Impact of Hydrogen Standards on the UK Transportation System (iHYLAST)

Deliverable D1

UNIVERSITY OF BIRMINGHAM | BCRRE

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Sustainable Transport Solutions

1. Standards Landscape

A project to introduce hydrogen powered trains into passenger service on the GB mainline railway network will require engineering and operational conformity with standards relevant to both hydrogen systems and to railway safety and interoperability.

Appendix 2 provides a list of standards relevant to the introduction of hydrogen powered trains in the UK. They are separated into standards relevant to new hydrogen vehicles and systems in table 1, and standards relevant to new or modified rail vehicles, and their integration into the railway system in table 2.

1.1. Hydrogen Propulsion System Standards

Under the European Community type-approvals framework, the primary pieces of legislation relevant for the introduction of a hydrogen power system are EC 79/2009, and EU 406/201, the associated implementing regulation. While the legislation is primarily aimed at hydrogen powered motor vehicles, there is precedent for the use of EC type-approval for the hydrogen system in isolation in a rail vehicle. The Alstom Coradia iLint hydrogen train used this approach to gain authorisation for the hydrogen system, then safe integration of the hydrogen power system into the train and the wider rail environment was completed using the Common Safety Method Risk Assessment. However, given that EC type-approvals are no longer applicable following the UKs withdrawal from the EU, a UK project can voluntarily conform with EC 79/2009, presenting a Technical File to a Notified Body against Hydrogen Legislation. However, the safety measures in EC 79/2009 have not been proven in a railway context. Therefore, if these standards were to be adopted as codes of practice for rail in the UK, further analysis would be required to assess their suitability to rail, particularly regarding crashworthiness in a rail environment. This, and a further gap analysis of published standards for the safe introduction of hydrogen powered trains is examined in section 3.

1.2. Railway Standards

Various types of railway standards are published in the UK. National Technical Specification Notices, NTSNs focus on ensuring the interoperability of the railway system. They directly replace Technical Specifications for Interoperability, TSIs, following the UKs withdrawal from the European Union. National Technical Rules, NTRs are a list of Railway Group Standards, RGSs, which provide network or country-specific requirements to supplement National Technical Specification Notices.

Railway Group Standards, RGSs, are a collection of standards, published by the Rail Safety and Standards Board, RSSB, that provide technical, engineering and operational requirements for railway projects in the UK. When RGSs are being used as NTRs, compliance is compulsory.

Rail Industry Standards, RISs, are a collection of standards, published by the RSSB, that define functional or technical requirements to be met in circumstances where the management of the railway system does not need a Railway Group Standard. RISs remove the need for companies to develop and maintain their own (company) standards in the areas covered by RISs.

Numerous European and International Standards are written for railway applications. However, compliance is voluntary unless the standard is referenced in a document which must be complied with, such as a National Technical Specification Notice or a Railway Group Standard. Notably, two standards are being developed for publication by the International Electrotechnical Commission (IEC) specifically for hydrogen fuel cell systems for use in trains, they are; IEC 63341-1 '*Railway applications – Rolling stock – Fuel cell systems for propulsion -Part 1: Fuel cell power system*' and IEC

63341-2 '*Railway applications – Rolling stock – Fuel cell systems for propulsion -Part 2: Hydrogen storage system*'. It is hoped that, upon completion and publication, these standards will be adopted for new rolling stock projects. Therefore, compliance should be mandated by an NTSN or RGS.

2. Train Approvals Process

Under UK law, new or newly modified rolling stock cannot be introduced into passenger service without following various processes to gain approvals and authorisations. Introducing a new train into passenger service can be achieved when an Approval to place into service (APiS) certification is issued from the Office of Rail and Road (ORR). For a significantly modified train (e.g., the addition of a hydrogen propulsion system), an Attestation statement is issued from the ORR, and serves the same purpose as an APiS certification. This is provided when rolling stock has been demonstrated to be compliant with specified industry standards, compatible with infrastructure and, able to be safely operated.

The approvals and certification pathway for new trains has been detailed below, and a simplified view of this process can be found in appendix 1.

In the UK, the rail industry must comply with the requirements of the Railways and Other Guided Transport Systems (Safety) Regulations 2006 (ROGS). In order to operate in the UK, Rolling Stock must be meet all essential requirements set out in standards and ROGS legislation. This is demonstrated by showing that the rolling stock is:

> **Compliant** to all applicable standards i.e., the NTSNs, NTRs and RGSs specific to national infrastructure
>
> **Compatible** with the infrastructure and other sub systems for the routes on which the rolling stock will operate
>
> **Safe to operate** on the railways in accordance with ROGS

It should be noted that this process applies only to rail vehicles operating on Network Rail infrastructure and does not apply to trams and light rail vehicles. However, similar processes are in place for these applications.

2.1. Compliance

Compliance requirements are contained within relevant National Technical Specification Notices (NTSNs) and National Technical Rules (NTRs). In the UK, NTRs contains Railway Group Standards (RGSs). Compliance to NTSNs is independently verified by an Approved Body (ApBo) and compliance to NTRs are independently verified by a Designated Body (DeBo).

Throughout the process of rail vehicle design/modification, the independent verification bodies (ApBo/DeBo) are present in examining the design, examples of the as-built trains, and in reviewing the manufacturers' internal validation and verification checks. The ApBo/DeBo also audit the supplier's quality management system (QMS) in relation to the production of the trains and their subsystems and, ensure that the QMS is being applied in a consistent manner. The ApBo/DeBo produce Intermediate Statements of Verification (ISVs) for interim phases of the project (e.g., for testing, operation without passengers) and, finally a Certificate of Verification (CoV) to confirm that their assessment is complete for introduction of the train service with passengers.

