen release management into different types (A, B and C), specifies acceptable release rates and outlines mitigation strategies to prevent hydrogen accumulation and ignition risks.

For ESS and HFS flammable gases release from ESS or HFS shall be vented away from potential ignition sources, particularly within confined or semi-enclosed environments. Additional requirements for managing the release of flammable gases are detailed in Section 11.

Section 4 Fire development mitigation measures

4.1 General

The presence of combustion engines, high-voltage electrical systems, HFS, ESS introduces risks of fire spread that shall be effectively controlled. This section defines measures to limit fire propagation, contain thermal hazards and protect critical systems for track machines.

4.2 Performance requirements

The design of track machines shall, through hazard assessment, identify mechanisms whereby fire development on the vehicles could be rapid and wherever reasonably practicable to do so, include in the vehicle design measures to mitigate such events.

While major collisions are difficult to mitigate through design alone, a risk-based safety assessment shall be undertaken to assess the impact of minor impact events and derailments.

4.3 Deemed to satisfy provisions

4.3.1 Track machines

The performance requirement of Clause 4.2 shall be deemed to be satisfied by the demonstration of compliance to the following:

(a) Heating, ventilation, and air conditioning system ducting having access for cleaning to prevent the build-up of dust which could aid fire propagation.

(b) The underframe equipment layout wherever practicable, avoids traps where debris such as litter or leaf matter can accumulate.

(c) Equipment and pipework containing flammable fluids is protected against puncture.

(d) Filling and drainage points for flammable fluids are positioned so that the accumulation of spilt/discharged fluid is prevented.

(e) Fuel and fluid piping systems incorporate cut-off devices or isolation valves designed to automatically shut off the flow of flammable liquids or gases in the event of a fire, vehicle rollover or system failure that poses a fire hazard.

(f) Reservoirs for flammable fluids are designed to ensure that they do not drain their contents in the event of vehicle rollover.

Commentary *C4.3.1-1*

Derailments and low-speed collisions can create fire hazards, particularly where rolling stock incorporates under-slung fuel tanks, battery systems or hydrogen storage. Structural protection measures such as shielding, reinforced housings and rupture-resistant enclosures can reduce the likelihood of puncture, fluid release or uncontrolled gas discharge in these events. Designers are encouraged to assess these risks early in the design process and adopt protective measures proportionate to the hazard and operating context.

Compartmentalised storage arrangements can also be used to limit the spread of fire or hazardous releases by isolating individual tanks, modules or pressure zones

Fluid and gas containment systems can incorporate reinforced structures and mechanical safeguards to reduce the risk of rupture or sudden release, with integrity confirmed by impact and rollover testing. Safety features include automatic isolation devices, flow-limiting valves and drainage prevention measures to control the release of hazardous contents in rollover events.

(g) Equipment and pipework, for flammable fluids or gases, such as hydrogen lines, HFS and ESS enclosures, is shielded against puncture or mechanical damage when tested in accordance with AS 1530.4:2014 or a material prequalified in EN45545-3:2024 Table 2.

Commentary *C4.3.1-2*

Inter-car connections present additional challenges in meeting fire safety requirements. Moving and exposed hoses are more susceptible to mechanical damage, wear and potential exposure to ignition sources. These risks are assessed and mitigated through the implementation of appropriate design measures, such as shielding, automatic shut-off valves and leak detection systems. The suitability of such systems for specific applications is determined through a documented risk assessment and in accordance with applicable standards and operational requirements.

4.3.2 HFS & ESS track machines

The performance requirement in Clause 4.2 shall be deemed satisfied by compliance with the following for track machines with HFS or ESS that are in addition to the mitigation measures in Clause 4.3.1:

(a) HFS and ESS is protected from exposure to train borne and external heat and ignition sources so far as is reasonably practicable. Hazards may include track-side fires and embers from a bushfire.

(b) HFS and ESS compartments' fire suppression, compartmentation, and ventilation strategies are adopted to reduce the fire hazard SFAIRP and be designed to tested industry standards.

(c) HFS and ESS compartments have systems to effectively disperse heat and gases.

Commentary *C4.3.2-1*

Hydrogen release and ventilation/discharge design for HFS is addressed in Section 11 and is derived from the project explosive-atmosphere assessment and safety analysis (including operating modes and ventilation conditions). IEC 63341-1 also sets limits for hydrogen concentration in discharged gas mixtures where an exhaust mixing approach is used (4% moving average over 3 s, 8% peak).

(d) A BMS and BTMS is installed that provides appropriate monitoring, control fault detection and alarms clearly visible to staff in all operating conditions and interfaces with the fire detection system.

Commentary *C4.3.2-2*

Additional fire mitigation strategies for ESS to prevent escalation of thermal events can include:

1. Isolation of faulty cells or modules using solid-state switches to stop fault propagation.

2. Passive propagation barriers between cells to limit heat transfer and contain thermal runaway;

3. Controlled degassing channels to direct and vent flammable gases safely during thermal events, reducing the risk of explosion or re-ignition.

(e) For HFS, hydrogen leak detection systems incorporate defined warning and initiate emergency management systems. This may include shutdown procedures and ventilation systems referenced to the lower explosive limit (LEL).

(f) For HFS, the system, at a minimum, activates a warning alarm at a pre-defined concentration and automatically initiate shutdown and ventilation responses at a higher but still safe trigger level, in accordance with IEC 63341-1:2025 and the requirements of Section 11.

Commentary *C4.3.2-3*

The reaction of the HFS in a fire event is to be coordinated with the evacuation and emergency response strategy.

(g) For HFS, if a fire is detected in the vehicle, the hydrogen shut-off valves automatically close.

(h) For HFS, explosion-proof enclosures and pressure relief valves are incorporated into HFS to prevent pressure buildup and mitigate explosion risks.

(i) For HFS, hydrogen containers are equipped with thermally activated pressure relief devices (TPRDs) to safely vent gas before the liner reaches critical temperatures.

Commentary *C4.3.2-4*

Refer to IEC 63341-2 for the applicable criteria and how TPRD are assessed.

While automatic fire suppression systems can assist in reducing the impact of external heat sources, primary protection of the HFS and ESS from external fires shall be provided by fire-rated barriers or enclosures designed to prevent heat and flame ingress, as part of the overall fire containment strategy.

Commentary *C4.3.2-5*

The design of an onboard suppression system needs to consider the impact on the vehicle's ability to travel to a safe location for staff evacuation, the space required, the duration of suppression it provides, the weight it adds to the rolling stock, the risk of unwanted discharge and the ongoing maintenance costs.

Section 5 Material fire performance

5.1 General

Material fire performance plays a key role in limiting fire growth, smoke generation and toxic gas production in track machines.

Effective control of combustible materials supports safe evacuation by reducing fire severity and maintaining survivable conditions during incidents involving track machines.

Material selection shall be based on factors such as the quantity and location of combustibles, the operating environment (e.g., tunnel or open track) and the time available for fire detection, train stoppage and evacuation.

Material fire performance testing shall be conducted by laboratories accredited to ISO/IEC 17025 for the relevant test methods.

Accreditation shall be by NATA or an equivalent body recognized under the ILAC Mutual Recognition Arrangement.

Materials classified as non-combustible under EN 45545-2 are exempt from additional fire performance testing under this document.

Commentary *C5.1*

EN 45545-2 defines non-combustibility based on EN 13501-1 Class A1 and materials listed in Commission Decision 96/603/EC. Materials that are classified as non-combustible under Australian or other international building and construction standards, where appropriate for the intended railway application, could also be considered exempt from additional fire performance testing

5.2 Performance requirements

Combustible component materials used on the interior and exterior of track machines shall have properties which:

(a) prevent significant fire propagation occurring when exposed to small ignition sources of the order of 1 kw;

(b) limit the propagation of the fire when exposed to large ignition sources greater than 50 kw;

(c) limit the rate of heat release of the fire when exposed to large ignition sources greater than 50 kw; and

(d) when exposed to large ignition sources greater than 50 kw, limit the production of optically dense smoke and large quantities of toxic fumes which could impair the ability of track machine occupants, to evacuate to a place of ultimate safety.

Commentary *C5.2*

In defining the material fire safety requirements, particular attention was given to the nature of ignition sources that materials can be exposed to during service. The following quantitative benchmarks are established for design reference:

a) small ignition source → 1 kW consistent with Bunsen burner-type material tests; and

b) large ignition source → 50 kW, representative of common rolling stock fire loads, such as burning newspapers. This benchmark is positioned between the ignition source reference values used in UIC guidelines and BS 6853.

In addition, the degree of material performance provided shall be commensurate with:

(e) the nature and location of the fire hazards present on the track machine;

(f) whether the potential ignition sources are piloted or non-piloted;

(g) the quantity of combustible material within the track machine;

(h) the location of the combustible material within the track machine;

(i) the expected fire growth rate associated with credible ignition scenarios;

(j) the time required for the track machine to travel to and stop at a safe place for evacuation;

(k) the time required for evacuation of track machine occupants to be completed;

(l) the ability of installed systems to detect precursor conditions and provide adequate warning time; and

(m) the potential generation of toxic smoke, gases and reduced visibility conditions during a fire.

Combustible component materials that are fitted inside equipment enclosures which are manufactured and certified with fire resistant construction are not required to have a qualified level of fire performance if:

(n) the construction of the enclosure will protect the internal materials from becoming involved in a fire external to the enclosure for a duration not less than the time required for the rolling stock to detect a fire, travel to and stop at a safe place plus the additional time for occupants to evacuate; and

(o) the construction of the enclosure will prevent a fire that starts within the enclosure from propagating outside the enclosure for a duration not less than the time required for the rolling stock to detect fire, travel to and stop at a safe place plus the additional time required for occupants to evacuate.

Where applicable, the level of rolling stock material fire performance shall support the specification of design fire being used for the rail infrastructure.

Where applicable, the level of rolling stock material fire performance shall be commensurate with the maximum credible fire load and hazard associated with HFS or ESS, ensuring materials can limit propagation, heat release and toxic emissions under these conditions.

5.3 Deemed to satisfy provisions

5.3.1 General

Fire test reports and certificates shall remain valid as long as they accurately represent the material, production and assembly process in current use and the rolling stock has been maintained and cleaned in accordance with the technical maintenance plan.

Where fire test reports are more than five (5) years old, the validity of the test report should be reviewed to confirm they remain representative of the current product and installation. If there is no change in the product characteristics, manufacturing process and requirements, new testing of the material is not required.

Where compliance with the material fire performance requirements of this document or with EN 45545-2, is not achievable due to functional necessity, non-compliant materials may be used when the fire safety objectives of this document are maintained, see Clause 5.2.

Integrity and insulation periods when tested to AS 1530.4:2014 are deemed equivalent to the integrity and insulation period requirements stated in EN45545-2:2020+A1:2023 for technical cabinets and fire barriers.

Material classified as non-combustible in accordance with AS 1530.1:1994+Amd 1(2005)+Amd 2(2016) may be used without the need for further fire performance testing.

Where a different operation category (e.g., reduction in the numerical value from OC4 to OC3) and corresponding hazard level is deemed more appropriate for the rolling stock operation than that designated under EN 45545-1:2013, agreement shall be sought from the RSO and RIM.

5.3.2 Track machines

The performance requirements of Clause 5.2 shall be deemed to be satisfied by the demonstration of compliance with the following for a track machine:

(a) Combustible materials comply with the requirements of EN 45545-2:2020+A1:2023 to the relevant hazard level as required by the rolling stock operation category and design category.

(b) Non-listed products (as defined in EN 45545-2:2020+A1:2023, Clause 4.5) with a grouped mass less than 1,000 g and an exposed surface area less than 0.2 m2, mounted to the exterior of the track machine, or compartments considered external under EN 45545-2:2020+A1:2023, are not required to be qualified for their fire performance.

(c) Non-listed products (as defined in EN 45545-2:2020+A1:2023, Clause 4.5) with a grouped mass greater than 1,000 g or exposed surface area greater than 0.2 m2, mounted to the exterior of the track machine or in compartments considered external under EN 45545-2:2020, are required to be qualified for their fire performance in accordance with EN 45545-2:2020+A1:2023.

(d) Combustible materials fitted within technical cabinets of the track machine, including the cab, are exempt from the EN 45545-2:2020+A1:2023 material fire performance requirements where the cabinet is protected by an automatic fire detection and fire extinguishing system in accordance with Section 9 of this document.

There are no requirements for combustible materials which are fitted to compartments of the track machine which are protected with a fixed fire detection and extinguishing system.

5.3.3 HFS and ESS track machines

The following requirements apply to track machines powered by HFS or ESS, in addition to the requirements under Clause 5.3.1 and Clause 5.3.2:

(a) The use of combustible materials within areas containing hydrogen storage tanks, fuel cells, and batteries shall be minimized so far as is reasonably practicable. Where used, combustible materials shall comply with the requirement of EN 45545-2:2020+A1:2023 hazard level 3 to reduce fire spread, smoke and toxic gas following ignition or thermal runaway.

Commentary *C5.3.3-1*

The phrase within areas refers to the following with respect to the fire-resistant enclosures (specified in Section 6) that contain the hydrogen storage tanks, fuel cells, or batteries:

- Internal and external surfaces of the enclosure
- Components within the enclosure (noting containment rules under EN 45545-2:2020+A1:2023, Clause 4.2h)

More specifically, the above clause applies to structural panels, internal linings, and equipment mounting surfaces that can be subject to direct flame impingement or elevated temperatures arising

from a fire within the compartment. It does not extend to battery or HFS equipment for which hazard level 3 may not be reasonably practicable or to remotely located equipment connected via piping (e.g., underfloor or roof-mounted lines), unless such equipment is situated within the same defined compartment.

(b) Materials within 3 metres of vents for enclosures containing HFS & ESS used for traction shall comply with the requirements of EN 45545-2:2020+A1:2023 hazard level 3 to reduce fire spread, smoke and toxic gas following ignition or thermal runaway.

Commentary *C5.3.3-2*

The phrase within 3 metres of vents for enclosures applies to any material that could reasonably be exposed to vented gases or ejected hot particles during an ignition or thermal runaway event. This includes cable trays, ducting and any material located in the projected path of the venting flow—whether oriented laterally, vertically or otherwise. Structures mounted underfloor or on the roof could fall within this scope, depending on the venting arrangement and direction. All vents are to be to the track machine exterior of the train, not to the interior. Therefore, the clause only applies to exterior materials, not to interior materials.