A Technical File is produced by the applicant with the assistance of the verification body (ApBo/DeBo), and should contain technical descriptions, technical drawings, test methods and results, simulations, calculations, and operational and maintenance requirements. It should also contain a Safety Assessment Report from the AsBo (see section 2.3.), a Certificate of Verification

(CoV) from both the DeBo and ApBo. Upon the approval of the technical file by the ORR, an APiS certification is issued, allowing the train to enter passenger service. Upon the issuing of an APiS certification, the train is entered into the National Vehicle Register (NVR), a database maintained by Network Rail Ltd.

For compliance with standards that are outside the scope of NTSNs or NTRs, the project must define how this compliance will be demonstrated and verified and agree this with the ORR. For example, BS ISO 23273:2013 '*Protection against Hydrogen hazards for vehicles fuelled with compressed Hydrogen*' is applicable to Hydrogen powered trains and therefore a compliance plan must be created, with compliances verified.

2.2. Compatibility

For operation on Network Rail infrastructure, Railway Group Standard GE/RT8270 '*Assessment of Compatibility of Rolling Stock and Infrastructure*', describes process that must be followed before the rolling stock is accepted for operation. This must demonstrate that no unmanaged risks will be imported onto the railway by the introduction of new rolling stock and covers all aspects where the train interacts with the infrastructure (e.g., vehicle gauging, electro-magnetic compatibility, signalling interfaces, wheel/rail interfaces, platform interfaces and coupling compatibility with existing trains and assistance arrangements).

The output from the GE/RT8270 process is a summary of Rolling Stock/Infrastructure Compatibility which defines on which routes the new or modified rolling stock can operate and any restrictions that apply. Given Network Rail are the infrastructure manager in the UK, the internal Network Rail standard, NR/L2/RSE/100/04 '*Introduction of New or Modified Vehicles*', is of particular interest.

2.3. Common Safety Method

The Railways and Other Guided Transport Systems (Safety) Regulations 2006 state that a standardised form of risk assessment is used when a significant change is made to the railway. The introduction of a new type of rolling stock, or the storage of Hydrogen fuel at a depot would be defined as a significant change and would therefore require the application of the Common Safety Method for Risk Evaluation & Assessment (CSM-RA).

The CSM-RA starts with a system definition for the project, which describes the project and the resulting change made to the railway. A systematic hazard identification process is employed, usually in the form of Hazard Identification (HAZID) and Hazard and Operability (HAZOP) studies. These are then used to determine methods of best managing these risks and assigning hazard owners. Once identified, hazards are then collated into a Hazard Record, where hazards can be marked as open or closed, and mitigating actions can be noted. Hazards are assessed and scored used a risk matrix, where each score is classified as negligible, intolerable, or tolerable if the risk is reduced to be as low as reasonably possible.

The correct application of the CSM-RA is independently verified by an Assessment Body (AsBo), who produced a Safety Assessment Report (SAR). The SAR is then submitted to the ORR with the Technical File.

2.4. Safe to Operate

Under ROGS, an entity in charge of maintenance (ECM) is required. An ECM is a competent person or organisation that is responsible for the safe maintenance of rolling stock. Rolling stock can only be placed into service if the vehicle has an ECM assigned to it and that person or organisation is registered as the ECM in the National Vehicle Register (NVR).

Alongside processes to approve each type of new train (resulting in the issuing of an APiS certification), each Train Operating Company (TOC) must undergo an internal management of change procedure. The introduction of a new type of train (and changes in fuelling procedures etc. that will be present when introducing a fleet of Hydrogen trains) would be considered a 'major change'. Therefore, through the TOCs internal safety management system, a major change will require hazard identification and mitigation from an operational perspective.

3. Gap analysis of standards relating to the safety of hydrogen powered trains

An exploration of the standards and guidance documentation relevant for the introduction of hydrogen powered trains in the UK can be found in section 1. Given the novelty of hydrogen powered trains in the UK, the network of published standards do not provide complete coverage of issues arising from the use of hydrogen as a fuel in a railway context. These predominantly relate to the hydrogen propulsion and storage systems and their safe integration with the wider railway system. These 'gaps' are considered below.

3.1. Applicability of EC 79/2009 to rail vehicle crashworthiness

The standards for the type-approval of the hydrogen power system (EC 79/2009 and EU 406/2010) are only applicable to road vehicles. However, EC 79/2009 and EU 406/2010 are being used as the primary source of requirements for the hydrogen power system by rolling stock manufacturers.

Notably, an analysis of the engineering values found in Annex IV '*Requirements for hydrogen components and systems designed to use compressed (gaseous) hydrogen and their installation on hydrogen powered vehicles*' should be carried out, against the requirements found in Railway Group Standard GMRT2100 '*Rail Vehicle Structures and Passive Safety*' and LOCPAS NTSN '*Rolling Stock – Locomotive and Passenger*'. This is due to the nature of crash and collision scenarios experienced by trains when compared to road vehicles. This analysis would also provide assurance the design parameters of the hydrogen system against forces and vibrations applied during normal rail operations.