Section 6 Fire resistance

6.1 Flooring

6.1.1 General

Fire resistance of structural assemblies is a critical component of fire containment in track machines.

Material fire resistance testing shall be conducted by laboratories accredited to ISO/IEC 17025 for the relevant test methods. Accreditation shall be by NATA or an equivalent body recognized under the ILAC Mutual Recognition Arrangement.

This section outlines minimum fire resistance performance for these compartmentation and separation elements, with deemed-to-satisfy provisions suited to various track machines.

6.1.2 Performance requirements

Flooring assemblies shall resist the spread of potential under floor fires into all occupied staff compartments and any other compartment which the track machine staff will be required to travel through as part of their emergency egress route.

The degree of fire resisting protection provided by the flooring assembly shall be proportionate to:

(a) the nature of the under-floor fire hazards (including potential external fire scenarios such as level crossing collision with a road vehicle and subsequent fire*)*;

(b) the location of the under-floor fire hazards;

(c) the time required to detect the fire;

(d) the time required for the track machine to travel to and stop at a safe place for evacuation; and

(e) the time required for evacuation of the track machine's staff to be completed.

6.1.3 Deemed to satisfy provisions

6.1.3.1 Track machines

The performance requirement of Clause 6.1.2 shall be deemed to be satisfied where the flooring assembly demonstrates compliance with achieving a minimum of 15 min integrity as per EN 45545-3:2024, verified by one of the following:

(a) Testing of the flooring assembly in a horizontal orientation is in accordance with AS 1530.4:2014 or an equivalent recognized international standard under comparable test conditions and acceptance criteria.

(b) Construction is from materials, such as those listed in EN 45545-3:2024, which have been pre-qualified as achieving the required integrity requirements.

(c) Penetrations are sealed using systems pre-qualified to the same performance level.

Flooring assemblies shall resist the spread of underfloor fires into all occupied staff compartments and any passageways used for emergency egress.

Floor assemblies shall extend the full width of the relevant occupied staff compartment or emergency egress passageway

Test specimens for track machine assemblies shall be not less than 1 m × 1 m in size and representative of the installed flooring construction. Larger or full-scale specimens shall be used where construction features, penetrations, interfaces or risk factors require to ensure validity of the fire resistance performance

6.1.3.2 HFS and ESS track machines

The following deemed-to-satisfy provisions apply specifically to track machines equipped with HFS and/or ESS. The performance requirement of Clause 6.1.2 shall be deemed to be satisfied by the demonstration of compliance with the following for track machines containing HFS or ESS in addition to the requirements in Clause 6.1.3.1:

(a) Where ESS or HFS equipment is installed above or beneath the floor, the flooring assembly complies with the fire resistance requirements specified for track machines in Clause 6.1.3.1. This includes cases where the floor forms part of an emergency evacuation route or is adjacent to systems supporting safe egress. This approach shall be supported by a documented risk assessment.

Commentary *C6.1.3.2-1*

Where credible fire scenarios indicate that detection, shutdown and evacuation can exceed 15 minutes, increasing the fire barrier rating to align with the maximum expected exposure time provides an additional safety margin. If the expected fire temperature exceeds the standard test profile (i.e. approximately 738°C at 15 minutes per ISO 834-1), additional assessment might also be required to confirm barrier performance under elevated thermal exposure.

6.2 Operating position

6.2.1 Performance requirements

The design of the partition at the rear of the cab or other occupied staff compartments, inclusive of access door (if present), shall prevent the spread of fire into the cab/compartment and internal escape routes such that in the event of a fire in the adjacent technical compartment, the staff is protected from

the fire and combustion products while the track machine is stopped at a safe place and occupant evacuation completed.

The degree of fire resisting protection provided by the operating position rear wall partition assembly shall be proportionate to the:

(a) nature of the fire hazard in the technical compartments adjacent to the operating position;

(b) time required to detect the fire;

(c) time required for the track machine to travel to and stop at a safe place for evacuation; and

(d) time required for evacuation of the track machine's staff to be completed.

It shall not be possible for fire to spread through the cavity above the ceiling into the operating position.

6.2.2 Deemed to satisfy provisions

6.2.2.1 Track machines

The performance requirement of Clause 6.2.1 shall be deemed to be satisfied where the occupied staff compartment rear wall partition and internal partition adjacent to an internal escape route (such as a vestibule backwall) achieve a minimum of 15 min integrity, verified by one of the following:

(a) The assembly is tested in a vertical orientation in accordance with AS 1530.4:2014 or an equivalent recognized international standard under comparable test conditions and acceptance criteria

(b) Partitions are constructed from materials, such as those listed in EN 45545-3:2024, which have been pre-qualified as achieving the required integrity insulation requirements. Penetrations shall be sealed using systems pre-qualified to the same performance level.

(c) Test specimens are full-size, extending from the fire-resisting floor to the underside of the vehicle roof

(d) Where full-size dimensions exceed the furnace opening, the maximum specimen dimension is 3 m in either direction.

(e) Representative penetrations, doors, escape route enclosures and adjacent partitions are included where these form part of the design.

(f) Design features that could compromise fire resistance performance are verified by assessment.

6.2.2.2 HFS and ESS track machines

The performance requirement of Clause 6.2.1 shall be deemed to be satisfied by demonstrating compliance with the following for track machines incorporating HFS or ESS in addition to the requirements of Clause 6.2.2.1:

(a) Where HFS or ESS equipment is located adjacent to or directly behind the occupied staff compartment partition wall or adjacent to an escape route, the fire resistance of the partition wall is determined by a documented risk assessment;

Commentary *C6.2.2.2-1*

Given the elevated fire load and temperature profile of HFS and ESS fires, the expected level of protection is EI 30 (30 min integrity and insulation). EI 15 (15 min integrity and insulation) might be insufficient to maintain staff survivability during the evacuation period.

If higher risk is identified, the designer could choose to increase the occupied staff compartment backwall fire resistance level to 30 min integrity and 30 min insulation.

(b) Where HFS or ESS equipment compartment is separated from the occupied staff compartment and internal escape route partitions, the occupied staff compartment and escape-route partition achieves at least 15 min of integrity and insulation.

Commentary *C6.2.2.2-2*

The EI 15 requirement is considered potentially sufficient in this case because a physical separation exists. Fire would need to develop within the HFS/ESS compartment, breach its own boundary and then act upon the occupied staff compartment or escape-route partition. This progression provides an inherent delay, meaning a 15-min integrity and insulation rating is typically expected to maintain survivability during the evacuation period.

(c) Where for the approach in (b) there is a documented risk assessment which has assessed the following:

(i) the fire-resisting capability of the HFS/ESS compartment.

(ii) the likelihood of smoke, heat and flame impingement on the occupied staff compartment or escape-route partition.

(iii) the evacuation time required for staff safety.

6.3 Compartments containing combustion engines, high power equipment, HFS, ESS or EDLC

6.3.1 Performance requirements

Compartments within track machines containing internal combustion engines, hydrogen tanks, fuel cells, lithium-ion batteries or high voltage traction circuit electrical equipment shall be separated from any adjacent occupied staff compartments or compartments that form part of the staff's escape route by fire-resistant construction.

Hot zones of combustion engines on-board track machines shall be separated from fuel or hydraulic oil tanks by fire-resisting construction.

The degree of fire resisting protection provided by the compartment partitions shall be proportionate to the:

(a) nature of the fire hazard in the compartment containing the engine and/or high-powered electrical equipment;

(b) time required to detect the fire;

(c) time required for the track machine to travel to and stop at a safe place for evacuation; and

(d) time required for evacuation of the track machine's staff to be completed.

6.3.2 Deemed to satisfy provisions

6.3.2.1 Track machines

The performance requirement of Clause 6.3.1 shall be deemed to be satisfied by the demonstration of compliance with the following:

(a) When test samples complying with Clause 6.4.2.1 are tested in a vertical orientation in accordance with AS 1530.4:2014 or an equivalent recognized

international standard under comparable test conditions and acceptance criteria and the compartment partition achieves at least 15 min integrity.

(b) When the compartment partition is constructed from a material, such as those listed in Table 2 of EN 45545-3:2024, which has been pre-qualified as achieving at least 15 min fire resisting integrity.

(c) Where penetrations are made through the plane of fire resistance (e.g., for doors or piping/electrical connections) to ensure that the integrity of the entire fire resisting plane is not compromised and these penetrations are be fire sealed using a system that has been tested in accordance with AS 1530.4:2014 or an equivalent recognized international standard under comparable test conditions and acceptance criteria; and has achieved a minimum fire resistance level of 15 min integrity.

(d) If the dimensions of the full-size test samples exceed that of the furnace opening, the minimum dimension of the samples in either direction to be 3 m

(e) Where the test samples contain representative service penetrations and doors, if such elements form part of the vehicle design and if necessary to demonstrate the insulation performance of the design.

6.3.2.2 HFS and ESS track machines

In addition to the above, the performance requirement of Clause 6.3.1 shall be deemed to be satisfied by the demonstration of compliance with one of the following:

(a) Compartments containing hydrogen tanks, fuel cells or lithium-ion batteries providing at least 15 min of integrity and insulation performance.

(b) The structural support frame for the HFS maintains its integrity under fire exposure for a minimum duration of 30 min, as specified in ISO 834-1:2025, Clause 6.1.1.

Section 7 Portable fire extinguishers and fire blankets

7.1 General

Portable fire extinguishers provide a first line of defence against small, accessible fires in track machines.

They are suited to incidents involving combustible materials, oils or low-voltage electrical equipment, where rapid manual intervention can contain the fire and prevent escalation.

7.2 Fires involving HFS or ESS

HFS fires can produce high heat and low-visibility flames that persist in low-oxygen environments, reducing the effectiveness of conventional agents such as CO_2 or foam. Depending on the storage design and failure mode, HFS events could also involve high-velocity jet-flame discharge or the mechanical ejection of components following rapid gas expansion.

ESS fires can involve thermal runaway, generating intense heat and toxic gases, with the potential for delayed re-ignition. Thermal-runaway events could also result in the release of flammable vapours, rapid gas discharge or the mechanical ejection of cell or enclosure components.

In these cases, portable extinguishers are not suitable for suppressing the primary fire and manual intervention by staff with portable fire extinguishers might not be safe.

None the less, extinguishers remain valuable for managing secondary fires in adjacent components, such as cabling, linings or equipment affected by heat or flame spread. Their use in these circumstances can limit further damage and assist safe evacuation.

7.3 Performance requirements

Track machines shall be provided with an adequate number of suitably sized portable fire extinguishers compliant with AS/NZS 1841:2007.

The number, size, type and installation location of portable fire extinguishers shall take into consideration the:

(a) nature of the fire hazards within the track machine;

(b) potential size of any fires which could possibly occur on the track machine; and

(c) type of fire fuel present, ensuring that suppression methods are appropriate for specific risks, such as:

(i) oil-based fires requiring wet chemical extinguishers;

(ii) fire blankets to prevent spread and flashover;

(iii) where cooking facilities involving the heating of oils or fats are provided, fire blankets shall be fitted in appropriate locations; and/or

(iv) the accessibility of fire extinguishers in case of an emergency, ensuring placement and signage comply with relevant safety standards for rapid response

7.4 Deemed to satisfy provisions

The performance requirements of Clause 7.3 shall be deemed to be satisfied by the demonstration of compliance with the following:

(a) A track machine is equipped with at least one 4.5 kg dry powder fire extinguisher compliant with AS/NZS 1841:2007 in each occupied staff compartment.

(b) Additional portable fire extinguishers are fitted in other locations where the track machine can be operated (e.g., control stations; monitoring stations) where identified through a fire risk assessment. Spaces only used transiently (e.g., toilets; passageways; engine bays) are not considered an operational location for this purpose.

(c) Where cooking facilities are provided, open heating elements involving the heating of oils or fats are not recommended due to associated fire risks. Where unavoidable, such installations is minimized and risk managed.

Commentary *C7.4*

Modern onboard catering practices generally rely on safer alternatives, such as induction cooktops or microwave ovens, which reduce ignition hazards and improve temperature control.

Induction cooktops eliminate open flames and limit residual surface temperatures, making them a preferred solution for heating applications in rolling stock environments where fire safety is critical.

(d) Fire blankets compliant with AS/NZS 3504:2006, are provided in accordance with AS 2444:2001.

(e) Fire extinguishers remain functional and accessible during all operating conditions.

(f) Signage for fire extinguishers and fire risk areas complies with AS 1319:1994.

Section 8 Staff ventilation system control

8.1 General

Effective airflow management during a fire helps isolate smoke, protect occupants and support safe evacuation.

8.2 Performance requirements

In the event of fire, whether internal or external to the rolling stock, the staff shall have the capability to control the ventilation systems to reduce smoke spread and assist with smoke removal.

8.3 Deemed to satisfy provisions

The performance requirements of Clause 8.2 shall be deemed to be satisfied by the demonstration of compliance with the following:

(a) in the event of smoke detection within a train car, the ventilation system shall automatically:

(i) close all means of external ventilation into the occupied staff compartments.

(ii) shut down air conditioning or ventilation systems to prevent the recirculation of smoke within occupied staff compartments.

It shall be possible for the staff to manually over-ride the automated response.

Toxic gas detection shall switch the system to a mode that prevents recirculation to occupied staff compartments and support external discharge only.

Section 9 Fire detection and suppression systems

9.1 General

Fire protection systems minimize the impact of onboard fires in rolling stock. Integration with control systems, including BMS and hydrogen safety protocols, supports hazard response and maintains operational safety.

Detection and suppression in high-risk areas enable early intervention, prevent escalation and support safe operations and evacuation.

9.2 Performance requirements

9.2.1 Fire detection and alarm systems Fire detection systems shall be fitted to track machines.

The type and arrangement of detectors shall be designed and tested to achieve a high level of reliability in detecting fires and/or gases and minimise the frequency of false alarms.

When actuated, fire detection systems shall provide a visual and audible alarm to the staff at their normal working locations.

Fire detection alarms tones shall be of sufficient volume to ensure they are audible to the staff under all operating conditions.

If the fire detection system has a fault or is inoperative for any reason, this shall be indicated to the staff.

Commentary *C9.2.1*

Onboard fire or smoke detection is required due to the benefit this provides in early detection and response to fires. Avoidance of unwanted alarms under all credible conditions including localised interior or exterior smoke sources or high atmospheric smoke conditions (e.g., from bushfires) is not reasonably practicable. The type, arrangement and sensitivity of the detection system should be selected to optimally balance early detection but also minimise the frequency of unwanted alarms.