3.2. Applicability of EU 406/2010 to the location of hydrogen systems in rail vehicles

The standards for the type-approval of the hydrogen power system (EC 79/2009 and EU 406/2010) are only applicable to road vehicles. Therefore, EU 406/2010 does not contain any requirements relating to the safe positioning of the hydrogen storage and propulsion system within a rail vehicle. This is especially relevant given that the hydrogen system may be positioned such that hydrogen is released into a part of the vehicle occupied by passengers. 'Flying ballast' – a phenomena where the aggregate used in the construction of trackwork becomes a projectile due to the forces of passing trains, has also been identified as a hazard for hydrogen systems placed on the underframe of a railway vehicle.

Given that EU 406/2010 only provides high-level requirements for the positioning of hydrogen propulsion and storage systems and does not consider the potential for 'flying ballast', the release of hydrogen into a compartment occupied by passengers and other hazards specific to a rail environment. Therefore, the requirements of EN 406/2010 should be assessed, considering the positioning of hydrogen systems within a rail vehicle. It is likely that the CSM-RA would identify and provide a process for mitigation of these hazards. However, it is preferable for these requirements to be captured within the EC 79/2009 and EU 406/2010 framework already in use. A review of the engineering requirements for the safe positioning of hydrogen systems within a rail vehicle should be carried out and compared to requirements found in EU 406/2010.

3.3. Applicability of GI/GN7621 to depots servicing hydrogen trains

GI/GN7621 '*Guidance for the Development and Design Considerations of Passenger Rolling Stock Depots*' is a guidance notice, and describes best practice, with compliance voluntary as rolling Stock depots largely fall outside the scope of Railway Group Standards. GI/GN7621 does not make any reference to hydrogen storage, refuelling, or the maintenance, storage and operations of hydrogen powered trains.

Given that the introduction of hydrogen powered trains will require the installation of new refuelling equipment, large amounts of hydrogen being stored on-site, additional safety considerations and new maintenance requirements, this GI/GN7621 should be expanded to provide guidance for the safe operation of hydrogen powered trains. While ISO 19880:2020 '*Gaseous hydrogen — Fuelling stations*' does prescribe the design of the refuelling equipment itself, the design of the larger depot context is outside the scope of this standard. However, *HyApproval* provides guidance on the design of refuelling stations and layout for best operational practice. Therefore, any additions to GI/GN7621 relevant to the use of hydrogen as a fuel in rail vehicles should be reviewed against *HyApproval*. Where *HyApproval* is not adequate for a railway depot environment, a risk estimation should be carried out to introduce best engineering and operational practice. This should not only consider the refuelling of hydrogen powered trains, but also the safety implications of the storage of trains inside depot buildings, the storage of large amounts of hydrogen on-site and allowances for hydrogen-specific maintenance tasks.

An appendix to GI/GN7612 is planned by the RSSB to support manufacturers and operators design and deploy hydrogen fuelled passenger trains.

3.4. Hydrogen emergency response standards & considerations

HyResponse D6.3 includes guidance on the strategies and tactics to be deployed by emergency services for the management of hydrogen accidents associated with hydrogen powered road vehicles. Currently this guidance does not include any specific information on hydrogen powered rail vehicles. The emergency response requirements within *HyResponse D6.3* do not consider any likely accident scenarios within the rail environment, including the release and ignition of hydrogen in enclosed structures following rail vehicles collision or derailment.

Therefore, the emergency response guidance within *HyResponse D6.3* should be reviewed to consider its suitability for application to the rail environment. Of note should be the implications of a hydrogen accident within an enclosed structure, such as a tunnel, under a bridge or in an enclosed station. Direct engagement with first responder organisations and railway infrastructure managers should also be considered during the development of a hydrogen powered rail vehicle will also elicit suitable rail specific emergency response arrangements. This should particularly consider the procedures for the electrical isolation of any infrastructure-based electrification (overhead line equipment or conductor rails).

3.5. Applicability of BS 7430 to hydrogen trains

BS 7430 '*Code of practice for protective earthing of electrical installations*' provides requirements for earthing and bonding. Earthing, bonding and protective shielding requirements for rail infrastructure and vehicles are derived from BS 7430. BS 7430 does not consider any specific requirements for hydrogen storage containers. This is particularly relevant for hydrogen storage containers located on or near the roof of rail vehicles, where there is potential for contact with Overhead Line Equipment, OLE, elements, leading to catastrophic damage.

Therefore, the potential scenario of hydrogen components coming into contact with OLE should be considered and assessed against BS 7430, noting the potentially catastrophic results of direct contact with OLE.

3.6. Applicability of safety integrity levels to hydrogen propulsion systems in rail

There are no specific rail requirements relating to the appropriate safety integrity level (SIL) for a hydrogen power safety instrumented system (as defined in EU 406/2010). Therefore, the applicability of BS EN 50129 '*Railway applications. Communication, signalling and processing systems. Safety related electronic systems for signalling*' should be considered for hydrogen power safety instrumented systems, given hazards and accident scenarios associated with hydrogen storage and propulsion systems.

3.7. Applicability of BS EN 45544 to hydrogen trains

Given the nature of possible hydrogen accident scenarios with a rail environment, alarm setting values will need to be proven to provide a suitable intervention point before hydrogen concentrations reach a lower explosive limit. Although alarm setting values for hydrogen detection are specified in BS EN 45544 '*Workplace atmospheres. Electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours*', these values do not consider likely accident scenarios in a rail environment. Therefore, alarm settings may be inappropriate for the purposes and warning and escalation traincrew and passengers of an escalation of hydrogen pressures in particularly vulnerable rail environments such as in tunnels.

Alarm setting values used in BS EN 45544 should be reviewed against foreseeable operational and accident conditions of a hydrogen powered train. Suitable alarm setting values should be selected such that the identification of a hydrogen hazard is made clear to traincrew at a suitable intervention point before a realisation of a hydrogen accident. The *HyTunnel* project will provide specific data and models for the accumulation of hydrogen in tunnels.

4. Recommendations

4.1. The development of IEC 63341-1 '*Railway applications – Rolling stock – Fuel cell systems for propulsion - Part 1: Fuel cell power system*' and IEC 63341-2 '*Railway applications – Rolling stock – Fuel cell systems for propulsion - Part 2: Hydrogen storage system*' should be continued. These standards are both currently in draft and, upon publication, should be introduced into rail code of practice.

4.2. An analysis of the engineering values found in Annex I-IV of EC 79/2009 should be carried out against the requirements found in Railway Group Standard GMRT2100 '*Rail Vehicle Structures and Passive Safety*' and LOCPAS NTSN '*Rolling Stock – Locomotive and Passenger*'. This will determine the applicability of EC 79/2009 for hydrogen propulsion systems in a rail environment.

4.3. A review of the engineering requirements for the safe positioning of hydrogen systems within a rail vehicle should be carried out and compared to requirements found in EU 406/2010. This will determine the applicability of EU 406/2010 for hydrogen propulsion systems in a rail environment.

4.4. An appendix to GI/GN7612 '*Guidance for the Development and Design Considerations of Passenger Rolling Stock Depots*' relating to the implications of hydrogen powered trains of rolling stock depots should continue to be developed.

4.5. The emergency response guidance within *HyResponse D6.3* should be reviewed to consider its suitability for application to the rail environment, particularly regarding hydrogen emergencies in enclosed spaces such as tunnels and enclosed stations.

4.6. A review of BS 7430 '*Code of practice for protective earthing of electrical installations*' should be made considering the implications of electrical arcing from an overhead contact system or elements of overhead electrification coming into contact with a hydrogen powered train.

4.7. The applicability of BS EN 50129 '*Railway applications. Communication, signalling and processing systems. Safety related electronic systems for signalling*' should be considered for hydrogen power safety instrumented systems in rail.

4.8. Alarm setting values specified in BS EN 45544 '*Workplace atmospheres. Electrical apparatus used for the direct detection and direct concentration measurement of toxic gases and vapours*' should be reviewed against foreseeable operational and accident conditions of a hydrogen powered train.

5. Further Reading

- Approach to Authorisation under the Interoperability Regulations Guidance for Applicants – Office of Rail and Road (2021)
- Hydrogen Powered Trains: Route to Enter into Service (T1172) – Rail Safety and Standards Board (2020)
- The Landscape of Standards in the Rail Industry for certifying Hydrogen Powered Trains

6. Glossary & Definitions

ApBo, Approval Body is an independent body assigned to verify that the project is compliant with National Technical Specification Notices.

APiS, Approval to Place into Service is a certification issued by the Office of Rail and Road that permits a new train to enter passenger service on the GB mainline network.

AsBo, Assessment Body is an independent body assigned to verify that the Common Safety Method for Risk Evaluation & Assessment has been correctly applied.

DeBo, Designated Body is an independent body assigned to verify that the project is compliant with National Technical Rules.

NTSN, National Technical Specification Notices are UK railway technical standards, focused on ensuring the interoperability of the railway system. They directly replace Technical Specifications for Interoperability, TSIs, following the UKs withdrawal from the European Union.

ORR, The Office of Rail and Road is a non-ministerial UK government department, responsible for the economic and safety regulation of Britain's railways, and the economic monitoring of National Highways. As part of the role of rail safety regulator, it issues Approval to Place into Service certifications, allowing new rolling stock projects to enter passenger service.

RGS, Railway Group Standards are a collection of standards, published by the Rail Safety and Standards Board, RSSB, that provide technical, engineering and operational requirements for railway projects in the UK.

RIS, Rail Industry Standards are a collection of standards, published by the Rail Safety and Standards Board, RSSB, that define functional or technical requirements to be met in circumstances where the management of the railway system does not need a Railway Group Standard. RISs remove the need for companies to develop and maintain their own (company) standards in the areas covered by RISs.

RSSB, Rail Safety and Standards Board is a British company, operating as a not-for-profit entity, its primary purpose being to bring about improved health and safety performance throughout Britain's railway network. It publishes and maintains Railway Group Standards, RGSs, and Rail Industry Standards, RISs.

TSI, Technical Specifications for Interoperability are EU-wide railway technical standards, focused on ensuring the safe interoperability of the railway system. In the UK, they have been directly replaced with National Technical Specification Notices following the UKs withdrawal from the European Union.

NTR, National Technical Rules are a list of Railway Group Standards, RGSs, which provide network or country-specific requirements to supplement National Technical Specification Notices. They directly replace Notified National Technical Rules, NNTRs, following the UKs withdrawal from the European Union.

CSM-RA, Common Safety Method for Risk Evaluation & Assessment, sometimes abbreviated CSM-REA, is a defined method for conducting a systematic risk evaluation and assessment. Its use is mandated by the Railways and Other Guided Transport Systems (Safety) Regulations 2006.

HAZOP, Hazard and Operability Study, is a structured and systematic examination of a system in order to identify and evaluate problems that may represent risks to personnel or equipment. The intention of performing a HAZOP is to review the design to pick up design and engineering issues that may otherwise not have been found.