It is expected that RSOs should have procedures in place to enable safe continued operation of Rollingstock during times of high atmospheric smoke conditions (e.g., from bushfires) which expects that detection system unwanted alarms are possible. Such procedures may require additional temporary measures to monitor the safety of the rollingstock in event of such unwanted alarms.

9.2.2 Fixed fire extinguishing systems

Fixed fire extinguishing systems shall be fitted to areas of rolling stock containing combustion engines.

If the fixed extinguishing system has a fault or is inoperative for any reason, this shall be indicated to the staff.

Provision of fixed fire extinguishing systems to other areas shall be determined through a risk assessment that considers the:

(a) likelihood and consequence of a fire that it would address;

(b) space required;

(c) duration of suppression it provides;

(d) weight it adds to the rolling stock;

(e) risk of unwanted discharge;

(f) ongoing maintenance costs;

(g) testing and certification that the system has achieved.

9.2.3 HFS and ESS track machines

These requirements do not apply to auxiliary battery power systems. These requirements only apply to ESS, EDLC and HFS equipment for traction power.

In addition to 9.2.1 and 9.2.2, fire protection measures applied to ESS, EDLC and HFS shall detect, contain and mitigate thermal events or gas releases before they reach hazardous levels.

Where hydrogen or battery powered propulsion systems are present, a gas detection system shall be installed in addition to the fire detection system within the enclosure.

When actuated, gas detection alarm systems shall provide a visual and audible alarm to the staff at their normal working locations.

Gas detection alarms tones shall be of sufficient volume to ensure they are audible to the staff under all operating conditions.

If the gas detection system has a fault or is inoperative for any reason, this shall be indicated to the staff.

Where the documented fire risk assessment identifies that credible ESS/EDLC/HFS fire scenarios require an onboard extinguishing or system, the system shall be designed to prevent the escalation of thermal events and limit the release of hazardous substances. In addition, the fire safety strategy shall:

(a) define the intended outcome of installed systems (e.g., control, containment, prevention of propagation), and

(b) provide design provisions to support emergency responder operations, including provision of an external firefighting access/interface where appropriate.

Fire detection for ESS, EDLC and HFS shall include detection of the specific failure phenomena associated with these technologies, including:

(c) hydrogen gas leaks below the lower flammability limit;

(d) hydrogen flame detection using technology suitable for low-visibility flames; and

(e) ESS thermal runaway indicators such as off-gas detection or abnormal temperature rise.

Fire detection and suppression for ESS, EDLC and HFS shall be integrated with relevant control systems, including the BMS and hydrogen safety controls, to support isolation, controlled venting and automatic shutdown where appropriate.

Detection systems for ESS, EDLC and HFS shall be capable of identifying early-stage events such as hydrogen accumulation or ESS off-gas emissions prior to ignition.

Commentary *C9.2.3*

Asset protection is excluded from the scope of this standard. However, faults during charging or re-fuelling activities for ESS, EDLC and HFS can present an increased risk of fire or deflagration. If such events occur whilst stabled at depots near to adjacent assets there may be a risk of fire spread between assets and increased asset loss. RSO's are advised to consider providing fire and gas detection systems which continue to operate during charging, re-fuelling and un-manned stabling. Provision of an automatic notification to depot site fire detection control and indication equipment, depot security offices, or network operations centres would address such events.

9.3 Deemed to satisfy provisions

9.3.1 Fire detection and alarm systems

Fire detection and alarm equipment shall be provided to monitor the areas specified in Table 1**Error! Reference source not found.**. The type of detection required in each area is also specified in this table. **Error! Reference source not found.**.

Table 1 Areas Requiring Fire Detection

Train Type	Occupied Staff Compartments	Cooking or catering areas	Combustion engines	Technical cabinets containing traction equipment [e]	Other high power technical cabinets	Other Low power electrical cabinets	Lithium ion batteries for auxiliary power	ESS Or HFS compartments for Traction Power
Track Machine	**SD**	**TD[d]**	**TD**	**TD**	**NR**	**NR**	**TD**	**TD GD**

- SD indicates smoke detection required
- TD indicates thermal detection requirement
- GD indicates gas detection as defined in 9.3.3
- NR not required

- [d] These areas are unlikely to be present on these types of trains. If they are present, then detection is required.
- [e] Does not apply to traction motors exterior to track machine. Does apply to traction transformers/power converters at any location on track machine.

Fire detection and alarm systems shall also be provided to monitor the following other areas:

(a) diesel burning or combustion heaters.

(b) areas of vehicles where required to ensure the compliance of the running capability concept defined in Section 10 of this standard.

Fire detection and alarm equipment shall:

(c) be functionally suitable for the expected fire products, for example, flames, smoke and heat;

(d) be tested and certified by an accredited authority for compliance with the relevant parts of either:

(i) AS/ISO 7240 (all parts) Fire detection and alarm systems; or

(ii) EN 54 series Fire detection and alarm systems.

(e) be certified as compliant with EN 50155:2021 Railway applications - Rolling stock - Electronic equipment;

(f) be selected to have a suitable activation threshold so as to reliably provide early detection whilst frequency of false alarms due to the range of normal expected equipment operating temperatures or small smoke incidents such as cigarette smoke at platforms;

(g) include control and indicating equipment to monitor the status of the detection devices and indicate an alarm;

(h) provide audible and visual alarm devices in the crew cab at the crew working position;

(i) be operational when the track machine is operational and in service;

(j) automatically indicate any faults for any fire detection and alarm equipment to the crew and /or operational control centre.

During design and commissioning, functional testing shall be conducted in accordance with ARGE Guideline – Part 1: Fire Detection in Railway Vehicles to determine the system response time.

Testing shall be conducted on a complete fire detection and alarm system installed to a complete track machine under the various different locations and HVAC operational conditions specified by ARGE Guideline – Part 1 for smoke detection in staff compartments.

Commentary *C9.3.1*

The response time for smoke detection system in occupied staff compartments is specified in ARGE requirements.

Fire detection systems shall automatically initiate the following actions upon activation:

(a) Activate an audible and visual alarm to alert the staff at their working position that complies with the requirements of AS 7533:2021.

(b) Indicate to the staff in which zone of the vehicle the fire detection system has activated via a visual alarm.

(c) Where CCTV coverage is provided automatically display the zone in which the fire detection system has activated.

(d) Initiate appropriate automatic actions to minimize the hazard posed by the fire which includes:

(i) stopping HVAC in the occupied staff compartments affected;

(ii) selective isolation of fuel supply to the relevant equipment for fire detection in combustion engines or fuel burning equipment;

(iii) selective isolation of hydrogen supply to relevant HFS equipment where fire is detected;

(iv) selective isolation of electrical power to/from the relevant equipment for fire detection in traction equipment, Auxiliary battery equipment, ESS or HFS equipment for traction power or other electrotechnical equipment fitted with fire detection; and

(v) activate fixed fire extinguishing systems, if installed.

Such automatic actions shall however be consistent with the running capability objectives defined in Section 10 of this standard. Where a detection system can isolate equipment, it shall be ensured that running capability is maintained either by separate redundant systems or continued operation in a degraded mode.