HAZID, Hazard Identification, is a qualitative technique for the early identification of potential hazards and threats that may cause death or injury.

ROGS, Railways and Other Guided Transport Systems (Safety) Regulations 2006 provide the overarching regulatory regime for rail safety, including the mainline railway, metros (including London Underground), tramways, light rail and heritage railways.

Technical File is the name given to the collection of documentation that is supplied to the Office of Rail and Road when seeking to introduce a new type of rolling stock to the GB mainline. It contains various technical design documents, evidence of compliance with standards, and evidence of verification by various independent bodies.

CoV, Certificate of Verification is the document provided by the Approved Body (ApBo) and Designated Body (DeBo) confirming compliance with NTSNs and NTRs (respectively).

TOC, Train Operating Company are businesses responsible for operating passenger trains in the UK.

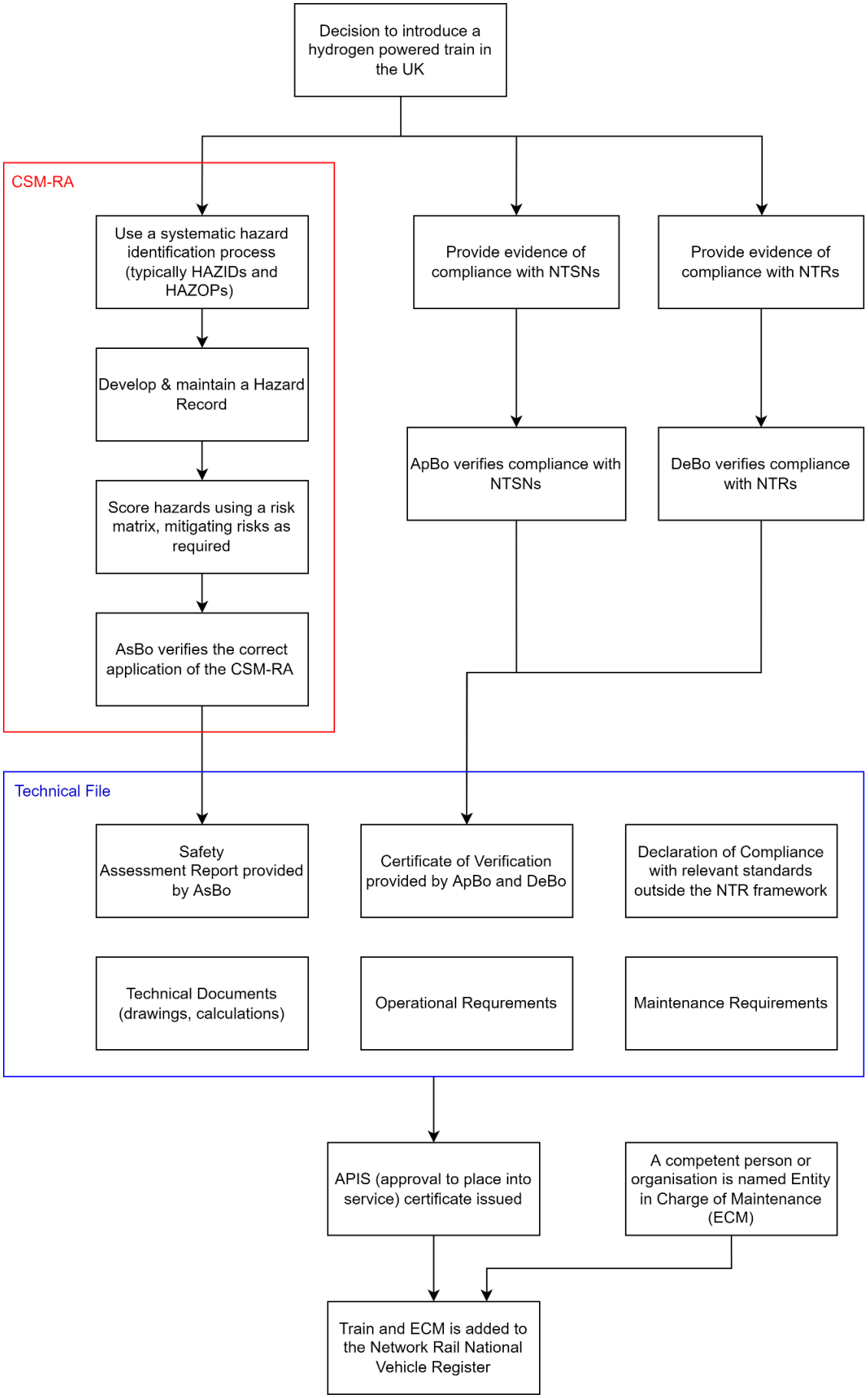
QMS, Quality Management System is a formalized system that documents an organisations processes, procedures, and responsibilities for achieving quality policies and objectives.

ISV, Intermediate Statement of Verification is a certification given to a project by an Approved Body (ApBo) or Designated Body (DeBo) to provide certification during intermediate stages of a project. In a rolling stock context, this would allow test runs to be completed on the mainline and staff training without passengers.

NVR, National Vehicle Register is a database maintained by Network Rail Ltd, containing information about each rail vehicle certified to run on Network Rail Ltd infrastructure.

Attestation statement is a certification issued by the Office of Rail and Road that permits a significantly modified train to re-enter passenger service on the GB mainline network. It is the equivalent to an Approval to Place into Service (APiS) certification for modified rolling stock.