9.3.2 Fire extinguishing systems

Fixed fire extinguishing systems, compliant to AS 5062:2022, shall be fitted to:

(a) underframe mounted diesel engines;

(b) underframe mounted diesel burning air heaters;

(c) areas of vehicles where required to ensure the compliance of the running capability concept defined in Section 10 of this standard.

The design of the extinguishing system, shall evaluate:

(d) the impact of track machine speed on fire extinguishing capability;

(e) the status of other systems which may make fire extinguishing difficult or ineffective (e.g., forced ventilation and pressurised fuel supply systems); and

(f) the objectives of running capability defined in Section 10 of this standard.

Fixed fire extinguishing systems shall operate in all vehicle orientations.

If the fixed fire extinguishing system has a fault or is inoperative for any reason, this shall be indicated to the staff.

9.3.3 Additional requirements for HFS and ESS powered track machines

These requirements do not apply to auxiliary battery power systems. These requirements only apply to ESS, EDLC and HFS equipment for traction power.

These requirements apply where either:

(a) fire suppression is necessary;

(b) required based on the outcomes of a documented fire risk assessment; or

(c) required by operational conditions, such as tunnel operations or the carriage of flammable gases.

These requirements are in addition to the requirements of Clause 9.3.1 and Clause 9.3.2.

ESS, EDLC and HFS equipment for traction power shall:

(a) be provided with thermal fire detection as per Clause 9.3.1 to indicate when a fire is detected;

(b) be provided with gas detection as per this section;

(c) for HFS, be provided with Hydrogen gas detection within HFS enclosures;

(d) for ESS, gas detection includes either Hydrogen, Carbon Monoxide, Hydrogen Fluoride or other gas species detection; and

(e) for ESS include type of gas detection determined by risk assessment to be suitable for the specific type of battery technology used to detect onset of thermal runaway at an early time.

Fire protection measures for ESS shall be designed in accordance with recognized standards addressing the unique hazards of these technologies.

Commentary *C9.3.3-1*

Suitable reference standards include AS 7486:2022 and international standards such as IEC 62928 and CSA T/S 602.

The suppression system should be compatible with the configuration and failure characteristics of the ESS and shall be validated for effectiveness under representative fault and fire conditions.

Commentary *C9.3.3-2*

Fire suppression strategies for ESS are influenced by the specific failure behaviours of the battery system, including thermal runaway, release of flammable vapours, re-ignition and emission of hazardous substances. Lithium-ion batteries using fluorinated electrolytes (e.g., $LiPF_6$) can produce hydrogen fluoride (HF)—a corrosive and toxic gas—through reaction with moisture during thermal events. Fires can also generate combustible vapours and phosphorus oxides, which could present additional health and equipment risks, particularly in enclosed or poorly ventilated environments.

UL 9540A is a test method, not a certification, that evaluates thermal runaway behaviour in energy storage systems. It characterizes propagation, heat release rate and hazardous gas emissions (including HF) and can be used to assess the effectiveness of suppression or containment under representative fault conditions. In the context of rolling stock, UL 9540A provides a recognized verification pathway for risks associated with ESS fire events that are not fully addressed in EN 45545 or other railway standards.

Integration of fire suppression with the BMS should support effective fault response, including isolation, alerting and mitigation of gas release or thermal propagation.

For HFS, fire protection design shall follow the established and emerging standards IEC 63341:2025, CSA T/S 601:2024, ISO 16111:2018 and ISO 13985:2006. These standards provide requirements for safety, fire protection and system design relevant to hydrogen applications in rail and other land transport vehicles.

Commentary *C9.3.3-3*

NFPA 2:2023 is an option to be used to inform general hydrogen safety provisions where rail-specific standards are not available.

The principles of AS 5062:2022 should be applied to support hazard identification, system classification and the selection of suppression technologies appropriate to the environment and fuel type.

The following requirements are derived from and extend the application of the referenced HFS and ESS standards. They shall be applied to support the compliant implementation of fire protection measures for these systems:

(a) In compartments containing or exposed to hydrogen emissions—whether from hydrogen fuel systems, energy storage systems or as a by-product of thermal

events—fire suppression is integrated with controlled venting, battery system isolation and automatic shutoff functions.

(b) where passive venting is incorporated into battery designs, the compartment is configured to safely disperse gases and prevent accumulation.

(c) detection methods appropriate to the hazards are present and could include:

(i) off-gas and thermal runaway indicators for ESS; and

(ii) hydrogen sensors, high-temperature sensors, flame detectors for HFS systems.

(d) fire detection and suppression systems are integrated with other onboard systems, including other fixed fire suppression systems, BMS, BTMS, hydrogen safety controls and ventilation.

For HFS, the fire protection strategy shall include hydrogen detection, ventilation control, automatic shutoff of the hydrogen supply and integration with pressure relief devices, TPRD and compartment venting systems.

Section 10 Running capability in the event of fire

10.1 Performance requirements

10.1.1 Track machines

Track machines that operate through tunnels greater than 100 m in length shall be fitted with an appropriate number of self-rescue devices such that, in the event that the staff of the track machine is required to evacuate through a smoke-filled tunnel, they are provided with equipment to reduce the hazard posed by the smoke during evacuation.

10.1.2 HFS and ESS track machines

In addition to Clause 10.1.1, track machines with HFS or ESS systems shall maintain sufficient operational capability to reach a designated safe stopping location in the event of a developing fire.

Commentary *C10.1.2*

The objective is to reduce risks to staff and infrastructure by supporting continued controlled movement under initial fire conditions.

10.2 Deemed to satisfy requirements

10.2.1 Track machines

The performance requirements of Clause 10.1.1 shall be deemed to be satisfied if:

(a) each occupied staff compartment of track machines, which operate through tunnels greater than 100 m in length, is fitted with self-rescue devices that are compliant with the requirements of EN 403:2004;

(b) the number of self-rescue devices provided in each cab is not less than the number of staff who will occupy that cab in normal service operations; and

(c) the type of self-rescue equipment installed provides smoke protection for not less than the expected egress period in the tunnel systems in which the track machine will operate.

10.2.2 HFS and ESS track machines

In addition to Clause 10.2.1, the following shall be used to demonstrate compliance for track machines with HFS or ESS systems:

(a) Compliance with EN 50553:2012 so far as is reasonably practicable, ensuring that the track machine maintains operational capability for a sufficient duration to reach a designated safe stopping location in the event of a fire.

(b) Demonstration that ESS thermal management systems can mitigate thermal runaway and maintain sufficient energy reserves by operating in reduced power mode.

(c) Demonstration that HFS is equipped with active hydrogen leak detection-controlled venting and emergency hydrogen isolation systems, ensuring that hydrogen storage and controlled venting mechanisms operate safely in tunnels and enclosed spaces without compromising track machine functionality.

(d) Demonstration that HFS propulsion systems can maintain operational capability in degraded mode without immediate train stoppage unless required for safety reasons.

Commentary *C10.2.2*

The scope of EN 50553 states that it is applicable to passenger-carrying rolling stock. While some of the fire sources/scenarios may not be applicable to track machines, the concepts of EN 50553 are applicable to assessing the running capability of a track machine with HFS and ESS systems.

Section 11 Flammable or toxic gas release management

Compartments housing equipment that can emit flammable gases or gases presenting acute toxicity hazards during normal operation or under fault conditions shall be provided with venting arrangements designed to control internal gas concentrations and ensure safe discharge to the exterior of the rolling stock.