Appendix I


Decision to introduce a hydrogen powered train in the UK
CSM-RA
Use a systematic hazard identification process (typically HAZIDs and HAZOPs)
Develop & maintain a Hazard Record
Score hazards using a risk matrix, mitigating risks as required
AsBo verifies the correct application of the CSM-RA
Provide evidence of compliance with NTSNs
Provide evidence of compliance with NTRs
ApBo verifies compliance with NTSNs
DeBo verifies compliance with NTRs
Technical File
Safety Assessment Report provided by AsBo
Certificate of Verification provided by ApBo and DeBo
Declaration of Compliance with relevant standards outside the NTR framework
Technical Documents (drawings, calculations)
Operational Requrements
Maintenance Requirements
APIS (approval to place into service) certificate issued
A competent person or organisation is named Entity in Charge of Maintenance (ECM)
Train and ECM is added to the Network Rail National Vehicle Register

Appendix 2

Table 1 Key Standards and legislation relevant to new hydrogen vehicles and systems. This list should not be treated as exhaustive, as every project is different.

Standard Number	Standard Name	Standard Type
1999/92/EC	Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres	EC/EU
2010/35/EU	Directive 2010/35/EU of the European Parliament and of the Council of 16 June 2010 on transportable pressure equipment and repealing Council Directives 76/767/EEC	EC/EU
2014/34/EU	Equipment and protective systems intended for use in potentially explosive atmospheres	EC/EU
2014/68/EC	Pressure equipment (recast from EU 97/23)	EC/EU
406/2010/EC	Implementing Regulation (EC) No 79/2009 on type-approval of hydrogen-powered motor vehicles	EC/EU
79/2009/EC	Regulation (EC) No 79/2009 of the European Parliament and of the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC	EC/EU
94/9/EC	Equipment and protective systems intended for use in potentially explosive atmospheres	EC/EU
BS EN 13648-2	Cryogenic vessels. Safety devices for protection against excessive pressure: Bursting disc safety devices for cryogenic service	BS/EN/ISO/IEC
BS EN ISO 17268	Gaseous hydrogen land vehicle refuelling connection devices	BS/EN/ISO/IEC
BS ISO 12619	Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel system components	BS/EN/ISO/IEC
BS ISO 19880-1	Gaseous Hydrogen — Fuelling stations - Part 1: General requirements	BS/EN/ISO/IEC
BS ISO 19880-2	Gaseous Hydrogen — Fuelling stations - Part 2: Dispensers	BS/EN/ISO/IEC
BS ISO 19880-3	Gaseous Hydrogen — Fuelling stations - Part 3: Valves	BS/EN/ISO/IEC
BS ISO 19880-4	Gaseous Hydrogen — Fuelling stations - Part 4: Compressors	BS/EN/ISO/IEC
BS ISO 19880-5	Gaseous Hydrogen — Fuelling stations - Part 5: Dispenser hoses and hose assemblies	BS/EN/ISO/IEC
BS ISO 19880-6	Gaseous Hydrogen — Fuelling stations - Part 6: Fittings	BS/EN/ISO/IEC
BS ISO 19880-7	Gaseous Hydrogen — Fuelling stations - Part 7: O-rings	BS/EN/ISO/IEC
BS ISO 19880-8	Gaseous Hydrogen — Fuelling stations - Part 8: Fuel quality control	BS/EN/ISO/IEC
BS ISO 19880-9	Gaseous Hydrogen — Fuelling stations - Part 9: Sampling for fuel quality analysis	BS/EN/ISO/IEC
BS ISO 23273	Protection against Hydrogen hazards for vehicles fuelled with compressed Hydrogen	BS/EN/ISO/IEC
BS ISO 26142	Hydrogen detection apparatus. Stationary applications	BS/EN/ISO/IEC
EC 2014/68	Pressure equipment (recast from EU 97/23)	EC/EU
EC 2019/795	Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of hydrogen-fuelled vehicles	EC/EU
HyApproval	Handbook for Hydrogen Refuelling Station Approval	Misc.
HyResponse D6.3	European Emergency Response Guide	Misc.
ISO 14687	Hydrogen fuel quality — Product specification	BS/EN/ISO/IEC

J2601	Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles	Misc.
J2719	Hydrogen Fuel Quality for Fuel Cell Vehicles	Misc.
J2799	Hydrogen Surface Vehicle to Station Communications Hardware and Software	Misc.
NFPA 2	National Fire Protection Associate - Hydrogen Technologies Code	Misc.
PD ISO/TR 15916	Basic considerations for the safety of hydrogen systems	BS/EN/ISO/IEC
UK SI 1999/2001	The Pressure Equipment Regulations 1999	UK Regulations
UK SI 2000/128	The Pressure Systems Safety Regulations 2000	UK Regulations
UK SI 2002/2776	The Dangerous Substances and Explosive Atmospheres Regulations 2002	UK Regulations
UK SI 2011/1885	The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment (Amendment) Regulations 2011	UK Regulations
UK SI 2016/1105	The Pressure Equipment (Safety) Regulations 2016	UK Regulations

Table 2 Key Standards and legislation relevant to new or modified vehicles and integration into the railway system. This list should not be treated as exhaustive, as every project is different.