For gases presenting acute toxicity hazards, the manufacturer and RSO shall jointly define, as part of the hazard identification process, credible release scenarios, expected release locations and flow rates, and exposure acceptance criteria for staff, occupied staff compartments and evacuation paths.

The venting design shall be demonstrated (by analysis and, where applicable, testing) to meet those acceptance criteria for the defined scenarios.

For hydrogen gas, venting shall be designed to limit release concentrations to levels that do not create hazardous explosive atmospheres, taking into account the system configuration (e.g., roof-mounted vs enclosed cabinet installations).

Release types shall be classified in accordance with IEC 60079-10-1:2020 as follows:

(a) Continuous release – Expected under normal operation, including permeation or minor leaks. Release limits comply with agreed standards (e.g., UN ECE R134:2019, ISO 19881:2018) and be validated at both component and system levels.

(b) Primary release - Occasional or periodic to be avoided by design.

(c) Secondary release – Through designated vent lines, typically triggered by overpressure or overtemperature. Manufacturers to provide expected rates based on component design.

(d) Other release – Caused by abnormal conditions (e.g., component failure or poor maintenance).

The venting system shall be designed to:

(e) prevent gas accumulation in enclosed spaces;

(f) avoid discharging toward the staff evacuation paths;

(g) mitigate explosion, fire propagation and toxic exposure risks during credible failure scenarios; and

(h) avoid discharging toward ventilation air intakes serving occupied staff compartments.

For hydrogen gas, the direction, location and integrity of the venting paths shall be validated through analysis and, where applicable, tested against relevant standards.

Commentary *C11*

Standards such as ISO 834-1:1999 for fire resistance and UN ECE R134:2019 or ISO 19880-1:2020 can be consulted for guidance on evaluating fire resistance and pressure-vessel integrity under thermal load conditions.

Some systems could involve gases where the primary hazard is toxicity rather than ignition. In these cases, the venting and discharge location are assessed for tenability impacts on staff and evacuation paths. Ammonia is one example of a gas that can create acute toxic exposure hazards and could require additional controls beyond those used solely for flammable gas dispersion.

A dedicated hazard analysis shall confirm the effectiveness of the design in protecting personnel and enabling safe egress in the event of flammable gas release.

Where the mitigation measures specified in this standard are not sufficient to adequately control residual risk, additional measures shall be provided and documented.

Section 12 Maintenance, modifications and refurbishment

12.1 General

Maintenance, modification, refurbishment or changes in operational conditions are not to reduce the fire performance of rolling stock below the level required by this document. The deemed-to-comply provisions provide guidance on how compliance can be achieved. Where these provisions are not met, a performance-based approach shall be applied in accordance with Section 2.

12.2 Performance requirements

Rolling stock shall be maintained, modified, and refurbished such that the vehicle's level of fire performance, measured by the requirements of this document is:

(a) not reduced from its initial level; or

(b) not reduced below the deemed to satisfy provisions specified by Section 3 to Section 10 of this document.

If the maintenance, modification, or refurbishment of rolling stock results in the fire performance of any given component being reduced from its initial level, this change shall be considered a performance based solution and as such the process defined in Section 2 of this document shall be followed to ensure that the overall level of fire safety achieved by the rolling stock still remains acceptable.

Where a change in operational use occurs, the fire safety performance of the rolling stock shall be reassessed to confirm continued compliance with this document.

Operational changes requiring reassessment include, but are not limited to:

(c) the introduction of new tunnel infrastructure on existing routes; or

(d) reassignment to networks with different tunnel or infrastructure characteristics.

Any reassessment shall consider the suitability of fire protection systems, evacuation capability and supporting equipment (e.g., self-rescue devices) and shall result in updates where required to maintain compliance with the performance objectives of this document.

12.3 Deemed to satisfy provisions

12.3.1 Maintenance

The performance requirements of Clause 12.2 relating to maintenance are deemed to be satisfied by implementing all of the following, where applicable:

(a) Component replacement shall be like-for-like to maintain the original fire performance level.

(b) Any change of components that is not like-for-like is considered a modification and shall meet the relevant requirements under Clause 12.3.3.

(c) Fire-resistant components, including thermal barriers, fire-rated wiring, shall undergo periodic inspection to maintain compliance.

(d) Cleaning processes used as part of rolling stock maintenance shall not degrade the fire performance of component materials or assemblies.

(e) Aggressive cleaning agents shall not be used in areas where there is a risk that they could result in the degradation of intumescent materials employed to provide passive fire protection.

(f) Cleaning processes shall not leave behind residues which in a fire event could promote flame spread.

(g) Materials relying on specific layering for fire resistance (e.g., seat trim, flooring, insulation layers) shall undergo periodic inspections.

(h) If degradation is identified, rectification works shall be undertaken.

(i) Fire barriers, insulation layers and vented hydrogen enclosures shall be checked for wear, damage or gaps that could compromise fire containment.

Where spark emissions are identified:

(j) Rolling stock shall be maintained to minimise spark emissions SFAIRP, which could cause ignition of trackside materials.

(k) Short and long term mitigation measures (e.g., modifications) shall be implemented to effectively manage these occurrences.

Maintenance activities shall include periodic inspections, functional testing and compliance verification to prevent system degradation, leaks or thermal hazards.

ESS and HFS shall be maintained in accordance with the manufacturer's instructions to ensure operational safety and fire risk mitigation.

ESS maintenance procedures shall include periodic battery cell health checks to identify defective or degraded cells, thereby reducing the likelihood of thermal events or system damage during service operation.

12.3.2 Fire protection system maintenance

Fire protection systems shall be maintained in accordance with the requirements of AS 5062:2022.

Fire suppression systems in ESS, HFS and combustion engine enclosures shall undergo functional testing to verify response time and effectiveness.

Reservoirs and piping containing fuel, oil or other flammable fluids shall be periodically inspected for leaks or defects and rectified to minimize fire risks.

Hydrogen containment systems and pressure relief devices shall be tested and inspected for leak prevention and controlled venting integrity

Self-rescue devices provided shall be maintained in accordance with manufacturer instructions and applicable regulatory requirements.

Self-rescue devices shall be inspected periodically, tested functionally (where applicable) and replaced prior to expiry.

A process shall be established to reassess the specification of self-rescue devices where tunnel length, ventilation profile or egress duration changes.

The number of self-rescue devices shall be reviewed whenever staff configurations change, ensuring sufficiency for normal operation.

12.3.3 Modification and refurbishment

The requirements of Clause 12.2 in relation to modification and refurbishment are deemed to be satisfied where the following provisions are demonstrated to maintain the fire safety performance of the rolling stock.

New components introduced to a track machine as part of a modification or refurbishment program for the first time shall be compliant with the applicable deemed to satisfy provisions of this document.

Where existing components or materials are replaced as part of a modification or refurbishment program (e.g., obsolescence, product improvement, supplier change), the replacement component or material shall be demonstrated to provide equivalent or improved fire safety performance. This can be achieved by following the methods below:

(a) If the original component or material is certified to an internationally recognized railway fire performance standard (e.g., EN 45545-2:2020+A1:2023), then it is acceptable to replace it with another equivalent-type component or material that is:

  (i) certified to the same standard with the same or higher level of performance; or

  (ii) certified to the requirements of EN 45545-2:2020+A1:2023 to the relevant hazard level as required by the rolling stock operation category and design category.