Standard Number	Standard Name	Standard Type
2014/30/EU	Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast)	EC/EU
BS 6853	Code of practice for fire precautions in the design and construction of passenger carrying trains	BS/EN/ISO/IEC
BS 7430	Code of practice for protective earthing of electrical installations	BS/EN/ISO/IEC
BS EN 12663-1	Railway applications. Structural requirements of railway vehicle bodies. Locomotives and passenger rolling stock (and alternative method for freight wagons)	BS/EN/ISO/IEC
BS EN 15227	Railway applications - Crashworthiness requirements for railway vehicle bodies	BS/EN/ISO/IEC
BS EN 16186	Railway applications. Driver's cab - Integration of displays, controls and indicators	BS/EN/ISO/IEC
BS EN 50122-1	Railway applications - Fixed installations - Electrical safety, earthing and the return circuit	BS/EN/ISO/IEC
BS EN 50124-2	Railway applications - Insulation coordination - Part 2: Overvoltages and related protection.	BS/EN/ISO/IEC
BS EN 50125-1	Railway Applications -Environmental Conditions For Equipment - Part 1: Rolling Stock and On-board Equipment	BS/EN/ISO/IEC
BS EN 50129	Railway Applications - Safety Related Electronic Systems	BS/EN/ISO/IEC
BS EN 50153	Railway applications. Rolling stock. Protective provisions relating to electrical hazards	BS/EN/ISO/IEC
BS EN 50163	Railway applications. Supply voltages of traction systems	BS/EN/ISO/IEC
BS EN 50264-1	Railway applications - Railway rolling stock power and control cables having special fire performance - Part 1: General requirements	BS/EN/ISO/IEC
BS EN 50343	Railway applications. Rolling stock. Rules for installation of cabling	BS/EN/ISO/IEC
BS EN 50500	Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure	BS/EN/ISO/IEC

BS EN 50592	Railway applications. Testing of rolling stock for electromagnetic compatibility with axle counters	BS/EN/ISO/IEC
BS EN 60529	Degrees of protection provided by enclosures (IP Code)	BS/EN/ISO/IEC
BS EN 60947-5-5	Low-voltage switchgear and controlgear. Control circuit devices and switching elements. Electrical emergency stop device with mechanical latching function	BS/EN/ISO/IEC
BS EN 61010-1	Safety requirements for electrical equipment for measurement, control, and laboratory use. General requirements	BS/EN/ISO/IEC
BS EN 61287-1	Railway applications - Power convertors installed on board rolling stock Part 1: Characteristics and test methods	BS/EN/ISO/IEC
BS EN 61287-2	Railway applications - Power convertors installed on board rolling stock Part 2: Additional Technical Information	BS/EN/ISO/IEC
BS EN 61340-5-1	Electrostatic Control Part 5-1: Protection of electronic devices from electrostatic phenomena - General requirements	BS/EN/ISO/IEC
BS EN 61373	Railway applications. Rolling stock equipment. Shock and vibration tests	BS/EN/ISO/IEC
BS EN 62305	Protection against lightning Part 1: General principles - CORR	BS/EN/ISO/IEC
BS EN 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes. Safety requirements for secondary lithium cells and batteries, for use in industrial applications	BS/EN/ISO/IEC
BS EN 62927	Rolling stock - Onboard lithium-ion traction batteries	BS/EN/ISO/IEC
BS EN ISO 13849-1	Safety of machinery — Safety-related parts of control systems Part 1: General principles for design	BS/EN/ISO/IEC
BS EN ISO 13849-2	Safety of machinery — Safety-related parts of control systems Part 2: Validation	BS/EN/ISO/IEC
BS ISO 2017-2	Mechanical vibration and shock — Resilient mounting systems — Part 2: Technical information to be exchanged for the application of vibration isolation associated with railway systems	BS/EN/ISO/IEC
EN 45545-1	Railway applications - Fire protection on railway vehicles Part 1: General	BS/EN/ISO/IEC
EN 45545-2	Railway applications - Fire protection on railway vehicles Part 2: Requirements for fire behaviour of materials and components	BS/EN/ISO/IEC
EN 45545-3	Railway applications - Fire protection on railway vehicles Part 3: Fire resistance requirements for fire barriers	BS/EN/ISO/IEC
EN 45545-4	Railway applications - Fire protection on railway vehicles Part 4: Fire safety requirements for rolling stock design	BS/EN/ISO/IEC
EN 45545-5	Railway applications - Fire protection on railway vehicles Part 5: Fire safety requirements for electrical equipment	BS/EN/ISO/IEC
EN 45545-6	Railway applications - Fire protection on railway vehicles Part 6: Fire control and management systems	BS/EN/ISO/IEC
EN 45545-7	Railway applications - Fire protection on railway vehicles Part 7: Fire safety requirements for flammable liquid and flammable gas	BS/EN/ISO/IEC
EN 50121-3-1	Railway applications - Electromagnetic compatibility Part 3-1: Rolling stock - Whole vehicle	BS/EN/ISO/IEC
EN 50121-3-2	Railway applications - Electromagnetic compatibility Part 3-2: Rolling stock - Apparatus	BS/EN/ISO/IEC
ERA/ERTMS/033281	Interfaces Between Control-Command And Signalling Trackside And Other Subsystems	Misc
GB/T 25120-2010	Railway Applications--Traction Transformers And Inductors On Board Rolling Stock	RGS
GE/RT8006	Assessment of Compatibility of Rail Vehicle Weights and Underline Bridges	RGS
GE/RT8014	Axlebox Condition Monitoring - Hot Axlebox Detection	RGS
GE/RT8015	Electromagnetic Compatibility between Railway Infrastructure and Trains	RGS
GE/RT8073	Application of Standard Vehicle Gauges	RGS