(b) If the original component or material is not certified to an internationally recognized railway fire performance standard (e.g., EN 45545-2:2020+A1:2023), then it is acceptable to replace it with an equivalent-type component or material that:

  (i) is certified to the requirements of EN 45545-2:2020+A1:2023 to the relevant hazard level as required by the rolling stock operation category and design category; or

  (ii) has been demonstrated to have equivalent or better performance than the existing via comparative testing using the relevant EN 45545-2:2020+A1:2023 product category testing requirements.

Commentary *C12.3.3*

EN 45545-2:2020+A1:2023 compliance is not required for either existing or replacement but is rather used as a method to perform a comparison.

(c) Modifications affecting ESS, HFS or high-voltage electrical systems are assessed for thermal stability, fire containment and explosion risks.

(d) Any penetrations made through fire-resistant structures during modifications are fire-sealed to maintain barrier integrity.

(e) Changes to ventilation and gas dispersal systems are evaluated to ensure they do not increase the risk of explosions or fire spread.

(f) Thermal management and suppression systems are reassessed to confirm effectiveness in the modified configuration.

(g) Following any modification, fire protection systems shall undergo functional validation and testing, ensuring continued compliance with this document.

Appendix A Hazard Register (Informative)

A.1 ARISO hazard register

Hazard number	Hazard
5.1.1.6	Sparks from exhausts causing fire
5.1.1.7	Sparks from brake equipment causing fire
5.1.1.8	Combustible wayside material causing fire
5.1.1.14	Fire causing (excessive pollution)
5.1.1.15	Fire caused by rolling stock
5.3.1.23	Fire causing burns by thermal radiation
5.4.3	Explosion
5.32.1.1	No separation or barrier existing between sources and fuel causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.2	The environment not being controlled to reduce smoke and heat production (Smoke and heat not controlled - Fire not controlled)
5.32.1.3	Properties, quantity or distribution of combustible materials not being controlled (Smoke and heat not controlled - Fire not controlled)
5.32.1.4	Fire not being vented (Fire propagation not controlled - Fire not controlled)
5.32.1.5	Fire not being detected (Fire not suppressed - Fire not controlled)
5.32.1.6	No or insufficient suppressant being available (Fire not suppressed - Fire not controlled)
5.32.1.7	Fire not being contained (Fire propagation not controlled - Fire not controlled)
5.32.1.8	In traction systems the heat source is not eliminated, or the rate of heat release is not sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.9	In braking systems the heat source is not eliminated, or the rate of heat release is not sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.10	In electrical systems the heat source is not eliminated, or the rate of heat release is not sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.13	In the event of a malicious act the heat source is not eliminated, or the rate of heat release is not sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.17	Fuel - Combustible material not being eliminated or combustibility not being sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)

Hazard number	Hazard
5.32.1.20	Interior surfaces - Combustible material not being eliminated or combustibility not being sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.21	Exterior surfaces - Combustible material not being eliminated or combustibility not being sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.22	Oil - Combustible material not being eliminated or combustibility not being sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.23	Waste / rubbish - Combustible material not being eliminated or combustibility not being sufficiently reduced causing the heat source to interact with combustible material (Fire not prevented)
5.32.1.26	Fire products harming persons or property causing risk to Immobile property or persons (Persons or property not protected from fire)
5.45.1.15	Being overcome by fire products (Unable to reach exit safely - Unable to successfully evacuate)
5.45.1.17	Being overcome by fire products (Unable to use exit safely - Unable to successfully evacuate)
5.45.1.5	No functioning fire / smoke detection systems so the need for evacuation is not detected (Evacuation not successfully initiated)
5.53.1.2	Human error
5.53.1.3	Invalid test procedures
5.53.1.9	Incorrect analysis methods (Design error)

A.2 Other identified hazards

Hazard
Thermal runaway initiation within electrochemical battery cells or modules, resulting in rapid heat release and fire escalation.
Thermal propagation between adjacent battery cells, modules, or packs, resulting in uncontrolled spread of the battery fire event.
Release of flammable, toxic and/or corrosive gases during battery cell failure (including pre-ignition off-gas emissions), creating secondary ignition and toxicity hazards.
Internal over-pressure within battery enclosures during failure events, leading to rupture, explosion and/or uncontrolled venting, creating fire and projectile hazards.
Jet flames and/or high-velocity flame fronts resulting from venting or rupture of pressurised gas storage or distribution components, causing rapid fire spread and severe thermal exposure.
Ejection of battery fragments, cell components and/or high-temperature debris during failure events, causing secondary ignition and injury hazards.

Hazard
Re-ignition following initial suppression due to residual thermal energy and/or delayed battery cell failure, resulting in renewed fire development.
Electrical arcing, short-circuiting and/or persistent voltage hazards during and after electrical energy storage failure events, creating ignition sources and impeding suppression or intervention.
Leakage of hydrogen from storage vessels, pipework or fuel cell system components, creating flammable gas release and ignition potential.
Accumulation of hydrogen in confined or semi-enclosed spaces, leading to flammable or explosive atmospheres.
Hydrogen flames that are difficult to detect visually due to low luminosity, resulting in delayed recognition and delayed or ineffective response.
High-pressure hydrogen storage failures, including structural rupture and rapid decompression, resulting in immediate fire and/or explosion hazards.

Bibliography (Informative)

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

- AS 2676.2:2020, *Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings, Part 2: Sealed cells*
- AS 7501:2019, *Railway rolling stock - Rolling stock certification*
- IEC 60077:2017, *Railway applications, Electric equipment for rolling stock*
- IEC 60571:2012, Railway applications, *Electronic equipment used on rolling stock*
- IEC 61881-3:2013, *Railway applications, Rolling stock, Capacitors for power electronics, Electric double-layer capacitors*
- IEC 62619:2022, *Secondary cells and batteries containing alkaline or other non-acid electrolytes, Safety requirements for secondary lithium cells and batteries for use in industrial applications*
- IEC 62928:2020, *Railway applications — Rolling stock — On-board energy storage systems*
- IEC 63341-3:2025, *Railway applications, Hydrogen and fuel cell systems for rolling stock, Part 3: Performance test methods for fuel cell power system*
- ISO 19880-1:2020, *Gaseous hydrogen, Refuelling stations, Part 1: General requirements*
- ISO 19881:2025, *Gaseous hydrogen, Land vehicle fuel containers*
- EN 13501-1:2018, *Fire classification of construction products and building elements*
- BS 6853:1999, *Code of practice for fire precautions in the design and construction of passenger carrying trains, now withdrawn*
- CSA T/S 601:2024, *Safety and fire control for hydrogen-powered passenger rail vehicles*
- NFPA 2:2023, *Hydrogen technologies code*
- NFPA 130:2023, *Standard for fixed guideway transit and passenger rail systems*
- NFPA 497:2024, *Recommended practice for the classification of flammable liquids, gases, or vapours and of hazardous (classified) locations for electrical installations in chemical process areas*
- UL 9540A:2025, *Test method for evaluating thermal runaway fire propagation in battery energy storage systems*
- 96/603/EC, *Commission Decision of 4 October 1996 establishing the list of products belonging to Classes A 'No contribution to fire'*
- Australasian Railway Association (ARA) (2024), *Decarbonising Australia's Rolling Stock Fleet, Accelerating the transition to net zero, White Paper, October 2024*