GE/RT8075	AWS and TPWS Interface Requirements	RGS
GE/RT8273	Assessment of Compatibility of Rolling Stock and Infrastructure - Gauging and Stepping Distances	RGS
GI/GN7621	Guidance for the Development and Design Considerations of Passenger Rolling Stock Depots	RGS
GI/RT7073	Requirements for the Position of Infrastructure and for Defining and Maintaining Clearances	RGS
GL/GN1612	Guidance on DC Conductor Rail Energy Subsystem and Interfaces to Rolling Stock Subsystem	RGS
GL/RT1210	AC Energy Subsystem and Interfaces to Rolling Stock Subsystem.	RGS
GL/RT1212	DC Conductor Rail Energy Subsystem and Interfaces to Rolling Stock Subsystem	RGS
GM/RT2044	Braking System Requirements and Performance for Multiple Units	RGS
GM/RT2045	Compatibility Requirements for Braking Systems of Rail Vehicles	RGS
GM/RT2100	Rail Vehicle Structures and Passive Safety	RGS
GM/RT2100	Requirements for Rail Vehicle Structures	RGS
GM/RT2113	Rolling Stock Subsystem and Interface to DC Conductor Rail Energy Subsystem	RGS
GM/RT2120	Requirements for the Control of Risks arising from Fires on Railway Vehicles	RGS
GM/RT2130	Vehicle Fire Safety	RGS
GM/RT2141	Permissible Track Forces and Resistance to Derailment and Roll-Over of Railway Vehicles	RGS
GM/RT2142	Resistance of Railway Vehicles to Roll-Over in Gales	RGS
GM/RT2160	Environment Inside Railway Vehicles (Audibility of Detonators)	RGS
GM/RT2161	Requirements for Driving Cabs of Railway Vehicles	RGS
GM/RT2173	Size of Vehicles and Position of Equipment	RGS
GM/RT2176	Air Quality and Lighting Environment for Traincrew Inside Railway Vehicles	RGS
GM/RT2177	Emergency and Safety Equipment and Signs on Rail Vehicles	RGS
GM/RT2180	Visibility and Audibility Requirements for Trains	RGS
GM/RT2185	Train Safety Systems	RGS
GM/RT2304	Equipotential Bonding of Rail Vehicles to Running Rail Potential	RGS
GM/RT2461	Sanding Equipment Fitted to Multiple Units and On-Track Machines	RGS
GM/RT2466	Railway Wheelsets	RGS
GM/RT2472	Requirements for Data Recorders on Trains	RGS
GM/RT2477	Track Circuit Assister Configuration for Rail Vehicles	RGS
ICNIRP 494-522	ICNIRP Guidelines for limiting exposure to time-varying electric and magnetic fields (up to 300GHz) published in: Health Physics 74(4)	Misc.
IEC 61427-1	Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 1: Photovoltaic off-grid application	BS/EN/ISO/IEC
IEC 61427-2	Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 2: On-grid applications	BS/EN/ISO/IEC
IEC 62281	Safety of primary and secondary lithium cells and batteries during transport	BS/EN/ISO/IEC

IEC 62620	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Secondary lithium cells and batteries for use in industrial applications	BS/EN/ISO/IEC
LOCPAS NTSN	NTSN: Rolling Stock - Locomotive and Passenger (LOCPAS)	UK Regulations
NFPA 130	National Fire Protection Associate - Standard for Fixed Guideway Transit and Passenger Rail Systems	Misc.
NOI NTSN	NSTN: Rolling Stock - Noise (NOI)	UK Regulations
NR/GN/SIG/50005	Methodology for the Demonstration of Compatibility with TPWS Track Sub-system	Misc.
NR/GN/SIG/50014	Methodology for the Demonstration of Compatibility with Lineside Equipment	Misc.
NR/SP/SIG/50012	Methodology for the Demonstration of Compatibility with 50Hz Single Rail Track Circuits	Misc.
PRM NTSN	NTSN: Persons with Reduced Mobility (PRM)	UK Regulations
RIS-0725-CCS	Electromagnetic Compatibility of Train Detection Infrastructure with Rail Vehicles	RIS
RIS-2004-RST	Rail Vehicle Maintenance	RIS
RIS-2453-RST	Vehicle Registration, Marking and Numbering	RIS
RIS-2472-RST	Data Recorders on Trains	RIS
RIS-2700-RST	Rail Industry Standard for Verification of Conformity of Engineering Change to Rail Vehicles	RIS
RIS-2706-RST	Recording of Rolling Stock Data	RIS
RIS-2730-RST	Vehicle Fire Safety and Evacuation	RIS
RIS-2761-RST	Rail Industry Standard for Driving Cabs	RIS
RIS-2777-RST	Functionality and Management of Track Circuit Assisters (TCAs) on Rail Vehicles	RIS
RIS-2780-RST	Rail Vehicle Structures	RIS
RIS-2790-RST	Rail Industry Standard for Compatibility of Rail Vehicle Couplings and Interconnectors	RIS
RIS-7016-INS	Interface between Station Platforms, Track, Trains and Buffer Stops	RIS
RIS-8270-RST	Route Level Assessment of Technical Compatibility between Vehicles and Infrastructure	RIS
RT/E/G/27225	Guidance Manual for Stations and Depots – Equipment Maintenance	Misc.
SRT NTSN	NTSN: Safety in Railway Tunnels (SRT)	UK Regulations
T326	Human factors good practice guide to managing alarms and alerts	Misc.